CHEMISTS CORNER

Introduction to Cosmetic Formulating

First edition

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Introduction

Welcome to the wonderful world of cosmetic formulating. This ebook was put together based on over 30 years of experience in formulating and creating cosmetic products. If you go through each chapter and make an effort to understand the concepts, you will be well on your way to becoming a cosmetic chemist who can create effective, stable, and safe cosmetic products. A wealth of insider industry information is covered in this book much of which you won't find in other similar books.

Not only will this ebook help you learn how to make formulas for a range of cosmetic and personal care products, you will also learn how professional, cosmetic industry chemists formulate including the type of equipment used, the raw materials, the science, and even full-scale production

The general layout of the book is as follows.

This first chapter is designed to introduce you to the cosmetic industry. While you may have some experience in cosmetics, you likely don't know the complete scope of the industry. This introduction will cover the cosmetic industry including the market, some regulations, the types of products, and ingredient naming.

In the second chapter the process of setting up a lab is further described. This is an overview of the entire process of putting together a lab and the equipment needed and why. Also, the recordkeeping for formulating is described. To get started making cosmetics, you need the right equipment.

The third chapter starts with the specifics of formulating cosmetics. Here the key raw materials used to create cosmetics are described. Topics covered include types of ingredients, the science of how they work, the amounts used, and when they are included.

The fourth chapter is an introduction to the different types of cosmetic product forms. Every major type of cosmetic product formulation type is discussed including solutions, emulsions, gels, sticks, powders, and more.

In the fifth-, sixth- and seven-chapters details of the different types of cosmetic products including skin care, hair care, and color cosmetics are explored. In these chapters the science of how things work is described, the problems these products try to solve and how to actually make them. Each category will feature an example formula.

In the eighth chapter you will learn how to take your formula from the beaker to a larger, production sized tank. If you are serious about producing your products on a large scale these are the types of things that you will have to consider. In this chapter we also cover the various type of records and paperwork you need to collect if you are going to sell your formulations.

In the final chapter we go through all that is required for testing your product. In this lesson you will learn different types of quality control testing and the purpose behind these. You will also learn about claims testing, safety testing and a method for ensuring your products are stable.

Remember, a lifetime of experience isn't a prerequisite for being a good formulator (although it helps), but knowledge of the raw materials and science is essential.

Chapter 1

GETTING STARTED

Getting Started

Before getting started making cosmetic formulas it is helpful to learn the important background details about the cosmetic industry. This includes the definitions of cosmetics, the types of products, industry information, and the regulatory organizations that create rules for making products.

Cosmetics Defined

The definitions for cosmetics differ slightly around the world, but they are basically any substance or mixture that is intended to be applied to the external parts of the human body or the teeth and mucous membrane. In the United States cosmetics are regulated by the Food & Drug Administration (FDA) and the formal definition for cosmetics is as follows...

> "articles intended to be rubbed, poured, sprinkled, or sprayed on, introduced into, or otherwise applied to the human body...for cleansing, beautifying, promoting attractiveness, or altering the appearance" [FD&C Act, sec. 201(i)].

It is interesting to note that in the US, soap is not actually considered a cosmetic even though it would fit into this definition. When the regulations were created, somehow the soap manufacturers were able to get an exemption from the regulations. This means that soaps sold in the US are not required to follow the same rules as cosmetic makers. However, the claims for soap are extremely limited and if you make any cosmetic type claims about the soap product, it then becomes a cosmetic required to follow cosmetic regulatory rules.

In the EU, the definition is stipulated in the EC Council Directive No 1223/2009 which states that cosmetics are...

> "substances * or mixtures of substances intended to be placed in contact with the external parts of the human body (epidermis, hair system, nails, etc.) or with the teeth and the mucous membranes of the oral cavity with a view exclusively or mainly to cleaning them, perfuming them, changing their appearance, protecting them, keeping them in good condition or correcting body odours."

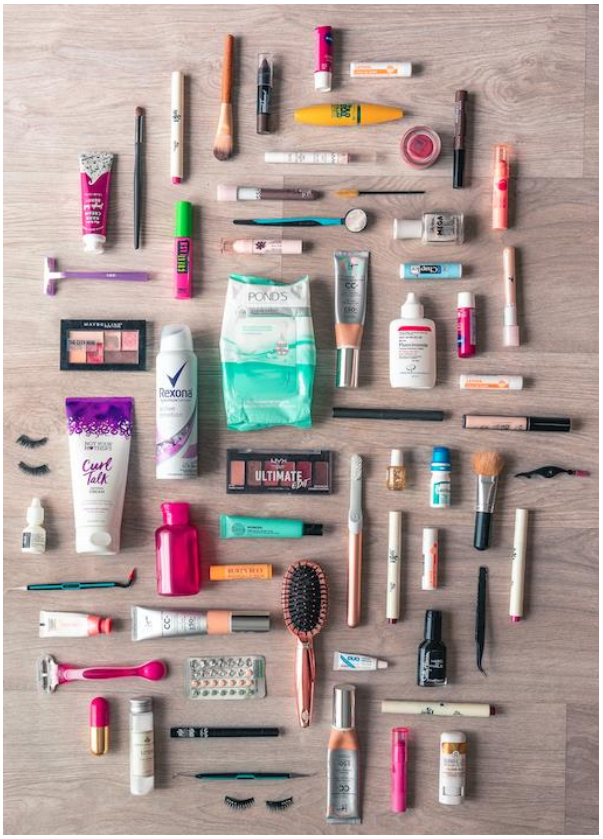
While most other governmental regulations would follow closely what the US and EU use to define cosmetics, there are slight differences depending on the country. For example, in the US a product like sunscreen is actually considered a drug while in the EU it is simply a cosmetic. When formulating to sell products for a specific market, be sure to check and follow the local rules and regulations. We will discuss different regulatory groups later in this chapter.

Natural Cosmetics

The definitions of cosmetics have not changed much since the FDA was first started in 1938, but there has been a growing movement towards “green” chemistry in the cosmetic industry. While governments have not yet modified regulations to reflect more natural cosmetics, a number of groups have attempted to create their own “natural” standards by which cosmetics are made. The natural standards will be covered later but for now it is useful to know the following about natural cosmetics.

- There is no official governmental definition for natural cosmetics.
- In the US, the department of agriculture has published standards by which a cosmetic maker could use their Organic seal.
- Some cosmetic product retailers have guidelines for acceptable ingredients for products called natural
- Generally, natural products use sustainable ingredients derived from plants

Types of cosmetics



While knowing the legal definition of cosmetics is necessary, it is much more useful to know the specific types of products that are cosmetics. In general, cosmetics can be placed in the following categories:

- Skincare
- Haircare
- Color Cosmetics
- Fine Fragrances
- Oral Products

Skincare products
Skincare products represent the most popular types of cosmetic products sold. These include moisturizing creams, cleansers, toners, skin whitening, self-tanners, hair removers and anti-aging products. These products are all designed to improve the appearance of skin or change the way it feels or smells.

Haircare Products
The second most popular types of cosmetics are haircare products. These include shampoos, conditioners, styling products, relaxers, perms and hair colors. They are used to clean hair, improve the appearance, or permanently alter the shape or color.

Color Cosmetics
Color cosmetics or make-up is what most people think of when they hear the word cosmetics. The other “cosmetic” products mentioned are more frequently called personal care products. Color cosmetics include things like foundation, mascara, lipstick, nail polish, eyeshadow and more. They are used to improve the appearance by concealing blemishes or enhancing the appearance of facial features.

Fine Fragrances
Fragrances are some of the oldest types of cosmetics having been used to improve natural body odor for thousands of years. These products go by different names including perfume and cologne. They are often composed of hundreds of ingredients and can sometimes cause allergic reactions to people sensitive to certain chemicals.

Oral Care / Hygiene Products
These products are designed to improve the appearance and health of teeth or other parts of the body. They include products such as toothpaste and mouthwash. Since these products often contain some type of active ingredient like fluoride which prevents cavities, they are usually classified as over-the-counter drugs in the US.

The Cosmetic Market around the World

Share of the market by region

The total global market size of cosmetics was approximately $511 billion in 2021. Since most people around the world use cosmetic products sales of these products are distributed throughout the globe (share and estimates vary greatly but this provides a rough distribution of sales globally).

Region	Market share
North Asia	35%
North America	26%
Europe	22%
South Asia/Middle East/North Africa	10%
Latin America	7%

This distribution is not in line with the population distribution of the world so there are significant opportunities to grow the cosmetic market in areas like South Asia, Latin America and Africa.

Share of market by category

Breaking down the market by the amount of sales per category, we see that skincare accounts for the largest market share. Haircare has the second largest sales, followed by color cosmetics and fine fragrances.

Category	Market share
Skincare	41%
Haircare	22%
Color Cosmetics	18%
Fragrances	11%
Hygiene products	10%

When you are considering the type of cosmetic to produce, it is useful to know how much money you could potentially make.

Cosmetic Industry Regulations

Since cosmetics are chemicals that get applied to people's bodies, governments from around the world strive to ensure they are safe. It's a laudable goal, but a challenging one to implement since there is no universal standard for what is "safe".

The most difficult thing about cosmetic regulations for cosmetic formulators is that few people know definitive answers about the rules. They are almost always open to interpretation so your actions will depend primarily on what your company regulatory expert thinks the regulations mean. We will provide you with reasonable regulatory guidelines to follow when formulating. However, regulations change without warning so it is helpful to look to the regulatory agencies in the country in which you will be selling products for the most up-to-date answers. You can find that information in the following places.

Cosmetic Regulatory Agencies

Here's a quick list of the regulatory agencies that affect the cosmetic industry around the world.

- FDA - USA
- European Commission- EU
- Health Canada
- Ministry of Health - Japan
- Department of Health - Australia
- China FDA
- Cofepris - Mexico
- Department of Health and Family Welfare - India
- CTFA - South Africa
- ASEAN Cosmetic Directive - Southeast Asia nations
- ANMAT - Argentina
- INMETRO - Brazil

North America Cosmetic Regulations

FDA - USA

One of the most common claims you'll hear about cosmetics is that they are not regulated in the United States. This is false. Cosmetics are very much regulated in the United States. In fact, the word Cosmetics is mentioned specifically in the regulations that govern it, the Federal Food, Drug and Cosmetic act. First passed in 1938, it created the government agency responsible for regulating cosmetics, the Food & Drug Administration (FDA). If you are a formulator in the cosmetic industry, you need to know the FDA rules regulating cosmetics and cosmetic ingredients. While the FDA only regulates cosmetics in the United States, it's rules also impact anything that is imported or sold into the US.

The US is also affected by the efforts of individual states, particularly California which has passed regulations related to environmental emissions (CARB), carcinogens, and organic labeling.

Health Canada
If you are creating products for the Canadian cosmetic market then you'll have to follow the guidelines set up by Health Canada. They follow many of the same rules as the US but they also have adopted some of the rules of the EU. They are in the process of banning animal testing of cosmetics.

Cofepris - Mexico
Mexico's equivalent to the FDA is the Federal Commission for the Prevention of Sanitary Risks, COFEPRIS. In 2015 they updated their regulatory standards that apply to cosmetics, perfumes, and personal care products. The two standards that affect product labeling and allowed ingredients are NOM 159 and NOM 259.

Europe

European Commission
The EU represents 28 countries which makes it pretty convenient if you are a formulator for multiple countries in Europe. In the EU, cosmetics are regulated by a document called the Cosmetics Directive 76/768/EEC. Their regulations tend to be a bit more detailed than in the US specifically governing ingredients that can and can't be used. They also have banned animal testing of cosmetics. With the recent Brexit change, the UK is their own cosmetic regulations. However, as of this writing they are not substantially different than the EU.

South America

There are a variety of countries in Central and South America. They primarily follow international regulations for cosmetics adopting some of the EU and US rules.

INMETRO - Brazil - The biggest cosmetic market in South America is Brazil. The also tend to have the most complicated regulations to follow. But INMETRO has published a document which will aid formulators who are interesting in selling products in this market.

ANMAT - Argentina - If you are formulating for Argentina, this is the regulatory agency to connect with.

Africa Cosmetic Regulations

Countries in the Middle East and Africa are predicted to be the fastest-growing markets over the next five years for the cosmetic industry. There aren't a lot of specific regulatory groups for the area but South Africa is probably the most developed.

CTFA - South Africa - The Cosmetic, Toiletries, and Fragrance Association of South Africa is not the government but an industry trade organization that plays an important role in steering and creating regulations for the cosmetic industry in South Africa.

Asia Pacific

China FDA - China continues to emerge as one of the most important cosmetic markets in Asia. It is a growing economy and has a huge population that will use cosmetics. They tend to update their regulations more frequently than other places so if you are formulating for China, be sure to check this site for any updates.

Department of Health and Family Welfare - India - This is the second most populace country in the world but it has some of the oldest cosmetic regulations. Their food drug and cosmetic act equivalent was passed in 1940 and has been updated a few times since. For information about the latest rules governing formulations in India, this is the site to visit.

ASEAN Cosmetic Directive - Southeast Asia nations - In 1967 countries throughout southeast Asia signed on to become part of a single organization that will help promote security, economic development and trade. Through this group a set of regulations affecting the cosmetic industry was produced. These rules affect cosmetics sold in the 10 member countries of the ASEAN including Indonesia, Thailand, Singapore, Vietnam, Malaysia, Philippines, Myanmar (Burma), Cambodia, Laos, Brunei.

Ministry of Health - Japan - The Japanese cosmetic market is regulated by the Ministry of Health. They follow many of the same rules as the EU and US but they have more restrictions on specific ingredients, especially preservatives. If formulating for the Japanese market, you'll want to check the latest restrictions listed by the Ministry of Health.

Department of Health - Australia - In many ways the Australian cosmetic market is like the European and American markets. They follow most of the same rules and categorize products similarly. For formulating in this market, be sure to check with this website first.

Non-Government Cosmetic Regulatory Groups

In most countries, governments rely on input from industry groups and independent organizations for help in crafting appropriate regulations. It is helpful for cosmetic formulators and marketers to know the rules set up by these organizations.

PCPC - Personal Care Products Council - This organization sets the ingredient naming rules for the cosmetic industry in the US. They produce the INCI Dictionary whose naming conventions have been adopted by most every country around the world. They also issue reports and comments about the safety of cosmetic ingredients

CIR - Cosmetic Ingredient Review - This is an independent group of scientists & regulators funded by the cosmetic industry which is responsible for evaluating the safety of cosmetic ingredients. If you are wondering about the safe levels of ingredients that are used in the cosmetic industry, then this is the place to find the information. Their conclusions are based on peer reviewed experiments and evaluations by toxicologists.

IFRA - International Fragrance Association - Whenever you are using fragrances or ingredients that go into fragrances, it's a good thing to check this group for the allowed safety levels. The European Commission uses IFRA recommendations when it comes to regulating fragrance ingredients.

SCCS - Scientific Committee on Consumer Safety - This is a government funded group of scientists that evaluate the safety of cosmetic ingredients for the European cosmetic market. They do the same job as the CIR but are not industry funded.

CTPA (UK) - The Cosmetic, Toiletry and Perfumery Association (CTPA) is considered the voice of the cosmetic industry in the UK. They are the equivalent of the PCPC in the US and publish a range of information about the safety of cosmetic products.

Cosmetics Europe – This is an organization similar to the PCPC in the US. It represents European cosmetic manufacturers and sets guidelines on industry standards on how products should be made and marketed

Japan Cosmetic Industry Association - This group is similar to the CTPA and the PCPC but relates to the Japanese cosmetic industry.

Chapter 2

SETTING UP A COSMETIC LAB

Setting up a Cosmetic Lab

To be a cosmetic chemist you need a proper lab area. Ideally, you'll have a section of counter-tops specifically designated to be the place where your cosmetics are produced. This area will be specifically separated from any other activities. It is particularly important if you ever get to the point of marketing your own products. In the US, if you sell cosmetics the FDA has the legal right to inspect your manufacturing facilities. Therefore, it behooves you to follow the proper guidelines for setting up a lab.

Physical Lab space

It is up to you to determine the facilities you use for your lab and other manufacturing activities. It is only required to be of a suitable size, design, construction, and maintained in a clean manner. Here are some suggestions.

- Space & Size – You just need a space that is big enough to allow you to create your products while preventing cross contamination of raw material, finished products, and prototypes.

- Filth & Pest control – You have to ensure that the lab and manufacturing areas are free of animal pests & their waste and other objectionable matter. Just keep the lab area clean.

- Construction – Floors, walls and counter-tops should be made of smooth and easily cleanable surfaces

- Lighting & Ventilation – You just need to make sure you have adequate lighting for making batches and ventilation. You do not need a special fume hood as many labs have if you are not working with excessively volatile ingredients. You just need to control dust, humidity, temperature, and microbes.

- Sanitation areas – During an inspection they will look to ensure you have a place for washing and adequate plumbing.

- Drainage – The lab should be set up in a manner that prevents condensation or contamination from dripping.

For a single person lab, the ideal lab setup is to have a counter-top that is at least 8 feet long (2.4 meters) and about 3 feet (1 meter) wide. It will have cabinets down below and easily accessible shelving above the counter-top. However, it should not be right above the counter-top as you will need room to set up your mixer stands.

You also need a designated area to store your raw materials, your packaging, your equipment and your finished products. As you can see, it can take a lot of room to make a cosmetic lab. And if you are going to do production-sized batches you'll need even more space. Just be sure to keep everything in well separated areas.

Lab countertops

Perhaps the most important part of the lab is the surfaces of the counter-tops. Ideally, you will get an epoxy resin counter-top which provides the best combination of chemical and thermal resistance. Fortunately, you will not be working with chemicals that are excessively corrosive in a cosmetic lab so you don't need to go through the expense of this kind of counter-top if you don't have to. A phenolic resin countertop is also an excellent choice for a cosmetic laboratory as it has great chemical resistance, stain resistance and is suitably hard. It will also be lower price than an epoxy resin counter-top. The least expensive option is probably high-pressure plastic laminate. It will not work as well in chemical and stain resistance as the other options but it may be worth the price if you have a limited budget. For other surfaces, you may be able to cover them with Aluminum Foil to prevent chemical stains or spill damage.

Laboratory Equipment

If you want to be a cosmetic formulator and make cosmetic products, there is certain essential equipment you'll need to get. Be sure to keep this equipment separate from any other projects you are doing. In this section we will cover all of the basic equipment including:

- Weighing equipment
- Containers
- Mixers
- Heating & Cooling devices
- Testing equipment

Balances and Weighing Equipment

A key piece of equipment needed for making formulas is the weighing equipment.

While recipes for cosmetic products abound on the Internet in hobby blogs and other social media sources, they typically list the ingredients in terms of volume measurements like tablespoons or cups. While this works fine enough for cooking food, it is not suitable for cosmetic formulas. This is primarily because you need more accuracy and consistency when making a cosmetic product. Small deviations from the amount of an ingredient can result in

formulas that are unstable, ineffective or even unsafe.

Whenever you are making a formula you need to measure things in terms of mass, not volume! To see why mass measurements are better than volume, consider the measurement of 1 tablespoon.

If a formula calls for 1 tablespoon of water, that is the equivalent of 14.8 g (see this conversion calculator). If you were making a 100 g batch that would be the equivalent of 14.8%. Now, suppose you didn't get exactly 1 tablespoon but were off by something like 10%. That's equal to 13.3 g or 13.3% in your formula. Your small measuring error has been magnified and you've changed the formula significantly. If you weighed out the 14.8 g on a scale you could get much closer & have a more accurate formula.

Scales

Therefore, when setting up a lab it is crucial that you have a scale to accurately measure your ingredients. There are a wide variety of scales available and the cost can range from rather cheap to obscenely expensive. The exact scales you get will depend mostly on the size of the batches you'll be most often making. The ideal cosmetic lab will have three types of scales.

Small measurements - This is a scale that can measure things in quantities of 100 g down to 0.001 g. When you are making smaller sized batches, you'll need to have accuracy on the lower end. Ingredients like dyes can have a huge impact on the resulting batch so if color is going to be part of your formulating get a good, small sized scale. For this scale having it enclosed is helpful to prevent any air currents from impacting the measurement. This makes it less convenient to use by improves accuracy. A scale like this balance from US Solid is a reasonable choice.

Mid-range measurements - This is the scale which you are going to use most often and it is the most important one to get. This scale can measure ingredients from 2000 g down to 0.01 g accuracy. For most anything you make you could probably use this scale. Especially if your batches are less than 1000 g. When getting a scale for this purpose you'll want to make sure it is accurate enough but is also durable enough to maintain its accuracy while being used repeatedly. You also don't need to worry about air currents so no enclosure is required. In fact, it's better not to have one because it makes taking measurements easier. A scale like this Ohaus scale is a typical choice.

Large measurements - If you are going to make larger scale batches (>2000 g) then you'll want to have a scale which can make larger measurements than 2K. To make these batches you should have a scale that will measure up to 10Kg. Although, if you are making really large batches, for example production sized batches, you'll want to have an even larger scale. The larger you get however, the less accurate the measurement. However, accuracy is not as important as your batch gets larger. If you are off by 2 g on a 10,000 g batch, it is much less

impactful than if you are off by 2 g on a 100 g batch. For a large measurement scale something like this scale would be reasonable.

If you can only afford one scale for a cosmetic lab, get the mid-range measurement scale. This will be accurate enough for most purposes.

Key attributes of a scale

To summarize the key qualities to look for in a scale:

- **Measurement range** - you need something that has a wide enough range that will work for most of the batch sizes you'll have to make.
- **Accuracy** - you need something that will be accurate enough to measure the smallest ingredient amounts you might measure. The measurements should also be repeatable so when you measure the same thing multiple times, you get the same result.
- **Durability** - Get something from a brand proven to be useful under laboratory conditions. The scales that people use in home kitchens are not typically durable enough.
- **Calibration** - you should be able to calibrate the scale to ensure that it remains accurate over the life of its use.

Other lab supplies

In addition to the scale there are other useful supplies that you should get for your cosmetic lab. These include weigh boats, pipets, and spatulas.

Weigh boats are polystyrene plastic pans to which you can pour you liquid or solid raw material in to weigh. These help keep your scale clean.

Wax paper squares are also useful when you need to measure powders or solids. They are much cheaper than weigh boats so they can save you some money. Aluminum foil can work for this too.

Plastic, disposable pipets are useful for measuring liquid ingredients.

And stainless steel spatulas are helpful for scraping out containers to ensure you get as much of the measured ingredient into the batch as you can.

As you can see, there is a wide range of choices and prices when it comes to getting a lab scale. If you are trying to keep your costs low, you can try one of the inexpensive kitchen scales, but if you are serious about being a cosmetic chemist, you'll need the accuracy of a more expensive lab scale. But above all else, always measure your ingredients in terms of mass, not volume!

Containers

Containers are used to hold your raw materials and formulations. There are three primary types of containers that every cosmetic lab needs. These include

- Raw material containers
- Prototype making containers
- Product storage containers

Raw material containers

The type of container used for storing raw materials depends on the nature of the cosmetic raw material. The most versatile container is a glass jar. These are useful for storing both solids and liquids, plus they can hold pretty much any kind of chemical without worry of chemical interaction. The specific glass jar you use depends on how many batches you make and how much of an ingredient you use. The more of an ingredient you use, the larger a container you'll want. In the lab that I worked, we made batches daily. We found that clear, one-quart jars were most useful. For ingredients we used a lot of, like Sodium Lauryl Sulfate, we stored it in a large gallon jar or even a 5-gallon plastic pail.

Labs at smaller companies can get away with using smaller glass containers to hold their raw materials. Useful sizes include 4oz, 8oz and 16oz jars. You can get appropriate glass storage jars here.

While clear glass jars work well for many applications, there are some ingredients that can break down when exposed to light. For these you'll want to use brown colored glass jars which prevent light from reaching the raw material. Ingredients like fragrances, essential oils, and other oils should be stored in these types of bottles.

Most raw material samples will be sent to you in plastic containers and it is ok to store ingredients in those containers as well. However, there is a chance that the plastic can interact over time with the ingredient so this is not ideal. Glass storage of ingredients is best.

We will cover which raw materials you should stock in your lab in the raw material section.

Mixing containers

You'll need containers for making your batches and the most common ones of these are glass

beakers. For a cosmetic lab the sizes that are most useful include 100mL, 500mL, 800mL, 1000mL, 2000mL. I personally, found the 500mL most useful because it fit the mixer blade perfect for a 400g batch. Beakers with a pour spout are particularly useful because they make transferring your products to other containers easier.

The beakers you use should be made of a treated glass like Pyrex that can withstand the temperatures needed when making batches. Most cosmetic formulas are made at temperatures below the boiling point of water but if your container is put directly on the hot plate, the temperature at that juncture can get much higher.

You should get a case of beakers of assorted sizes since they can break easily, especially the smaller ones.

Other containers you might use for making formulations are plastic buckets (the 5-gallon pail works well) and stainless-steel pots. Many of the containers that are used in cooking would also work for making cosmetic products on a larger scale. But for small scale work, you should use beakers.

Storage containers

Another type of container you'll need is a storage container for your finished products and prototypes. Again, the exact type of container you use will depend on the type of product you're storing and how much. I've found that the same type of containers you use to store raw materials can be used to store cosmetic prototypes. These include glass jars and 1-gallon or 5-gallon buckets.

For doing cosmetic stability tests 4-ounce jars are great although some thicker products will require 8-ounce jars. This makes taking readings for viscosity and pH much easier.

You'll also want to get finished packaging for storing your prototypes. For most types of products these are PVC, PET or HDPE plastic bottles. The exact container again depends on the type of formula / product you are making.

Other storage considerations

When setting up your lab, you're going to have a lot of containers and you'll have need for storing unused containers. So, be sure to have an area set aside for storing fresh new containers and packaging, an area for storing your raw materials and another area for storing your finished prototypes. Finally, you'll need one more storage area for your beakers and other lab supplies. While it doesn't really require a lot of space to make cosmetic product batches, you will need a lot of room for storing all the containers and raw materials needed for making them. Just be sure you consider this during your lab setup design.

Mixers

Your mixer is one of your most important pieces of equipment when setting up a cosmetic product lab.

Factors influencing mixer type

If you have done any searching on the Internet, you've probably gotten the advice that you can use a hand mixer or immersion blender. While this may be true, this is not the proper way to make cosmetic products. Immersion blenders are fine enough for the kitchen but to make working, stable formulas you are going to need proper mixing equipment.

Here are a few things to consider when choosing a proper mixer.

Product Type - There are numerous types of cosmetic products that you can make from liquids to gels to emulsions. You want to have a mixer that is versatile enough to handle as many different types of products as you'll make. Some things to consider.

Product viscosity — If you are going to be making very thick products like gels and creams you need a mixer that has enough torque to move the solution. Stick blenders and magnetic stirrers will just not work for most cosmetic formula applications.

Formula sample size — One of the things I see people doing wrong is that they make batches that are too small. Even if you are going to make a product for yourself a 100 g batch is just too small for most purposes. This is because it is too difficult to weigh to the right accuracy but more importantly, it is too difficult to get proper mixing without incorporating too much air. Air in batches is not good. Laboratory overhead mixers are designed to process up to a certain amount, usually specified in liters. Examples: 35, 100, 150 and 200 liters. Since viscosity issues enter the equation in direct proportion to volume both must be considered when picking a mixer.

For most cosmetic labs ideally, you'll have two types of mixers. One that works for batch sizes of 5000g or less and one that works for batches up to 5 or 10 gallons.

Mixing speed — The maximum mixing speed your stirrer can achieve is another thing to consider when picking a mixer. You want to have a device that can start slow (to avoid splashing contents all over the place). Then you can adjust the mixing speed after it starts. A variable mixer speed control is important. Examples are stirrers operating from 50 to 500 RPM, from 40 to 2,000 RPM and 20 to 700 RPM. This should be adequate for most cosmetic product labs.

Other mixer features — There are a number of fancy mixer features you can get such as programming time and schedules plus digital RPM displays. Related to stirring time is an automatic shutdown if the stirrer motor overheats or is subjected to an overload due to viscosity increases. They have mixers with programmable control panels that allow you to adjust the torque, mixing speeds, and even keep digital or printed records. None of this is of much use to a cosmetic formulator. It may be nice to have if you can afford it, but it's not really necessary.

Types of Mixers

Some people use kitchen equipment to make their cosmetics. This may be fine enough for DIYers, but this is not the right equipment to use in a professional cosmetic lab. Even a DIYer would be better served by getting proper equipment and avoiding things like stick blenders, immersion blenders, food processors, blenders, and hand mixers. Making cosmetics might resemble cooking, but it isn't exactly like cooking.

Overhead mixers

The best type of mixer to get for a cosmetic lab is a center-stir, overhead mixer. An example is the Scilogex mixer shown in the picture to the right.

This mixer has all the specifications that you would need for a lab and you'll be able to make a wide variety of types of products. Although this type of mixer will only be suitable for small to medium sized lab batches. If you want to make more than 5000g batches, you'll need a more heavy-duty mixer. For a less expensive (but less durable / versatile option) you might try the Mophorn Overhead stirrer,

If you are looking to make small sized production batches then you'll want something larger with more torque. Something like an open-drum mixer would work.

Homogenizers

While an overhead, center stir mixer will work for most formulas, if you are making larger scale emulsions you may want to invest in a homogenizer. Something like this homogenizer would work for a lab. The reason you need a homogenizer is because when making emulsions you need to create tiny droplets of the internal phase. The more mixing, the more energy, and the smaller particles you can achieve. The key is that you do not want to incorporate any air into your emulsion however. This is why a homogenizer is superior to a stick blender.

Mixer blades, paddles and impellers
The mixer motor is only one aspect of your mixing setup. The other important piece is the mixer blade also known as the impeller. We've written an entire article in factors to consider when picking a blade and I encourage you to go see the cosmetic stirrer recommendations. When I formulate I mostly use a paddle mixer like the one in the picture to the right. But propeller mixers, X-mixers and spatula blades can all work for different types of formulas.

Other mixing equipment
In addition to the mixer motor and impeller you'll also need various equipment like the following…

Stands to hold the mixer above the mixing container
Clamps to secure the mixer (and container) to the stand
Platform to set the container. This could just be the counter, top of a hotplate, or water bath.

Getting a mixer is a key piece of equipment to outfit your cosmetic lab. You may be tempted to skimp here to save money but don't do it. You will be using this mixer often and you don't want to get something you have to replace every few months. Price does make a difference. Whatever you choose, remember if you want to be a professional, you should get professional equipment.

Heating & Cooling Devices

There are a few reasons why you need a way to control the temperature of your prototypes. These include…

- Melting water-insoluble solid ingredients
- Creating emulsions
- Reducing air entrapment
- Reducing viscosity
- Speeding up production

Since many cosmetic ingredients are solids that aren't soluble in water and most finished products are liquids or creams, when formulating you need a way to melt them. This is particularly true when creating emulsions. Creams & liquids are typically emulsions and these need to be heated above the melting point of some of their ingredients, then mixed at a high temperature to ensure you get a small particles size when finished. It takes energy to make an emulsion.

From a production standpoint there are good reasons to have lab heating and cooling abilities. If you don't have the proper mixing equipment it is likely that you'll trap air in your batch. When you make products at a higher temperature the air is less likely to get trapped. Also, if you are producing a product that is very thick often heating will reduce the viscosity making it easier to incorporate other ingredients. Finally, your production people like batches to be a little warmer than room temperature because this makes it easier to pump and fill the bulk formula.

Lab Temperature Control Systems

To set up a proper cosmetic lab you'll need a way to easily heat and cool your batch. The best option for heating your batches is a hot plate. The best option for cooling your batches is a water bath. Additionally, you'll need a thermometer to be able to measure the temperature inside your batch.

Cosmetic lab hotplates

Hotplates have a number of features that are variable such as their top temperature, the heating surface, and temperature controls. For a cosmetic lab it is useful to have

- A ceramic coated plate for chemical resistance which is also easy to clean
- A temperature range of at least 200C. Since most formulas don't require you to go higher than 100C, this is more than adequate.

- Stirring capacity of at least 3L. Depending on the size of your batches you may need a larger hot plate than this.
- Temperature control - so you can modify the speed at which your batch heats.
- Lightweight - Since you will often be moving your hot plate it is useful to be lightweight

I personally don't like to heat beakers or other containers directly on the heating plate. For this reason, I like to use a metal bowl filled with water. That way you ensure that the batch never goes over 100C. Also, when you are ready to cool down the batch you can simply add cold water to do that.

Cooling water bath

As I said, I don't like to heat directly on the hot plate but rather use a bath full of water to surround the beaker and heat up the water around it. This gives you much better temperature control and allows you to cool the batch without relying on only air. To do this you need a container that has a wide opening and is also shorter than your mixing container. A stainless-steel pan like this would work well.

You fill the container with water, place it on the hotplate then put your beaker container in it so the water surrounds it. Only fill it as high with water so it covers about an inch of the beaker. This controls the heat well enough and you don't have to worry about it boiling over. When cooling, you can add cold water and ice. You can also change the water if it gets too hot again. Just remember to remove it from the hot plate.

Lab water bath

Speaking of water baths, these are useful for storing samples that you are trying to cool or even heat up. A water bath like this one is helpful in a cosmetic formulation lab.

The heating and cooling equipment in your lab is crucial to have for setting up a cosmetic lab. Fortunately, it will be one of the less expensive things that you have to get.

Miscellaneous

To have a complete cosmetic lab there are some miscellaneous devices that will prove helpful. For example, you should have a timer because most batches require you to hold a batch at a certain temperature for a set amount of time. To cover batches, you should have a good supply of plastic wrap and aluminum foil. Additionally, don't forget to have a supply of something like Kimwipes which will help immensely in keeping your lab and equipment clean.

Testing Equipment

After you've finished a cosmetic formulation, you'll need to test it to ensure that it meets specifications. For this, you'll want to have a couple of useful instruments. Once crucial device is a pH meter. These are much more accurate and useful than things like pH strips. For measuring product thickness you'll also want to have a viscometer. We'll discussion these devices in greater detail in a later lesson but for now you will want to start saving up to get these things. If you are unable to test the finished characteristics of your formulas you will be hard pressed to make serious, high-quality formulas.

There are other things you will need if you are setting up a serious cosmetic lab. One of the most important types of testing that you will do is stability testing. To do this you will need a refrigerator, a freezer, and a temperature-controlled oven. Unless you work for a company these things may be outside of what you can do, but you need to find some way to store your products at elevated and reduced temperatures for an extended amount of time to ensure they remain stable over time.

Waste disposal

When making cosmetic formulas, numerous batches will no longer be needed are have some kind of flaw. Unlike a kitchen where you can discard your waste in the trash or down a garbage disposal, unused cosmetic batches are chemical waste and should be disposed of properly.

Fortunately, cosmetic chemicals and products are not particularly hazardous, but you do need some method of proper disposal. For aqueous and non-flammable materials the use of plastic (e.g., polyethylene jerrycans) or metal (galvanized or stainless steel) safety containers for the collection of liquid waste is strongly encouraged. It is helpful to have a 5-gallon bucket around in which you can dump your waste.

The regulations for chemical waste disposal differ from country to country, state to state and even city to city. You should check with your local regulators to see what is appropriate for your area. In some locales it is ok to dump small levels of non-hazardous waste into the sewers. In others, you have to pay for special disposal. The bottom line is that you need to have some plan for handling your chemical waste.

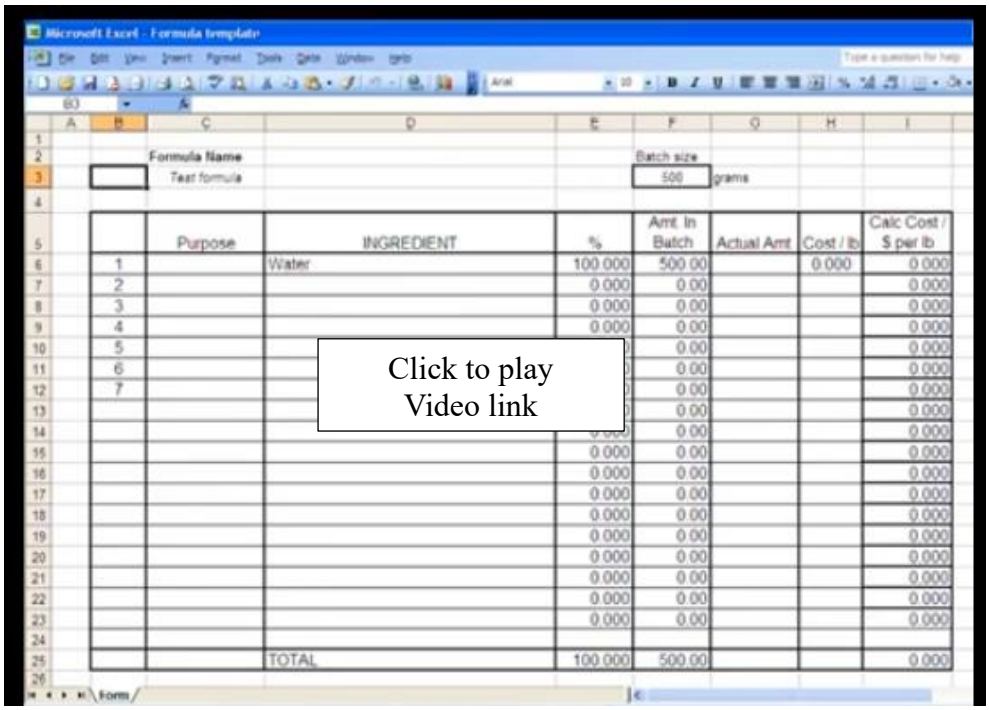
Technology

It used to be that cosmetic chemists needed only equip themselves with a lab notebook for keeping track of their formulations and experiments. Indeed, most chemists still use a notebook because it can be more secure, more reliable and easier to use in cases of lawsuits. But computers have become so inexpensive and portable they have proven themselves to be a crucial tool in the lab.

You don't need the latest technology but you do need a basic computer that can run simple spreadsheet software. It also needs enough storage capacity to hold your formulations.

Cosmetic Formulation Spreadsheet

Using spreadsheet software is a common method of creating cosmetic formulas. The spreadsheet I use is described in the linked video and can be downloaded here if you are connected to the Internet.



All of the example formulations in this book were created using this spreadsheet. This was all I ever needed for doing my formulation work. It works. It's easy to use, it's easy to change, it's easy to read and it's free. Using a spreadsheet like this has a number of advantages. But there are a number of disadvantages such as:

- Harder to update
- Harder to search
- Difficult to see formulation patterns
- Harder to integrate with company computer systems
- Harder to optimize formulas

Formulation Software

For these and other reasons, a number of companies have come out with formulation software meant to make life easier for cosmetic chemists. If you are disappointed with how you are currently creating and tracking formulas, these might be a good option. Here is a list of possible cosmetic formulation software packages that I could find. You may want to try them out

because a number of them have free trial packages.

Creativity Formulation Software
Valdata Systems
Mar-Kov Recipe Manager
Formulator
beCPG
Coptis Lab
Smart Formulator

So, there you have it. All the cosmetic formulation software options that are worth testing. Like I said, I've used paper notebooks and spreadsheets almost exclusively because they have met all my needs, but I may not be representative of all cosmetic formulators or all cosmetic companies. If you are looking for a new solution and spreadsheets just aren't working, try one of these.

Good Manufacturing Procedures

When setting up a lab you are encouraged to follow Good Manufacturing Procedures as described by the FDA. Even if you are not from the US these guidelines provide a reasonable list of procedures to ensure you can produce safe, high-quality cosmetics.

Some things to note that will make your lab work easier.

Raw Materials – You should have a system of identification for your raw materials. Since it is unlikely that you will work with more than 10,000 ingredients you could implement a 4-digit coding system that corresponds to each unique raw material. Whenever you start working with a new, unique raw material you would assign it a new code number. Keep the master list of code numbers for the ingredient and label the sample with that code number. You should also include important information include date received, expiration date, and chemical lot number. This information should be provided to you by the raw material supplier.

Also, have a list of quality control tests that you conduct on each raw material to ensure that it meets the agreed upon specifications. One of the most helpful documents for this is the Certificate of Analysis. (COA). You should have one of these from the supplier of every raw material you receive.

Raw materials arrive with a certificate of analysis (COA) meant to ensure the product conforms to certain specifications. COAs are also very important to review when starting to work with a new or unfamiliar material because parameters covered on the COA can help you understand how the material will function in a formulation and warn you of potential pitfalls. Since the meaning of many of the terms on a certificate of analysis are not obvious, below are some common COA characteristics with information about what they mean when it comes to formulation.

Common Certificate of Analysis Terms

Ash Content — Describes the inorganic content of a material. In ash content analysis the sample is charred and the remaining ash is expressed a percentage of the initial sample weight. Most minerals are converted to oxides, sulfates, phosphates, chlorides or silicates. This information is important when working with ingredients that may be sensitive to metal salts.

Iodine Value — Measures the degree of unsaturation in fats and oils. The lower the iodine value the lower the degree of double bonds and the more solid the material will be. Double bonds may be stronger than single bonds, but they are more reactive, making iodine value a good indicator of stability. Using a material with a higher iodine value may require the addition of an antioxidant and special care in storage.

Refractive Index (RI) – Measures how much the speed of light is reduced when it travels through a specific medium. A raw material will have a narrowly defined range for RI. RI matching can also be used to create clear formulations.

Penetration — In this test method a needle or cone is pushed into a solid or semi-solid sample with a standard weight. The main determinant of penetration is the hardness of the material. But it can also be telling of the crystalline structure and yield properties. These properties are important when using waxes to stabilize some W/O emulsions or for controlling the properties of lipsticks.

Saponification (Sap) Value — Indicates the mean molecular weight of triglycerides. In the test, the amount of potassium hydroxide needed to saponify (make soap from) 1 gram of a fat or oil is determined. Triglycerides with longer fat chains have a low saponification value because there will be fewer fat chains to saponify in a 1-gram sample than a sample with many short chain triglycerides. Sap values are important for making soap and soap-stabilized emulsions. Saponification values for NaOH are also available but most commonly reported by KOH, so be sure to check the test method referenced on the COA.

Unsaponifiable Matter Content — While the Sap value describes fat chain length, unsaponifiable matter content is a measure of the other organic components contained in fats and oils. This may be contaminant like mineral oil or naturally occurring sterols, tocopherols, pigments, etc. This test involves the saponification of a sample followed by dilution and extraction with an organic solvent.

Hydroxyl Value – Triglycerides in fats and oils are subject to hydrolytic rancidity. Hydroxyl value measures the free —OH groups formed by cleavage of fat chains from the glyceride molecule that occur with hydrolysis. The hydroxyl value can be used as an indication of the quality of the material.

The Anatomy of a Formula

Here is a standard cosmetic formulation. At the top of the spreadsheet, there is a section for naming the formulation. You should get into the habit of naming all of your formulas and also assign a unique code number. When assigning a code number, it should correspond to a page on your laboratory notebook. For example, the first formulation I ever made was a shampoo that was called formula 2458-1A. My lab notebook number was 2458 and 1A referred to the book page number (1) and the labeled formula (A).

Formula Name _____ Batch size

Test formula number _____ 500 grams

	Code	Purpose	INGREDIENT	%	Amt. In Batch	Actual Amt.	Temp
1	9029		Water	69.800	349.00		
2	5026		Sodium Laureth Sulfate	30.000	150.00		
3	2061		Guar Polymer	0.200	1.00		
4			etc...	0.000	0.00		
5				0.000	0.00		
6				0.000	0.00		
7				0.000	0.00		
				0.000	0.00		
				0.000	0.00		
				0.000	0.00		
				0.000	0.00		
				0.000	0.00		
				0.000	0.00		
				0.000	0.00		
				0.000	0.00		
				0.000	0.00		
				0.000	0.00		
				0.000	0.00		
			TOTAL	100.000	500.00		

Procedure: **Specifications**

All of your formulas should have trackable code numbers. This makes sense from a lab efficiency standpoint and from a legal standpoint. It is much easier to track your work if you label things systematically.

On the formula spreadsheet there is a listing of all the ingredients, ideally listed in the order in which they are supposed to be added to the mixing batch. Sometimes there are multiple phases so these phases are listed separately and the particular phase is listed on the batch sheet.

We will cover the naming of ingredients and raw materials in depth in the raw material chapter. When writing a formula, it is more helpful to list the trade name of an ingredient rather than the specific INCI name. But when creating a list of ingredients on your packaging, you must use the INCI name.

When formulating it is helpful to list the purpose of an ingredient. This will help remind you and guide future formulators who join your company as to why ingredients are included in a specific formula.

Another useful piece of information to record is a raw material's manufacture lot number (or code). This will help you in the future if you ever have to track down whether a specific ingredient is causing a problem in your formulation. Sometimes a raw material from a specific lot can be contaminated and may ruin multiple batches

As you can see from the spreadsheet ingredients are listed in two ways. First, there is the percentage of the ingredient in the total formula. Creating formulas in terms of percentages is the easiest way to change the batch size. It is a simple calculation to make any size batch you want just by changing the number for the total batch size.

Along with the ingredient percentage the formulations will also have an absolute number (usually grams) of the ingredient that you are required to add. This particular example is a 500g batch and you need to add 349 g of water. When you are creating a formula the % of each ingredient added together should add up to 100% and the total grams of all the ingredients should equal the total size of the batch.

Another feature of every formula is a specification. These are chemical and physical parameters that your formula must achieve if it is a suitable and high-quality creation. During prototype development having rigid specifications is not as critical as when you are ready to move to scale-up and production. The further along in the development process that you get, the more defined your specifications should be. We'll discuss this more in a future chapter but for right now it's enough to know that all batches should have specifications including Appearance, Color, and Odor. Additional specifications of pH and viscosity are also common in cosmetic formulations.

The final filled-in feature of a formula batch sheet is the procedure. This is the section of instructions that tell you when to add which ingredients and what type of processing should be done. You will find information about temperatures to add things, levels of mixing required and other tips that make the formula work. It is helpful to be familiar with the formulation procedure before you start making the batch.

Fill in batch information

While you are making the batch it is helpful to keep records about when you added an ingredient and the temperature at which it is added. Additionally, you'll want to record observations about what types of changes (if any) that you see while making the batch.

Formulation Philosophy

I'm a formulation minimalist. That is, I believe that the best formulas are the ones that use the least amount of cosmetic ingredients at the lowest level to produce noticeable differences.

The implication of this philosophy is that I encourage you to use the least amount of ingredients at the lowest levels that produce noticeable differences.

This philosophy has a number of advantages for a small cosmetic lab including

1. Low inventory of ingredients
2. Low chemical exposure
3. Low production of environmental waste
4. Low cost of final formula
5. Low complication during scale-up

In the formulation chapter, we'll discuss the implications of this philosophy to a greater extent but I want you to know that Formulation Minimalism is NOT a philosophy of just creating the cheapest formula possible.

Instead, it is about creating a formula with the greatest value for the consumer. In this philosophy, PERFORMANCE always trumps cost. However, superior performance has to be demonstrably noticeable by the consumer. Unfortunately, this is extremely difficult.

While the philosophy also encourages the use of more sustainable ingredients, I do feel that it is important for you to understand traditional cosmetic formulating before you can move to creating effective natural or green formulations. You must understand the basics before you move to the more complicated formulas. It is more complicated to create natural or organic formulas that are effective and stable than creating traditional cosmetic formulas.

Chapter 3

COSMETIC RAW MATERIALS

Cosmetic Raw Materials

The objective of this chapter is to introduce you to the primary classes of ingredients used to create cosmetics and personal care products. Also covered is some of the science of how the compounds work but the majority of that will be found in later chapters that cover specific formulations types.

Cosmetic ingredient naming

In the US and most places around the world, it is a requirement that you include a list of ingredients on any cosmetic product that is sold. Actually, this is a more recent requirement for products produced in a lot of places around the world. The requirement for listing ingredient names was not enacted in the US until the late 1970's. In fact, when I started in the cosmetic industry Canada did not even require an ingredient list. But today, most every country and market does require an ingredient list and it is specifically to help consumers recognize what is in products in case they are allergic or otherwise want to avoid certain ingredients.

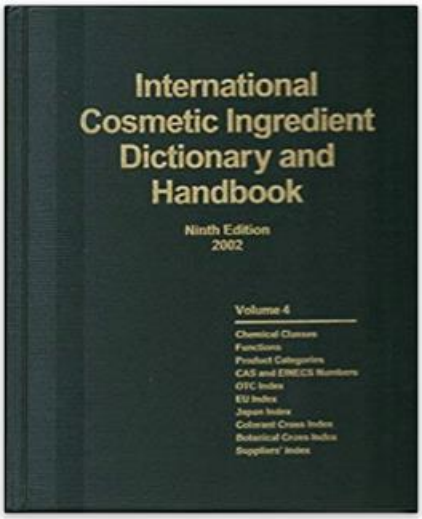
The names for cosmetic ingredients are codified by the government agency responsible for regulating cosmetics. Cosmetic rules are set by the Food and Drug Administration (FDA) and on their website you can even find the rules for listing ingredients which is incredibly helpful if you are just starting your own cosmetic line. But you must follow the rules and use official ingredient names. Let's look at the names of the cosmetic ingredients including where they come from, what they mean, and why they can be so complicated.

How chemicals get their names

If you took any chemistry courses during your schooling career, you will no doubt have heard the names of many different materials or chemicals. There are simple names like Acetic Acid, Sucrose, and Sodium Chloride. And you might have even heard some more complicated names like n,n Diethylmetatoluamide (DEET). The ingredient names you learned in chemistry courses include some common names, but most come from the naming system of the International Union of Pure and Applied Chemistry (IUPAC).

The IUPAC system was designed for chemists to easily communicate information about chemicals. If you are skilled in the nomenclature system, you can see the name of any ingredient and immediately know its molecular structure. The system is efficient, but complicated chemical structures can lead to incredibly long and complicated names. While this is useful for chemists writing academic papers, it’s not so useful for consumers who want to know the names of the ingredients in their cosmetics.

So, the Personal Care Products Council (PCPC) which is the self-regulatory body of the US cosmetic industry (with the blessing of the FDA) came up with their own ingredient naming system. The details are spelled out in the official book of cosmetic ingredient names, called the International Nomenclature of Cosmetic Ingredients (INCI). This naming system has been adopted by nearly all regulatory agencies around the world which helps to harmonize ingredient lists everywhere on the planet. This is incredibly helpful to consumers who may encounter products while traveling or if they are using imported goods.



The latest edition of the INCI Dictionary contains over 22,000 ingredients that have been registered for use in cosmetic products. Unfortunately, the book is not freely available. But you can purchase online access through the PCPC. In truth, for most formulators or even small companies it will not be worth it to purchase the book. However, for a big or medium sized companies it's a great resource if you can get it. Fortunately, the INCI name for any raw material you use should be provided to you by the supplier of that ingredient. If a supplier will not give you the INCI name of an ingredient, you shouldn't be using that supplier.

Naming cosmetic ingredients is complicated

While the IUPAC system is great for naming individual molecules, the reality is that most cosmetic ingredients are not individual molecules. Most cosmetic ingredients are blends of chemicals so naming them gets complicated. When the INCI naming system was put together in the 1970's there was an attempt to make names short and uncomplicated while still providing identifying information to consumers. And they've done a fairly good job of this.

However, raw material names have been made more complicated by the fact that different raw material suppliers create custom blends of multiple ingredients which they do to try and make their products stand out from the competition. This leads to all sorts of different names that aren't official INCI names. Let's look at the different types of cosmetic ingredient names you might encounter as a formulator.

Different Types of ingredient names

Cosmetic raw materials can have multiple names. Here are some that you can expect.

INCI names – These are the "official" names for specific cosmetic ingredients. When you are making your ingredient list these are the names you must use. As I said, when working with an ingredient always get the INCI name from your supplier.

Common names – There were a lot of ingredients that had common names before the INCI system was created and these names have stuck. Water, Glycerin, Lye, Salt are just some examples. Some were incorporated into the INCI system but others weren't. Unless the common name is also the official INCI name, it should not be listed on your ingredient list.

Trade names – These are the names that raw material suppliers give their ingredients. They brand ingredients so that you think in terms of their material rather than some competitor's. Take an example like Sodium Lauryl Sulfate. One company refers to it as Stepanol WA-100 while another company might call it RHODAPON© LX-28/AF3. They have the same INCI name, but they may not be exactly the same ingredient. This is one of the biggest challenges you'll have when communicating about ingredients online. Often people will give the trade name for a material rather than listing the more explanative INCI name. If you ever have formulation questions for me, please tell me the INCI names of the material you are using.

Ingredient Blends – Speaking of trade names, another thing suppliers do to complicate naming is to sell blends of ingredients. These materials are usually given a single trade name, but are made up of multiple INCI ingredients. An example would be a material like Plantasens® Natural Emulsifier HP30 from Clariant. This single material is actually a blend of multiple ingredients and has the INCI name of Glyceryl Stearate, Cetearyl Alcohol, Sodium Stearoyl Lactylate. If you were using this ingredient in a formula, you would have to list all of those components on your product ingredient list. Note, you are never supposed to use trade names or blend names when creating an ingredient list.

When formulating you'll have to get used to these different ingredient listings and how they are named. You'll want to learn what the cosmetic ingredient names are and what they mean. You can get a lot of information about the ingredients and what they do just by their names, even if you can't learn much about their structure. It's also not as important to learn trade names, but this can be useful especially when you are communicating with other formulators about the materials. Suppliers love to speak in terms of trade names while formulators are better served speaking in terms of INCI names.

Details of Ingredient naming

You can create cosmetic formulas without knowing what all the raw material names mean however, knowing the structure and chemistry of ingredients will help you better understand its function and why it is used in a formula.

Common Trivial Names

Since the INCI naming system was only created in the 1970's there were a number of compounds that already had existing names. So, rather than change what people already called these ingredients the system incorporated common names. Ingredients like Glycerin and Menthol are examples. Also, the INCI system used names for things that were already listed in sources like U.S. Pharmacopoeia (USP), National Formulary (NF), the Food Chemicals Codex (FCC), Merck Index, and more. Sometimes these names reflect the structure of the materials but usually they don't. To learn what the chemical structure of these materials are, you just have to look them up. Google or other Internet Search Engines are pretty good ways to find ingredient structure information.

INCI Naming Rules

It is useful to know a few of the general rules that the PCPC followed when putting together raw material names.

1. Use simple names are whenever possible – It's not written for chemists
2. Abbreviations are used where applicable – Keeps names short
3. Numbers are used sparingly – Keeps names less complicated
4. Names from other common systems are retained
5. Each component of a mixture is listed individually
6. System strives to create the short names

Hydrocarbons

Many cosmetic ingredients are hydrocarbons. Hydrocarbons refer to compounds that contain hydrogen and carbon. You may have first learned about naming hydrocarbons in Organic Chemistry. If not, don't worry about it. The important thing to know is that the IUPAC system learned in college provide ingredient names that are too long and complex for the cosmetic industry. However, the INCI naming system did incorporate the idea of stem names to designate hydrocarbons and other ingredients that contain primarily hydrogen and carbon.

Main Chain	Fatty acids	Fatty alcohols
8	Caprylic	Caprylyl
9	Pelagronic	Nonyl
10	Capric	Decyl
11	Undecanoic	Undecyl
12	Lauric	Lauryl
13	Tridecanoic	Tridecyl
14	Myristic	Myristyl
15	Pentadecanoic	Pentadecyl
16	Palmitic	Cetyl
17	Margaric	Heptadecyl
18	Stearic	Stearyl
20	Arachidic	Arachidyl
22	Behynic	Behenyl

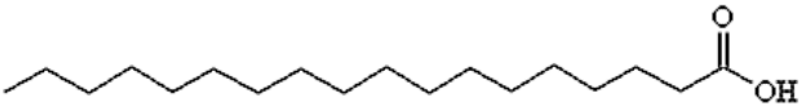
On this chart is listed the stem names used in the INCI system. Here is how it works

The first column on the left represents the number of carbons in the main chain of the molecule. So, C8 means 8 carbon atoms are strung together. C18 means there are 18 carbon atoms in a row on this molecule.

The next column represents the name for that molecule if the ingredient is an acid and the final column is the name of the ingredient if it is an alcohol. Later in this chapter we'll talk specifically about what the terms “alcohol” and “acid” mean in terms of ingredients but for now, you just have to know that an “acid” is an ingredient that contains a group with a Carbon attached to

two Oxygen atoms and a Hydrogen (a COOH group). An “alcohol” is a compound that has a Carbon atom attached to an Oxygen plus Hydrogen or an (OH) group.

Here is an example. Suppose you have an ingredient that has 18 carbons in its main carbon chain. For this, you would look on the chart for the C18 terms and find “Stearyl” for the alcohol version and “Stearic” for the acid version. Therefore, you have ingredients names of Stearyl Alcohol for the 18-carbon alcohol compound and Stearic Acid for the 18-carbon acid compound.

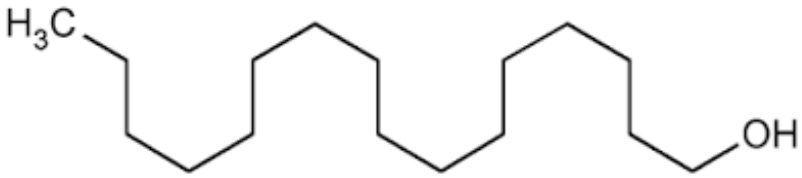


Stearic Acid

If an ingredient has 14 carbons, the stem name used is either Myristic for an acid, or Myristyl for an alcohol. The alcohol version is shown below.

Myristyl Alcohol

A slightly more complicated version is in the case of a 16-carbon ingredient. In this case, the term for the acid is “Palmitic” and the full name would be Palmitic Acid. However, the alcohol version has a different stem name. Instead of Palmyl alcohol, the stem name for the alcohol is “Cetyl” and the full name for this compound would be Cetyl Alcohol.



Cetyl Alcohol

It is helpful for a formulator to memorize this list. Fortunately, this type of name variation is an exception. Of the most commonly used cosmetic ingredients only C16 (Cetyl and Palmitic) and C6 compounds (Caproic and Hexyl) have names in which the alcohol and acid have different stem names.

There are some more complicated hydrocarbon molecules such as esters and unsaturated hydrocarbons but we will discuss those later in the book. Here it is just important to have a general idea of what these stem names mean.

Source names

Some ingredients come directly from natural materials like coconut oil, palm oil or sunflower oil. While these ingredients have a primary component, they are usually a blend of multiple fatty acids or hydrocarbons. Rather than spell out every ingredient in the material they are simply named using the starting material name. So, an acid that is derived directly from a reaction with palm oil would be called Palmitic Acid. Similarly, an acid derived from coconut oil may be called Coconut Acid. And derivatives of these materials also maintain the source stem name. That's how you get a name like Ammonium Palm Kernel Sulfate which is a detergent made from Palm Kernel oil.

		Percentage of Common Fatty Acid Distribution in Source Oil				
Acid Type	**Carbons**	**Coconut**	**Palm**	**Soybean**	**Tallow**	**Sunflower**
Caproic	6	0.5	-	-	-	-
Caprylic	8	7.0	-	-	-	-
Capric	10	6.0	-	-	-	-
Lauric	12	48.0	-	-	-	-
Myristic	14	19.0	2.0	-	3.5	-
Myristoleic	14	-	-	-	1.0	-
Pentadecanoic	15	-	-	-	0.5	-
Palmitic	16	9.0	42.0	11.0	25.3	6.3
Palmitoleic	16	-	-	-	4.0	-
Margeric	17	-	-	-	2.5	-
Stearic	18	3.0	4.0	4.0	19.4	4.1
Oleic	18	6.0	43.0	21.0	40.8	22.9
Linoleic	18	1.5	9.0	55.6	2.5	66.0
Linolenic	18	-	-	8.5	-	-
Arachidic	20	-	-	-	-	0.2
Behenic	22	-	-	-	-	-

To be a great formulator, you'll need to learn the fatty acid distribution of different types of starting raw materials. On this chart we list some common natural oils and the fatty acids of which they are composed.

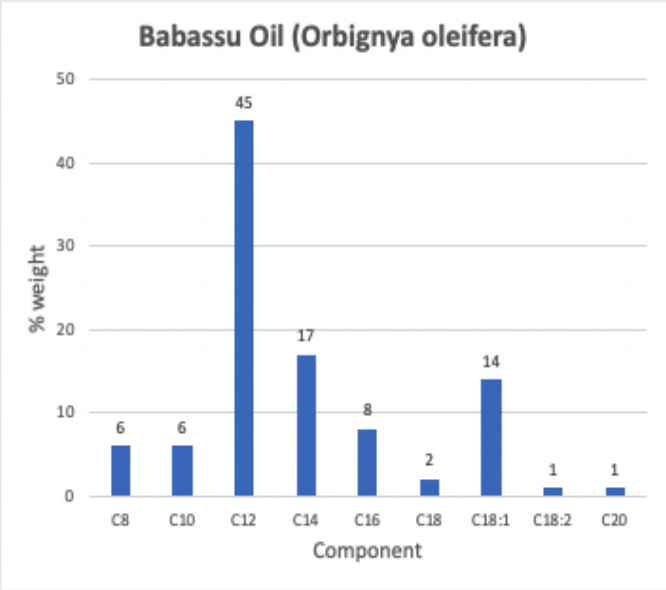
Using the chart is straightforward. The first column lists the stem names for the common carbon chain lengths of fatty acids found in cosmetic starting materials. The next column lists

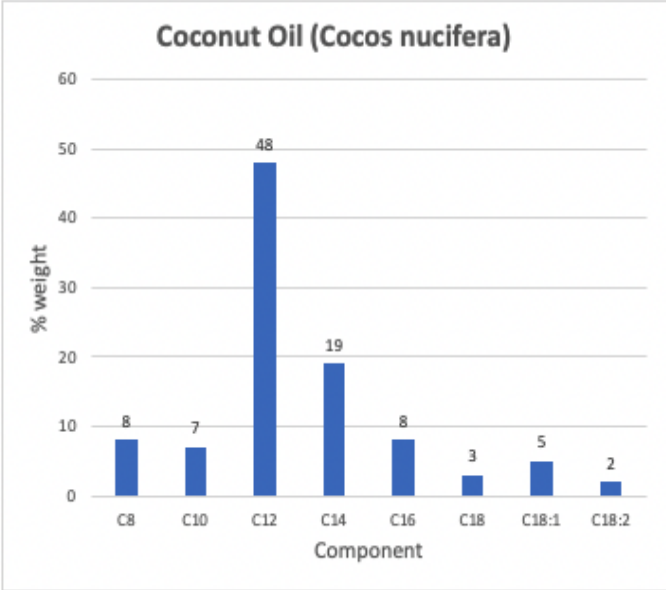
the number of carbon atoms in the chain. Then each column lists the percentage of makeup of these carbon chains in a specific raw material.

For example, Palm oil contains 2% myristic acid (which is C14). It contains 42% Palmitic acid, 4% stearic acid (which is C18), 43% Oleic acid (which is also C18) and 9% Linoleic acid (also a C18 molecule).

This illustrates a significant complication about cosmetic raw materials. They often aren't just single molecule types, but rather are mixtures of lots of different types of molecules.

Whenever you are working with a natural oil, it is helpful to look up the fatty acid distribution of that compound. This chart is a good guide, but if there are other less common oils not listed. Often, you will find that many ingredients have very similar fatty acid distributions. For example, Coconut oil and Babassu oil have very similar fatty acid distributions. This means that for many applications you can substitute one for the other.

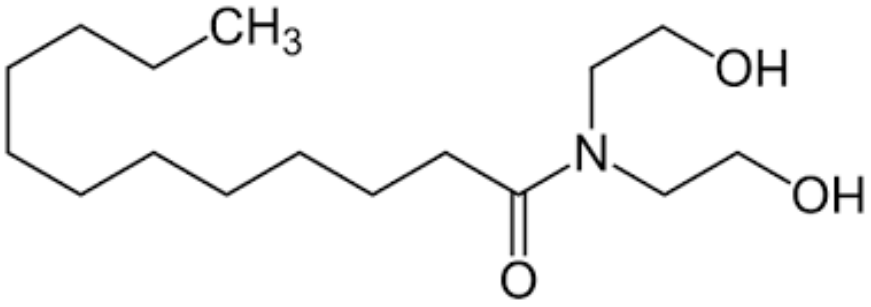




Nitrogen-containing materials

Hydrocarbons that contain nitrogen atoms are referred to as various names including amides, amines, or imines. This is just a common way that Nitrogen containing compounds are referred to in organic chemistry.

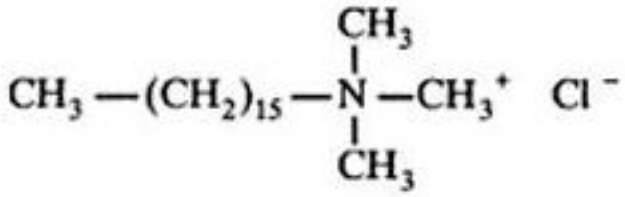
Therefore, the term “Lauramide” is used to describe a 12-carbon molecule (lauryl) that has an NH2 group on its end. If the nitrogen has other hydrocarbons attached, those are also named. So, Lauramide DEA would be that same 12-carbon molecule attached to a nitrogen, which also has ethyl groups attached to it. Here DEA stands for di-ethanol-amide.



Lauramide DEA

When these nitrogen-containing compounds are turned into salts, the suffix -monium is added. So, a 16-carbon molecule attached to a nitrogen with three methyl groups is Cetrimonium chloride. The “Ce-” refers to the carbon stem name, “trimonium” refers to a nitrogen atom with three methyl groups and the chloride refers to it being a salt.

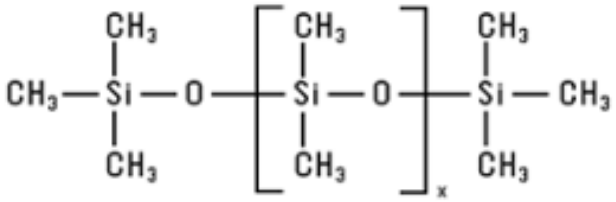
You don't have to memorize these molecular structures, but it is important to know that whenever you see -amine or -monium, etc. that the ingredient has a nitrogen.



Cetrimonium Chloride

Silicones

A number of materials in the cosmetic industry are those that contain silicone. These are similar to hydrocarbons but instead of having a repeating chain of Carbon atoms, they have a repeating chain of Silicon-Oxygen atoms. For these ingredients the phrase '-methicone' is typically used. Common ingredients include Dimethicone, Cyclomethicone, and Phenyl trimethicone. The term '-silane' is also used for materials that have silicone in them that is bonded to another silicone atom rather than an oxygen atom. There are some silicone polymers that are difficult to name using typical silicone terms so these ingredients are simply called Polysilicone with a number after it denoting the order in which it was registered in the INCI dictionary.



Dimethicone

Polymers

Speaking of polymers, there are a number of materials used in cosmetics that are polymers. Polymers are just molecules that have a long chain of repeating units. Most polymers have inherited names from how they had been commonly used at the time of the creation of the INCI dictionary. This is typically a name that covers the starting monomers and includes ingredients like Polyethylene Glycol (referred to as PEG) or Polyvinyl Alcohol, also called PVA. When a blend of monomers is used in creating a polymer, the term Copolymer is used and the names of the starting monomers are listed in alphabetical order. Acrylates/Acrylamide Copolymer is an example.

When there are four or more monomers, the INCI system allows for using a shortened term like Polyquaternium or Polyester with an arbitrary number following. A common hair conditioner has the name Polyquaternium 10.

To understand these ingredients and their effect on a formula you just have to look up the structure although most Polyquaterniums have the same function in a formula.

Botanicals

These days a lot of plant materials are being used in cosmetic formulation. This is especially true if you are a “natural” or “clean beauty” formulator. There has been some confusion about how these should be named or listed on your ingredient list. According to the INCI conventions botanicals are considered ingredients that have not undergone chemical modification and include extracts, juices, waters, distillates, powders, oils, waxes, saps, tars, gums, unsaponifiables, and resins.

The naming of these ingredients is based on the Linnean classification system using Latin names. So, you get names like Sunflower seed oil and Foeniculum Vulgare Fruit Extract. It can get a bit more complicated based on whether the ingredient is a blend of botanicals or which part of the plant it comes from. Also, when using botanicals, you typically have to list the solvent the ingredient is delivered in. Many botanicals are supplied in Propylene Glycol, Glycerin, Water or Propanediol. To find the exact name you should use on your ingredient list, ask your supplier.

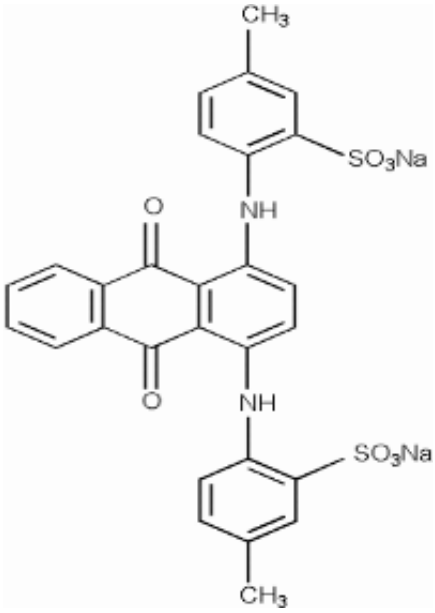
Fragrances

Fragrances are made up of a blend of many ingredients and if you had to list all the components, that would make ingredient lists really long. For that reason, the INCI system made things less complicated. We'll talk more about fragrances in a later chapter but for the moment it is useful to know that when you are naming fragrances you just call it “Fragrance.” Or if you are in the EU you can call it “Parfume.”

It's also important to note that in the EU (and most other countries just follow this rule) you are required to also list any of the 26 known allergens that are commonly used in fragrances. A couple of common examples that you see are Linalool and Limonene. When you see these on an ingredient list, just know that no one actually put those ingredients in a formula by themselves. They are part of the fragrance.

Colorant Additives

Color additives are another special case of naming. The organic molecules that make up colorants are very complicated and the true chemical names are complicated and long. For instance, 6,6'-(1,4-anthraquinonylenediimino)di-m-toluenesulfonic acid disodium salt is simply Green 5.



So, each colorant is designated by a color and some number. They used to be designated with letters like FD&C which stands for Food, Drug and Cosmetic. This referred to where these ingredients were allowed to be used. For example, D&C Green #5 which is allowed in Drugs and Cosmetics, but not in Food. Now, the INCI has adopted the European convention where they just list the color and a number. So, this color is now just Green 5.

Abbreviations

In cosmetic ingredient names you often find three letter abbreviations to replace much longer words. DEA replaces Diethanolamine. PEG replaces Polyethylene glycol. AMP means Aminomethylpropanol. The first section of the INCI dictionary lists all the acronyms that are used for ingredient names.

Naming summary

- Learn stem names
- Some names are source derived / blends
- Nitrogen containing ingredients are – “Amine”, “Imine”, “Amo”, “-monium”
- Quaternium – Has Nitrogen
- Polyquaternium = Polymers - Numbers are arbitrary
- Silicones usually have ‘cone’ in the name
- Colors are given numbers
- Fragrance is just Fragrance (or Parfume in the EU)

Knowing the names of the raw materials you use for formulating cosmetics will make you a smarter, more versatile cosmetic formulator. Hopefully, this section has given you a good glimpse at ingredient names and what they mean. If you could get to the point where you have a good idea of what an ingredient is from either its INCI name or its trade name, you will be well on your way to becoming a complete cosmetic chemist.

Remember, if you are curious about any raw material that you see on a bottle you can usually look it up on Google or a site like the INCI Directory and figure out what the molecule looks like.

Ingredient Purpose

To understand cosmetic ingredients, it is helpful to know the types that are available and their purpose. There is a cosmetic raw material aggregator website called Knowde.com which collects information about cosmetic raw materials. Currently, a popular ingredient aggregator website lists over 33,000 raw materials and blends available for formulators. The INCI dictionary which is the official resource of registered cosmetic ingredients around the world published by the Personal Care Product Council lists over 22,000 names of raw materials.

With that many options available to formulators, it can be challenging to learn them all. Fortunately, you don't have to know every ingredient to be a good formulator. You just have to know the main categories, the general functions and how to put them together when formulating.

While there are over 22,000 INCI dictionary names, all of the raw materials out there can be put into three different categories based on the reason they are used. These include

- Functional ingredients
- Aesthetic Modifiers
- Claims or Marketing ingredients

Of course, there is a little overlap, and these categories can be subdivided further, but on a top-level view, every ingredient can be placed in one of these categories.

Functional ingredients

Cosmetic products are made to impart specific benefits to the person using them. While the product may have some emergent benefits as a result of the entire formula, the formula itself typically relies on one or two ingredients to provide the main benefit. We call these functional ingredients. Every cosmetic product will have at least one functional ingredient.

Functional cosmetic ingredients are those that actually have an effect on the body. They are added by the formulator to make the overall product work. In fact, you cannot make a useful cosmetic product without including at least one functional ingredient. Interestingly enough, you can make a whole cosmetic product just using a single functional ingredient. For example, coconut oil makes a good hair treatment and consumers can buy a hair conditioner from the brand JASON made of 100% coconut oil. The skin care brand Vaseline began with a product made out of a single functional ingredient, petroleum jelly. In fact, this product is still around and sells quite well.

The exact functional ingredients that are put into formulas depends on the primary purpose of the product. If the product is meant to impart color, then a colorant will be the functional ingredient. If the product is meant to clean the body, then a cleanser is the functional ingredient. In general, functional ingredients include cleansers, conditioning or moisturizing agents, colorants, fragrances, reactive ingredients, film formers, and drug actives. Every useful cosmetic has at least one functional ingredient.

Aesthetic Modifiers

These ingredients typically make up the bulk of most cosmetic formulas. Aesthetic modifiers are added to improve the formula in a variety of ways. In general, they make the functional ingredients more pleasant to use by improving the look, feel, and smell and they make the formulas last longer by improving their stability. The different types of aesthetic modifier ingredients include solvents, thickeners, preservatives, fragrances, pH adjusters, plasticizers, fillers, appearance modifiers, anti-oxidants, anti-irritants, and delivery systems.

When you look at the ingredient list of most cosmetics, most of the ingredients are aesthetic modifiers. Since these ingredients don't typically have a functional benefit, formulators try to optimize the levels of these to keep costs down and simplify production. However, these ingredients do play a crucial role in the creation & experience of using a personal care product so it's important for a formulator to have a thorough knowledge of them.

Claims or Marketing Ingredients

While people use cosmetics to improve the way their skin and hair looks and feels, this isn't the main reason they buy cosmetics. Most of the time consumers will buy a cosmetic product because they like the story that goes along with the brand positioning. They also buy products because they like the packaging or the way that the product looks and smells. And to help support the marketing position and the claims made about the product, formulators have to include marketing specific or claims ingredients.

Claims ingredients (sometimes referred to as fairy dust or pixie dust) are ingredients added to a formula at low levels specifically for being able to list the name of the ingredient on the product label. Common claims ingredients include herbs and natural extracts, vitamins, proteins, biotechnology, advanced technology and fanciful made-up ingredient names. They are often talked about in the marketing materials for the product but they are not used in formulas at levels high enough to have any measurable effect. And it's almost always the case that they don't have an effect. But most consumers want a story to go along with their cosmetic products. They want to buy into the world that beauty brands create and claims ingredients are used to support those stories. The truth is without some good claims ingredients in a formula, products just do not sell as well in the marketplace.

You might be surprised to learn that a lot of ingredients that you see talked about and included in formulas do not really have much impact on the way the products function. Ingredients like vitamins and proteins in formulas are much more likely to be included because consumers like the words but they often have no impact on how well the product works.

Functional and Aesthetic modifier ingredients are crucial for making the formula work. Claims ingredients are mainly added to help tell a story.

Categories of Functional ingredients

As stated, functional ingredients are used because they make the formula work. There are only a few types of functional ingredients, and they include...

The functional ingredients include:

- Cleansers
- Conditioners / Moisturizers
- Color Additives
- Film Forming Polymers
- Active Ingredients

Cleansing Surfactants

Of all the ingredients you could use to formulate cosmetics, surfactants are perhaps the most important. They are used for a wide range of applications such as cleaning surfaces, delivering conditioning materials, making materials compatible, creating foam, killing microbes, and more. To be a complete cosmetic chemist you'll have to know about the chemistry of surfactants.

The Polarity of Molecules

To understand surfactants, it is first important to know about a property of all chemicals, polarity. We introduced this concept in the section on solubility but basically all compounds can be classified as polar and non-polar. Example of non-polar molecules are lipids or oils which have enough electrons in them to make them stable. Polar molecules, like water, have an imbalance in electrons which make them attracted to other imbalanced molecules. We refer to polar molecules as electrolytes. The important part to understand here is that Polar molecules are compatible with other polar molecules while nonpolar molecules are compatible with other nonpolar molecules. Or as chemists like to say,

Like attracts like

This is why there is the saying Water and Oil do not mix.

It is a bit more complicated since there is a range of polarity values and some polar molecules aren't compatible with others, but the old adage works fairly well in most situations.

Formulating cosmetics

If you are formulating a cosmetic product, you could create a product using only nonpolar molecules and it would be easy to blend them together. In fact, products like body butters, balms, salves and ointments are typically simple blends of nonpolar molecules. You could also formulate with only polar molecules and make things like moisturizing mists, moisturizers, and leave-in conditioners.

The problem is that single note formulas like these are extremely limited in the benefits you can deliver and they don't usually look, feel or smell good. Most cosmetic products are a blend of Polar and Nonpolar materials.

But as we said above, these materials don't mix. That is unless you have another material that is able to help. That's where surfactants come in.

What are surfactants?

Surfactants are materials that are made up of both polar and nonpolar parts. That means a part of the molecule will be compatible with polar molecules while another part of the molecule will be compatible with non-polar molecules. There are four technical terms you might hear when someone talks about surfactant molecules

Hydrophilic – the "water loving" or polar part of the molecule

Hydrophobic – the "water hating" or nonpolar part of the molecule

Lipophilic – the "oil loving" part of the molecule (same as hydrophobic)

Lipophobic – the "oil hating" part of the molecule (same as hydrophilic)

If you examine a surfactant molecule like Sodium Lauryl Sulfate, you'll see that one end of the molecule is hydrophilic and the other end is hydrophobic. This dual compatibility is what makes surfactants useful for cosmetic formulators.

Sodium Lauryl Sulfate

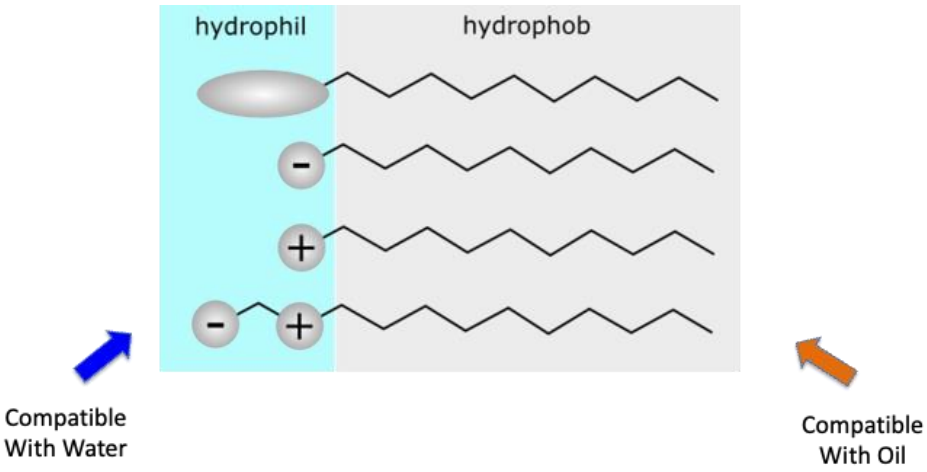
The term Surfactant is a portmanteau of the words Surface Active Agent. In a mixture of ingredients, surfactants are attracted to the surface between the polar molecules and the nonpolar molecules. At the surface they are active which means they can arrange themselves in different structures than just a single molecule floating around.

Surfactant Structures

Surfactants can arrange themselves in various structures depending on the concentration of the surfactant, the other ingredients in the formula, the chemistry of the surfactant, and more. We'll talk more about this when we get into the details of how surfactants work for specific functions. For now, all you have to know is that surfactants make it so that your cosmetic formulations are not limited to only-polar blends or only-nonpolar blends. They open up a wide world of possibilities. With special surfactants called emulsifiers you can create creams and lotions and all kinds of different types of cosmetics. You can take functional non-polar molecules like Emollients or Occlusive Agents and blend them with polar Humectants to get an elegant feeling skin moisturizer.

Surfactants are molecules that are compatible with both water and oil. The word surfactant is a combination of the terms "surface active agents" – surfactant. What is useful about surfactants is they allow you to combine oil and water.

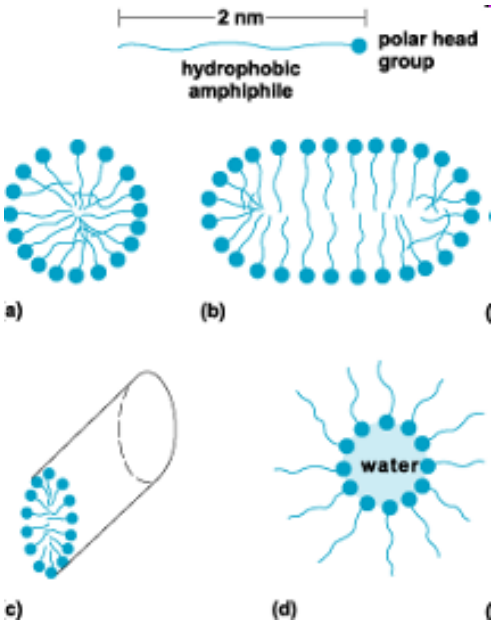
So how do they do this? You have to look at a surfactant molecule. All surfactant molecules have, to some extent, a hydrophilic head and a hydrophobic tail. This makes them compatible in both an aqueous medium and a non-aqueous medium.



Since surfactants have this property, they behave in an interesting way in a solution. When water and oil are put together, they're generally not compatible. And if you look at the surface, there's a tension created because the two substances won't interact. On a molecular level they try to get as far away from each other as possible.

When surfactants are present in a system, they go to those surfaces. Here the surfactants interact with the water and oil molecules, bringing everything closer together and reducing the surface tension. The interface is then more spreadable and more compatible with itself. Surfactants allow you to disperse oil in water, or also water in oil.

Suspending Dirt in Micelles



Surfactants also do another useful thing when put in solutions. When they are put into a water solution, they form different sorts of structures depending on the concentration of everything. One of the structures is a micelle. It is these micelles that help create an emulsion and suspend incompatible materials within each other. An emulsion is a mixture of oil and water using surfactant, but what happens is that the micelles will hold a material in the middle and suspend the particles in a solution.

In a typical surfactant solution, the surfactant is mixed with oil and then, the lipophilic tails will orient with the oil, and the polar heads will orient with the water, and the micelles are created. There has to be a critical concentration at which there's enough surfactant to start forming these structures. If you don't

have enough surfactant in your solution, then it won't form micelles so that the surfactant amount will just continue to mix around in the solution. Figuring out these proper percentages is one of the main jobs of the cosmetic formulator.

So why are surfactants important for cosmetics? For cleansing products like shampoos or body washes they are good for their cleaning effect of course, but also their wetting effect, their dispersing ability, their tendency to make foam while some can also condition and some are thickening.

Detergency

Perhaps, the most important thing about surfactants is their effect of detergency. When skin and hair get dirty there are really two types of dirt. There are solid particulates and there are also oily deposits. The oily deposits come from your natural sebum from your hair follicles which are always producing oil. Solid particulate comes from the environment and your body just naturally will pick up this dirt and dust from the environment. The way that solid particles adhere to your body is through Van der Waals forces. These are pretty weak forces, in fact, if you shake your head, you can get rid of a lot of the solid particles.

The way that surfactants in detergent help to get rid of the solid particles is that the anionics will coat the surface of the hair and increase the hydrophilicity of the surface. That makes these solid particles, which tend to be lipophilic, lift up to the surface of skin or hair where rinse water can help take them away.

Surfactants also remove oily materials like dirt and grease from the surfaces. The way this works is that the surfactants orient among the oil-water interface and then, the surfactant lifts the oil off the surface and that causes it to suspend the solution and then the oil gets around in a micelle and the rinse water helps remove the oil micelle. See the bonus video for an animation of exactly how it works.

Wetting

The term wetting is important when it comes to surfactants and cosmetics because it explains the tendency for surfactants to get onto the surface, spread out onto the surface and combine with the oils that are stuck there. If surfactants were put on the surface and could only get to the top layer of the oil or dirt that was there, they would not be able to lift them off the surface. You would only get the top clean. But surfactants have this wetting property which allows them to spread more easily on the surface and to inject itself between the oil particle and the skin or hair surface. This lifts up the oil and allows it to be removed. Wetting also prevents your product from balling up on the surface but makes it easy to spread. When you have a product that feels hard to spread it's because you don't have enough of a wetting surfactant to help it spread out.

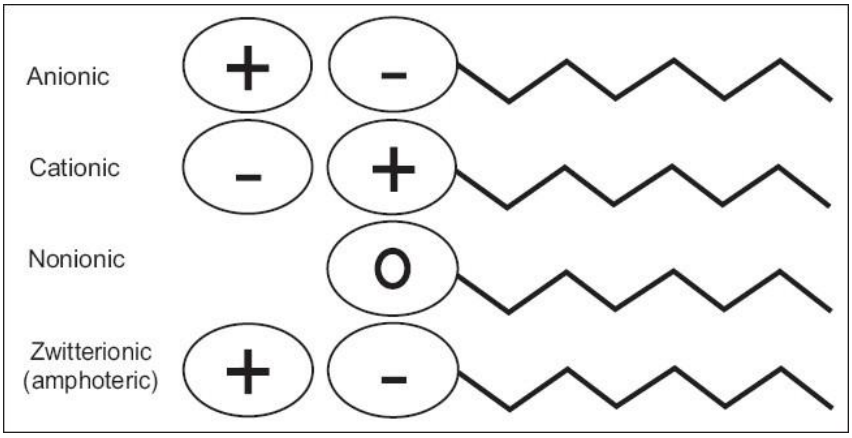
After the surfactant wets out onto the hair or skin surface, the oils are lifted off and suspended in the foam that is created from the surfactant and the wash water. When this is rinsed off, the dirt and oil is removed.

Foaming

Foam is formed because air is dispersed in the continuous liquid medium. The air bubbles are surrounded by little thin layers of liquid and the surfactants help to stabilize the bubbles that are formed. It's important to note that the foam doesn't really contribute much to the removal of dirt, but it's very important in a cleansing product to make it foam since foam is a cue to consumers which they like. Remember, great foam does not mean great cleaning but consumers expect it. So, it's important when making a cleansing product that you create lots of voluminous foam.

TYPES OF SURFACTANTS

Surfactants can be classified by the charge of their ion or whether they have an ion or not. There are anionic surfactants, which have a negatively charged ion. There are amphoteric surfactants, which are capable of both positive and negative charges depending on the pH conditions of the solution that they are in. Then there are cationic surfactants, which are positively charged. And finally, non-ionic surfactants which have no charge at all. As far as cleansing products go the most important are anionic, amphoteric, and nonionic. We'll cover cationics in the conditioner section.



Anionic Surfactants

Anionic surfactants are really the primary ingredient used in cleansing products, the most common of which are the alkyl sulfates. They are negatively charged surfactant ions. The most common examples found in shampoos include Sodium Lauryl Sulfate, also known as SLS and

Ammonium Lauryl Sulfate also called ALS. Basically, when you see the word “Sodium” or “Ammonium” at the start of a cosmetic surfactant, the material is probably an anionic surfactant.

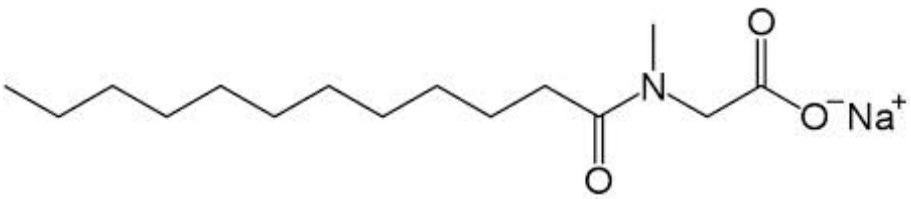
To make surfactants a little less irritating, sometimes the anionic surfactants are modified. For example, Ammonium lauryl sulfate is “ethoxylated” to produce ammonium laureth sulfate (ALES). Ethoxylated just means that it is reacted with Ethylene Oxide to add length to the molecule. This extra chemical processing makes it significantly less irritating. This also can make it slightly more water soluble. However, ethoxylating a surfactant also tends to reduce the foaming ability. So, SLS is a more efficient at foaming than SLES.

Sulfate Alternatives

Since some consumers are weary of “sulfates” some companies try to avoid ingredients with the name sulfate in them so other options are used. Other types include sulfosuccinates, alkyl benzene sulfonate, acyl methyl taurates, acyl sarcocinates, glucosides, the isethionates, propyl peptide condensates, monoglyceride sulfates and fatty glycerols, and ether sulfonates. These are all anionic surfactants that have been used in shampoos or body washes. We can't go into all the benefits and drawbacks of using each of these types but there are 2 basic benefits:

- **They don't use the word Sulfate**
- **They are less irritating**

However, when it comes to shampoo formulating, if you are looking to make a product that performs and foams well, you would mainly use a sulfate unless you are making a sulfate-free formula. For these types of products, you're probably going to use the Methyl Taurates or the Sarconcinates.



Sodium Lauryl Sarcosinate

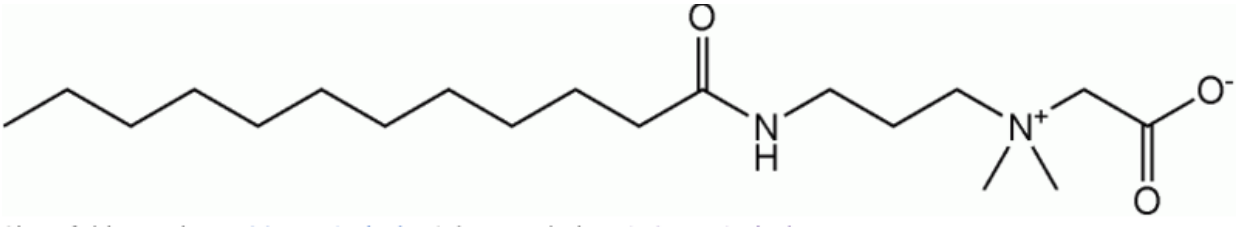
Anionics are excellent detergents, so they're really good at removing dirt and oil. They are also relatively inexpensive which most cosmetic marketers like. In fact, they are some of the least expensive surfactants you can use. They make very good foam and they make highly stable

foams too. Overall, they're very good materials to use for shampoos and other cleansing products.

Probably the biggest drawback is that they can be irritating, and they can also make hair and skin feel dry. Sometimes they just clean a little too well. But overall, anionics are by far, the biggest class of surfactants used for shampoos and cleansing products. Almost all of the best-selling shampoos use anionic surfactants.

Amphoteric surfactants

Amphoteric surfactants are those that can have both a negative charge and a positive charge depending on the pH. These materials are also referred to as zwitterionic materials, and they include ingredients like Cocamidopropyl Betaine, Cocoamphopropionate and Sodium Lauraminopropionate. These three are probably the most commonly used amphoteric surfactants in cleansing products, and particularly in shampoos.



Cocamidopropyl Betaine

Amphoterics are used because they have good detergency, of course, and they are less irritating than the anionics. They also can help to thicken the system and have a very good effect on foam and they could help make you foam have smaller bubbles that feel creamier.

Probably the biggest drawback to them is that they are significantly more expensive, and on their own, they don’t really foam well enough to produce a good shampoo. Often, you'll see amphoterics combined with anionics to create a really good shampoo. A blend of Sodium Laureth Sulfate and Cocamidopropyl Betaine is quite common.

Nonionic surfactants

These are surfactant molecules that do not have a charge. So if you put these in water, the molecule does not dissociate as the previous ones do.

Non-ionics are good foam enhancers and have low irritation potential. They are used as the primary surfactant in gentle cleansers like baby shampoos. Specifically, the most common is PEG-80 sorbitan laurate.

The reason these aren't used as the primary cleansing surfactant in most formulas is that they don't foam nearly as well and they are significantly more expensive. Overall, non-ionics are not as easy to create a consumer acceptable shampoo as using anionics.

Natural shampoo functional ingredients

For natural shampoos Alkyl Polyglucosides like Decyl Glucoside, Lauryl Glucoside or Coco Glucoside are most often used. They are surfactants derived from coconut oil and sugar and they also happen to be biodegradable. Unfortunately, they are tricky to work with because they do not build viscosity well and they don't foam as well as sulfates but they are considered more natural. Another drawback is that they are more expensive than most other primary surfactants so your finished formula will cost more than standard formulas.

All of the surfactant examples mentioned thus far are synthetic ingredients. Even the "natural" ones like the polyglucosides are chemically synthesized from natural sources. But there is one class of surfactant that is more natural than most since no synthetic manipulation is required. These are Saponins which are obtained through an extraction process from marine plants.

An example of one is Quillaja Saponaria Molina. These compounds are very difficult to purify, which makes them very expensive and hard to obtain. They also aren't nearly as effective as your typical synthetic surfactants. For instance, they produce about 40% less foam than typical sulfates. However, if you're trying to formulate a truly, from nature, natural formula, using Saponins is an option. They have a natural sounding name and a good story so maybe the cost and lower performance are worth it. One final formulation challenge is that these ingredients are very dark in color, so formulating a light or clear product may be impossible.

Conditioning and Moisturizing ingredients

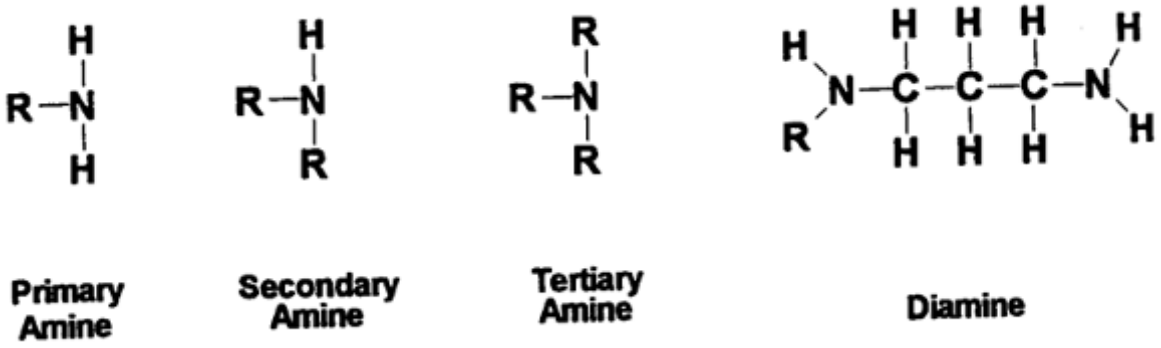
Conditioning and Moisturizing ingredients improve the feel or condition of whatever surface they are put on including the skin or hair. They typically have an 'oily' nature and for them to be effective they must also be substantive or left behind on the surface in some way. Materials that are easily washed away do not make good conditioning or moisturizing ingredients.

There are a wide range of different types of conditioning and moisturizing ingredients, but the most typical ones include:

- Quats
- Cationic Polymers
- Occlusives
- Humectants
- Emollients
- Proteins

Quats

The first type of conditioning ingredient we'll cover are cationic surfactants. These are also known as Quaternary Ammonium Compounds, Quaternized compounds or just simply “Quats.” They contain at least one Nitrogen atom bonded to 4 other hydrocarbon groups. In the example here you can see Nitrogen bonded to a Cetyl group and then 3 other Methyl (CH3) groups. This part of the molecule is positively charged so it is associated with a negative ion, Chlorine. Together they make Cetrimonium Chloride.



Some other common examples include Stearalkonium Chloride, Dicetyldimonium Chloride, and Behentrimonium Chloride. You should understand that Nitrogen can bond with 4 different hydrocarbon chains at a time. When it is bonded with only one the ingredient is called a primary amine. When it is bonded with 2 hydrocarbon chain it is called a diamine. When it's bonded to 3 it is a tertiary amine. This can be made even more complicated because two Nitrogens can exist in a molecule and when this happens you have a Diamine.

We know that these are surfactants, but they don't make good cleansing products. However, they do have one property that makes them excellent conditioning ingredients, particularly for haircare products. They are substantive to damaged protein sites on hair and skin. See when hair protein is damaged the protein molecule will typically acquire a negative charge. That means that positively charged molecules will be attracted to it. Remember negative and positives attract?

When you put a quat on hair or skin the positive portion of the molecule is attracted to the negatively charged damaged site and it creates an electrostatic bond. Then when water is rinsing things away it sticks on to the hair or skin. The nice part about this system is that you only get as much of the material left behind as you need. The cationic molecule will only stick to portions that are negatively charged. Everything else will be rinsed away!

Since these are hydrocarbon molecules (they have a hydrocarbon chain on them) the longer the hydrocarbon chain the more conditioning they will be. So, all things being equal a material like

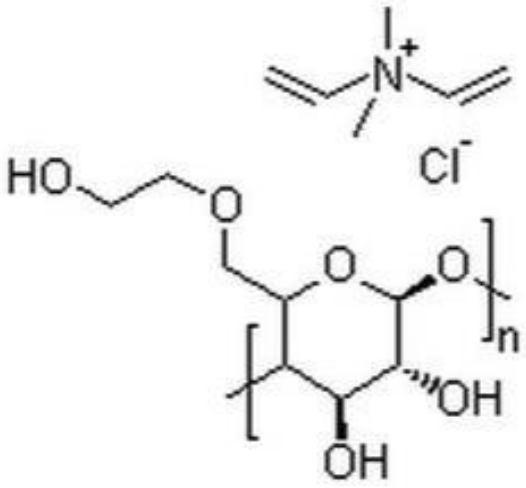
Behentrimonium Chloride which is a C22 carbon chain will be more conditioning than a shorter chain molecule like Cetrimonium Chloride which is a C16 carbon chain. Of course, as a formulator you can make a very nice formula with Cetrimonium Chloride, but it's easier if you start with Behentrimonium Chloride (for hair conditioners anyway).

As far as conditioning ingredients go, Quats have a number of benefits. They are noticeably effective, very easy to work with, and are less expensive than most of the other conditioning ingredients. You can't use too much of these ingredients however because they can be irritating. In fact, it is recommended that you do not use high levels of quats in any product that is meant to be left on. The Cosmetic Ingredient Review board has even set a maximum use level for any leave on product using Cetrimonium Chloride of 0.25%. But typical use levels of quats in hair conditioners for example is anywhere from 1% to 5%.

Cationic Polymers

While quaternized compounds are great conditioners the drawbacks of irritation and incompatibility with anionic surfactants led to the development of materials that could overcome those problems. That is what cationic polymers can do. They are compatible with anionic materials and are much less irritating.

Cationic polymers are long chain molecules that have multiple, positively charged sites on them. They're almost like a collection of cationic surfactants bonded together with a covalent bond. They are given the name “Polyquaternium” since they are a polymer and a quat. Some common examples include Polyquaternium 4, Polyquaternium 7, or Polyquat 10. Then there are some ingredients derived from the Guar plant like Guar Hydroxypropyltrimonium Chloride. These ingredients have a number of positively charged sites within their molecule.



Polyquaternium-4

Cationic polymers condition the surface of hair and skin in much the same way that cationic surfactants do. They have a large part of the molecule that is hydrocarbon based (oily) and a number of sites that are positively charged. When they are put on damaged hair or skin protein the positive portion of the molecule is attracted to the negatively charged damaged area. This creates an electrostatic bond which resists rinse off. Cationic polymers also have another method by which they can stay on the surface. This is a result of how they are formulated.

When a cationic polymer is put into a solution it may or may not be soluble. Typically, these materials are soluble in water but only to a certain extent. When there is a surfactant present in the solution then they become much more soluble in the system. However, when they are incorporated into a cleansing product, they are applied to a surface then exposed to more water. The additional water added to the system dilutes out the formula and causes the polymer to become less soluble or even insoluble. At this point it separates out from the water and gets deposited on the hair or skin. This is known as Dilution-Deposition and is the basis for a number of 2-in-1 shampoo technologies. The most common cationic polymer used for this purpose is Polyquaternium-10.

The reason that you would use a cationic polymer as your conditioning or moisturizing ingredient is because they are effective at low levels (even <0.2%), priced nicely, and they are compatible with anionic surfactants. That means you can use them in most any cleansing formula to improve the surface of whatever you're cleaning. They are excellent for things like moisturizing shampoos, facial washes or body washes.

One of the most significant problems however is that they can build up over time. The dilution-deposition effect means that future washings with the same cleansing system will not be able to remove the polymer that was left behind from previous washings. This can lead to people have dull, flat, weighed down hair over time.

Cationic polymers are effective at low levels. The maximum use level would be 5% but they are more typically used in a formula at levels below 1%. Polymers also have the added benefit of being multifunctional. For example, Guar Hydroxypropyltrimonium Chloride not only conditions but it also can improve the quality of your form and help make other conditioning ingredients like Silicones work better.

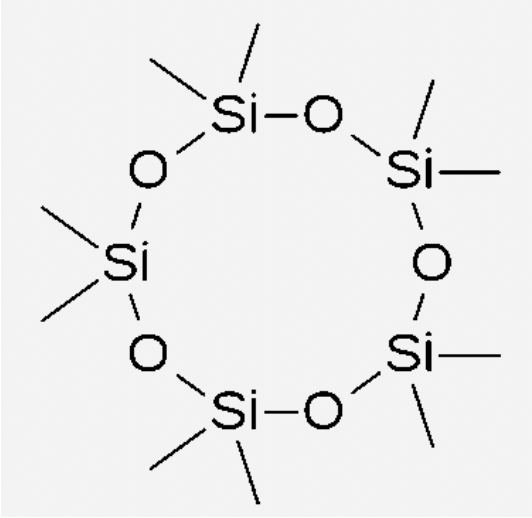
Silicones

Silicones are ingredients that are derived from the element Silicon. Unlike most of the other ingredients we've spoken about thus far, Silicones have a Silicon-Oxygen backbone in their molecule rather than a Carbon backbone.

Silicones are polymers which have an Si-O- repeating unit in their backbone. This is similar to the C-C backbone in hydrocarbons and like those compounds, we are able to

chemically bond materials to the top and bottom of the chain. In a material like Dimethicone, CH3 or Methyl groups are bonded to the top and bottom of the chain. The molecular chain is also capped with a Methyl group.

An ingredient like Cyclomethicone is made up of a Si-O- ring structure much like the hydrocarbon ring structure of Benzene. This gives the molecule the handy property of being volatile and any product that uses Cyclomethicone, will eventually evaporate from the surface it is put on.



Cyclomethicone

Silicones are not normally soluble in water so that could limit their use in cosmetics as most of the products are water based. However, chemists have chemically modified silicones by adding hydroxyl or -OH groups. This makes them water soluble and can be used in water-based formulas. You can tell a silicone has an -OH group in it when it contains an 'ol' in the name. So ingredients like Dimethicone Copolyol or Dimethiconol both contain hydroxyl groups that make them water soluble.

Silicones work as conditioning or moisturizing ingredients because they are normally insoluble in water. When creating your cosmetic formula, you incorporate silicones with an emulsifier to suspend them. When the product is placed on the surface and exposed to dilution and a rubbing action, the emulsion breaks and the silicone will plate out on the hair or skin. This is exactly the same mechanism by which other oils function as conditioning agents. It is interesting to note that since materials like Dimethicone Copolyol or Dimethiconol are made water soluble, they are much less conditioning because they are easily rinsed away during use. These silicones work best for leave-in products but don't do much in rinse off products.

Of all the materials that we've talked about Silicones are the best ingredients for imparting shine to a surface. Whenever you want to make a cosmetic that shines, silicones are the most efficient ingredient to use. They are also amazingly slick and slippery. Whenever you want your

formula to impart slickness, silicones are also an excellent choice. These properties are also why Silicones are used in so many other industries!

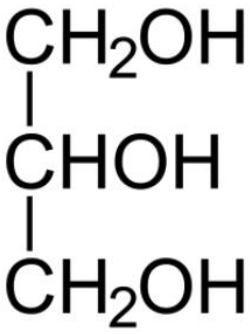
Silicones are also useful because they work on surfaces that are not damaged. Remember that cationics require a damaged surface on which to “stick”. If there is no damage or just a small amount the user may not notice any difference if they use a cationic material. A silicone material will work on any surface whether it is damaged or not. That is why silicones make an excellent secondary conditioning / moisturizing ingredient for hair products. Plus, they are compatible with both cationic and anionic surfactants.

However, they are not without their drawbacks. Since silicones are not soluble in water, they can be difficult to remove from the surface of hair or skin with simple cleansing products. Therefore, they can start to build up. While they are shiny, they also can attract more dirt and oil to your hair or skin which can lead to a dull, flat look. Hair can look weighed down or skin can feel greasy or heavy. You have to be careful with how you formulate with silicones. Typically, to prevent these problems silicones are used at levels of 2% or less.

Humectants

Humectants have been used as cosmetic compounds for as long as cosmetics have been around. They include natural materials like Honey, Aloe or Glycerin and are typically mild. The property that makes humectants useful is that they attract and hold water like a sponge. In fact, Glycerin can hold as much as 3 times its weight in water. Think of humectants as tiny molecular magnets for water. Therefore, when you have a surface that has a tendency to dry out like skin or hair, a humectant can be used to keep it moist. Incidentally, humectants can also help keep your formulation moist so if you're having problems with your product drying out in the container or a pump, using a small amount of humectant can help.

The most common humectants used in cosmetics include Glycerin, Propylene Glycol, Sorbitol, Sodium PCA, Hyaluronic Acid and various Hydrolyzed Proteins. Most hydrolyzed proteins will have a slight humectant property.



Glycerin

Humectants make good cosmetic ingredients because they are quite mild and almost no one has a negative reaction to them. They also are compatible with most other ingredients so they can be used in a number of cosmetic formulations.

They do have a couple of significant negatives related to them however. First, while they are able to absorb water this also causes them to feel sticky. Consumers may want their skin and hair to feel moisturized but they do not want it to feel sticky! Another problem with humectants is that they are water soluble so they will mostly be washed away when used in any rinse off product. This limits them to only cosmetic products that will be left on. This is great for things like skin lotions and leave-on hair conditioners but not so great for shampoos, body washes or rinse-out hair conditioners.

The typical use level for humectants is anywhere from 1% to 20% depending on the application.

Occlusive agents

Perhaps the most effective skin moisturizing ingredients are occlusive agents. These are oily materials that can create a thin coating on the skin or hair. As we'll see this coating has a significant benefit. Occlusive agents are ingredients that are not soluble in water. They are typically lipids with long chain molecules. The most common types of occlusive agents include Petrolatum, Mineral Oil, and Dimethicone. Natural oils like Coconut oil or Olive oil have some minor occlusive effect but this is not how they primarily work so we'll discuss them later.

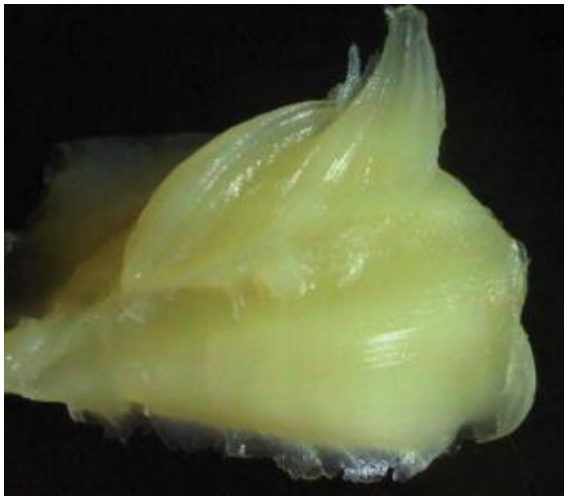
They are typically used in formulas anywhere from 1% to nearly 70%. Often these ingredients can double as the solvent in the case of products like hairdressings.

The way occlusives work is that when they are put on the skin (or hair) they form a thin, continuous film on the surface. Essentially you can think of them as painting your skin with a clear paint. This film is flexible and feels slightly greasy to the touch. This greasy feeling is the reason that you don't want to use too much of these ingredients in your formulas. The film also is resistant to water which helps explain its moisturizing effect.

To understand this though you have to know that skin is in a constant state of water loss. Your body just naturally loses water through your skin. Fortunately, it gets replaced when you ingest water from food or drinks but it is a constant battle for you to stay hydrated. When the air is more humid like in tropical climates your skin does not lose water nearly as fast. But in the winter when the air is dry, the rate at which you lose water increases. That's why winter skin feels drier than summer skin.

These occlusive agents can slow down your body's ability to lose water. Instead of the water just naturally evaporating through your skin, the occlusive agent creates a barrier. As the water tries to leave your body it hits this barrier and starts to accumulate in the outer layers of your skin (the epidermis). This extra moisture improves the way your skin looks and feels and also can reduce itching and redness. Occlusives like Petrolatum are so effective that they can actually be used as OTC drugs for skin protectants.

No discussion of occlusives would be complete without mentioning that Mineral Oil and Petrolatum are controversial ingredients to many people. In fact, natural and organic brands tend to avoid these ingredients because they are derived from non-renewable materials. Indeed, they are. But you may also see claims that these ingredients are unsafe or otherwise bad for skin. These claims are not based on science. In fact, the reason that mainstream formulators continue to use these ingredients is because there has not been any other ingredient that works as well to moisturize skin. Petrolatum continues to be shown to be the best skin moisturizer that we have. You can get close with a blend of other materials like humectants, polymers, and emollients but these still work the best.



Emollients

Emollients were some of the first ingredients that were used as cosmetics. They are not typically compatible with water and include ingredients like oils, butters, waxes, and esters. They are similar to occlusive agents except they tend to be lower molecular weight molecules and don't have the ability to form a continuous film to block water. But emollients are important ingredients for improving the feel of the surface of hair and skin and impart shine which is why they are primarily used.

When you are formulating skin creams, lotions, and even hair products you will use emollients to modify the way that your formulation feels, the way it rubs into the skin, the ease at which it spreads, and the length of time that it remains “workable.” As a cosmetic formulator getting familiar with the different emollients will be a crucial skill you need to develop. It is the subtle choice of emollient that can set your formulation apart from competitors.

Common examples of emollients include natural oils like Coconut Oil, Argan Oil, Almond Oil or Olive Oil. There are also a number of excellent esters that create emollients like Myristyl Myristate, Cetyl Palmitate, or Lauryl Laurate. Each of these feels slightly different and have different abilities to absorb into the skin. Many of the silicones can also make excellent emollients as they provide great slickness and shine.

The typical use level of emollients in formulations is anywhere from 1% to 25%. It really depends on the type of formula and the feel that you are going for.

Color Additives

Cleaning and conditioning are two of the primary benefits people want from their cosmetic products. The third most important benefit is color. Color cosmetics or make-up are specifically designed to change the color of the user's skin. In this section we are going to review the colorants used in cosmetics.

Color additives are pigments or dyes added to cosmetic formulations for the expressed purpose of either changing the color of the user's skin or hair, or to change the color of the product. There are two classes of ingredients that are added as colorants, organic pigments and inorganic or mineral pigments.

It's notable that in the US colorants are the most highly regulated ingredient that is allowed in cosmetic products. Manufacturers of cosmetics are not allowed to use any ingredient to color their products if it is not approved by the FDA. There are similar regulations around the world. This is primarily because certain materials which were traditionally used in cosmetics like lead or mercury containing ingredients caused significant health problems.

Note - ingredients used in permanent hair coloring are different than the ingredients we are discussing here. We will talk about those ingredients in the unit on hair products.

Inorganic pigments

Since mineral make-up and natural products are trendy these days let's first talk about inorganic pigments. These are the colorants used to make mineral makeup. They primarily include Iron Oxides which are available in three different colors including Red, Yellow, and Black. Using these three colors along with Titanium Dioxide (which creates a white color) every known shade of human skin can be produced. That is why these ingredients are most frequently used in Foundation and Concealer products. Being able to match skin tones using cosmetic colors is as much an art as it is a science and as a color cosmetic chemist you have to get good at doing these types of color matches.

There are some other inorganic pigments that are used to produce the many colors that are found in make-up kits. Bismuth Oxychloride is used to produce a silvery-grey color. A number of interference colors can be created from coated Mica coated with Titanium Dioxide. These are interference colors that work like a prism.

Chromium compounds are used for making green colors and Iron Ammonium compounds are used for blue colors. Violet colors are produced using Manganese compounds and Ultramarines are used for pink colors.

However, there are some downsides to using inorganic colorants and cosmetic chemists have found great utility in using organic colorants.

Organic pigments

There are six classes of organic colorants including Azo colorants, Xanthenes, Triarylmethane, Anthraquinone, Quinoline, and Indigoid. You can get a wide range of possible colors but unfortunately some (not all!) of these ingredients have been linked to health concerns. Therefore, there are only a limited number of ingredients allowed.

Organic pigments are most frequently used to produce bright and varied colors that you find in more colorful make-up kits. They are also the primary colors used to impart color in personal care products like shampoos, body washes, skin lotions, and more. They are useful because they are almost always easily incorporated into both aqueous and non-aqueous formulations. They can be used at incredibly low levels. In fact, to modify the color of a formulation you typically use ingredients on the order of 0.001% or less. When using colors in the lab you will usually make dye solutions to more accurately measure out dye levels. Even a small difference in dye level can result in a vastly different product color.

One challenge with organic pigments is that they can be susceptible to reacting with UV light or oxidizing and changing color. Green and Blue colors are particularly vulnerable to degradation.

You might wonder why everyone doesn't just use inorganic pigments in their formulations due to the safety concerns and stability problems of organic pigments. The primary reason is that organic colorants are easier to formulate with as they are more compatible with water and they produce much brighter colors. Inorganic pigments give a more dull, matte finish.

Active ingredients

These are ingredients that have been proven to have an effect on cell metabolism or treat some disease. For this reason, these ingredients are highly regulated by the FDA. In fact, the FDA publishes monographs which give instructions on how the ingredients can be used.

FDA Monographs

A monograph is essentially a recipe book that tells formulators exactly the ingredients, doses, and formulations they can use when creating an over-the-counter drug. It also gives the exact claims that can be made about the product and describes other labeling requirements.

Here are the main types of cosmetic/OTC products that are governed by an FDA monograph. If you are formulating one of these products, you will have to follow the rules described in the OTC monograph.

- **Anti-acne products** – This monograph describes 40 different ingredients that can be used for anti-acne. Rule was finalized in 1990 although there was some action in 2010 on Benzoyl Peroxide.
- **Toothpaste & anti-cavity products** – This monograph gives a list of over 20 ingredients that can be used to fight cavities. The final rule was issued in 1995.
- **Topical anti-fungal** – Products that are topically applied to places that need anti-fungal effects (diaper rash, feet, etc). Final rule was originally passed in 1993.
- **Anti-microbial products** – There is a long list of ingredients that can be used for topical anti-microbial products. For most of the antimicrobial ingredients, the final rule has not yet been issued. It is suggested you follow the proposed rules when formulating.
- **Antiperspirant** – This monograph is for products that are designed to stop sweating. The final monograph was originally issued in 2003. It lists 26 active ingredients that you can use.
- **Astringents** – These are classified as skin protectants. The final rule was originally issued in 2003.
- **Corn & Callus removers** – Definitely a niche product but some cosmetic companies might want to create these formulations.
- **Dandruff products** – If you are planning to create an anti-dandruff shampoo, then you have to follow the rules of this monograph. The final monograph was issued in 1991 & revised in 1992.
- **Hair growth / hair loss** – The final monograph for these types of products was issued in 1989 and includes nothing that works. However, in 1994, Minoxidil was switched from a prescription drug to an OTC. It remains the only non-prescription option.
- **Nailbiting products** – There is a monograph for products that are designed to stop people from biting their nails. Who knew? The final monograph was issued in 1993.

- **Psoriasis** – These products are designed to treat the condition of psoriasis. The tentative monograph was issued in 1986 and has yet to be finalized. Only a couple of active ingredients are allowed including Coal Tar and Salicylic acid.
- **Skin bleaching** – Skin lightening products are OTCs in the US. The tentative final monograph was issued in 1982 but it has yet to be finalized. There are only 2 active ingredients acceptable for skin lightening.
- **Sunscreen** – This monograph was just updated in 2013. It includes a number of ingredients including Titanium Dioxide, Zinc Oxide, Avobenzone and more.
- **Topical analgesic** – These products find a wide variety of application and cover products such as those designed for diaper rash, cold sore treatments, poison ivy treatments, and others.
- **Wart remover** – Products that are used to remove warts. The final monograph was issued in 1990 but updated in 1994. Thirteen active ingredients are listed.

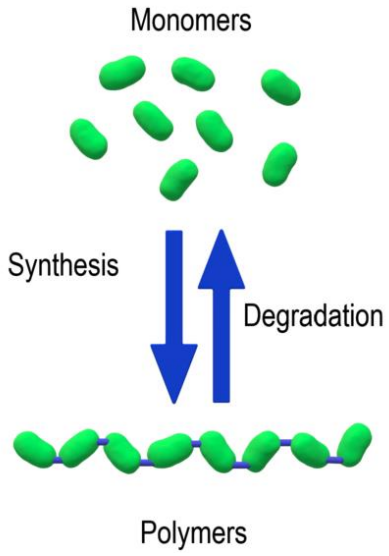
Monographs and the cosmetic chemist

It is crucial that you understand the monographs for any product that you are formulating. They list exactly the raw materials you can use, the amounts, and even dictate the claims you can make. And while it may be a bit restrictive from a formulating standpoint, it is useful to know exactly what ingredients have been tested and shown to be effective for some specific condition.

At this point you might be wondering where your favorite anti-aging or anti-wrinkle ingredient might be like Hyaluronic Acid or Niacinamide. These ingredients have not been proven effective to the level of a drug product so they are not technically “Active Ingredients”. However, we will discuss them further in the section on marketing ingredients.

Polymers

Polymers are long chain molecules made up of smaller, repeating units called monomers. They are used for a wide range of applications and could literally be included in every section of this review. We've talked about polymer conditioning agents but polymers are also used as thickeners, colorants, and hair styling materials.

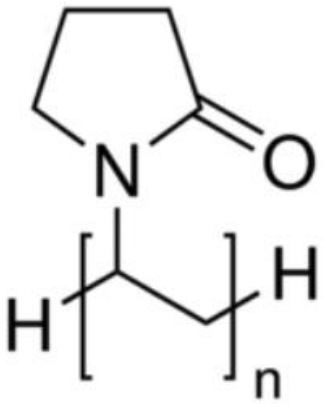


Proteins are actually polymers too but we'll talk about them in an upcoming chapter. For now, let’s focus on styling polymers because these ingredients are the primary function of the products in which they are included. In other applications

polymers are used to improve the aesthetics or functionality of the formulations.

Styling polymers are materials that are used to temporarily alter the shape of hair. They are used in products like hair spray, mousses, putties, and other types of hair styling products. There are three types of styling polymers including water-based polymers, alcohol-based polymers and wax-based polymers. They each work in a slightly different way to shape hair. We'll talk about the two primary types water-based and alcohol-based polymers.

The first type of styling polymer are ones that are soluble in water. They are used for products including hair styling gels and mousses. Some common examples include PVP (Polyvinylpyrrolidone), PVP/VA, and Polyquaternium 11. They are easily soluble in water and are used at levels of 2% or less.



PVP

When they are delivered to the hair, they create a slow drying film. As the film dries it get sticky, allowing for shaping the hair to any style desired. When the polymer film dries it hardens and keeps the hair in place. It's incredibly effective but unfortunately touching or combing the hair breaks the bonds and can ruin the style. These polymers are also sensitive to water so humidity can make the hair feel sticky.

Since there are these drawbacks with water-based polymers, alcohol-based polymers were created. These ingredients are not completely soluble in water, but they are soluble in alcohol. This makes them useful for hair sprays and alcohol-based gels. Two of the most common examples include Acrylates/Dimethicone Copolymer and Octylacrylamide/acrylates/Butylaminoethylmethacrylate copolymer. You can see these polymers often have long names.

These polymers work a little differently than the water-based polymers. They are delivered to the hair in a quick drying solution. As the solution dries, bonds are formed between hair strands. These hairs are “welded” together in the desired style. Since the polymers are not

compatible with water, they resist humid conditions and the hair style will hold. Unfortunately, since the film dries quickly it is difficult to reshape the hair after applying the product. These polymers are more useful as finishing sprays rather than workable stylers.

Reactive ingredients

These are ingredients that chemically react with either the hair, the skin, or themselves to produce a cosmetic effect. In most cases this effect will be permanent at least until either the hair grows out or the skin sloughs off.

In most cases cosmetic formulators do not want the ingredients used in cosmetics to have any chemical reaction with the hair or skin. Typically, a reaction is a negative result. However, there are some instances when a chemical reaction is desired.

Hair colors are different from the product colorants that were mentioned earlier. Permanent hair colors are actually a polymerization reaction in which monomers combine inside the hair to create long chain, colored molecules that get so big they are not able to leak out of the hair even after washing. The reaction to create this polymer typically involves Hydrogen Peroxide as an activator.

Hair relaxers are another type of reactive product. The main ingredient used in hair relaxers is Sodium Hydroxide, or Lye, and it works by chemically breaking bonds within the hair protein. Specifically, it breaks the hair Sulfur-Sulfur bonds found in proteins and allows the hair to be reshaped to become straight. This is a highly reactive ingredient and care must be used when relaxing hair because it can easily burn skin.

Perms are the opposite of hair relaxers. They are used to make hair curly or wavy. They work by creating the Sulfur-Sulfur bonds in hair in spots where there previously were none. In this way hair can be made to hold a new shape. The primary ingredient in perms is Sodium Thioglycolate and it smells awful. One area of research going on in haircare is to identify ingredients that can straighten or curl hair without being as damaging.

There are a couple of reactive products that are applied to skin. These include sunless tanners which are designed to change the color of skin. The primary ingredient is DHA or Dihydroxyacetone. It works by chemically reacting with the protein in the epidermis and turning it brown or orange depending on who you ask. The technology has improved greatly since it was first introduced in the 1960's.

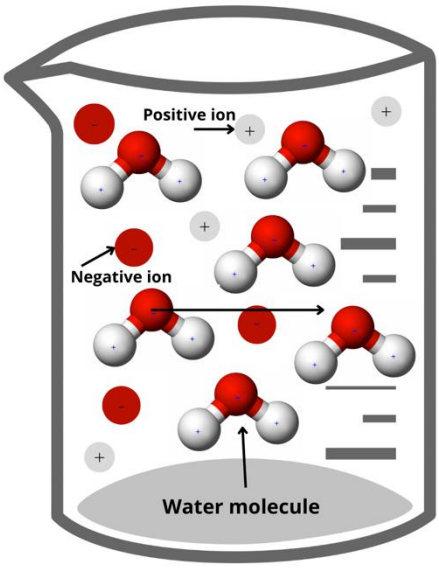
The last type of reactive ingredient are depilatories. These ingredients chemically break down hair and make it easy to remove. The most common ingredients used include calcium thioglycolate or potassium thioglycolate. These are effective but they can be incredibly irritating to skin so they are not recommended for people with sensitive skin or for use on the face.

Aesthetic ingredients

Functional cosmetic raw materials are not pretty and many don't smell good either. So, to make cosmetics more appealing we add ingredients that improve the aesthetics. These include Solvents, Adjusters, Preservatives, Thickeners, Fragrances, Fillers, and Special Effect ingredients. Delivery Systems would also be included in this class of ingredient. These ingredients definitely have an effect and function but they are added to improve the formula not necessarily the functionality of the formula.

Colorants would also be included here except they were already discussed.

Solvents



These are nearly always the most abundant ingredient in your formula. They are used to dilute the functional ingredient to make them more functional, less irritating, and more aesthetically acceptable. Solvents are the primary aid in delivery of the functional ingredients and they also are relatively inexpensive. In fact, the solvent that you use should be low cost to ensure that the formulation is low cost. Fortunately, water, the most common solvent is also an inexpensive ingredient. For most people it will be the most inexpensive cosmetic ingredient you can get.

In addition to being low-cost good solvents should be unreactive and compatible with a wide range of ingredients. Some of the most useful solvents include Water, Alcohol, Mineral Oil and Propylene Glycol. Some of these ingredients also double as conditioning ingredients. Whenever you can get a multifunctional ingredient, it is beneficial.

Adjusters/formulation aids

These ingredients allow for adjusting characteristics like pH and viscosity, or to help the formula look, feel or even perform better.

The most common ingredients are ones added to adjust the pH. These are acids like Hydrochloric Acid, Citric Acid, Lactic Acid, or Phosphoric Acid. To increase the pH or neutralize acids, alkaline ingredients like Sodium Hydroxide, Potassium Hydroxide, or Triethanolamine are used. As we've seen before for viscosity control of surfactant systems, a salt like Sodium Chloride or Ammonium Chloride are frequently added.

Another formulation added are chelating agents. Chelating agents are ingredients like Tetrasodium EDTA which have the ability of binding to free metal ions that are present in most water sources. Using them can improve the function of surfactants and also improve the efficiency of preservatives. Most aqueous formulas could benefit from the inclusion of a chelating agent.

Finally, there are solubilizers. Whenever you use an oily material like a fragrance there is a possibility that it is not compatible with the solvent you are using. Typically, this will result in a cloudy sample. To avoid this problem a non-ionic surfactant solubilizer like Polysorbate-20 or Oleth-40 are used.

All of these ingredients are used at low levels and can be extremely helpful during production when the formula can inadvertently out of the range of specification for pH or viscosity. Having a way to adjust pH and viscosity can be the difference between saving a batch worth thousands of dollars or throwing it away.

Preservatives

Why you need cosmetic preservatives:

- To stop microbes from spoiling your products
- To stop microbes from causing disease

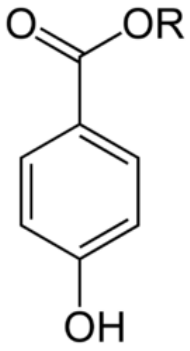
The microbes that can infect your formulas primarily include bacteria, mold, and yeast. In small quantities they don’t represent much of a problem but when they multiply, look out. Bacteria like Pseudomonas can cause all kinds of health problems including skin and eye infections, toxic shock, strep throat, and even food poisoning. Yeast like Candida albicans can cause thrush. And

many other bacteria can cause your products to smell awful, change color or otherwise break down (this is what stability testing is for).

Parabens

Parabens are the most commonly used preservatives. They are derivatives of p-hydroxybenzoic acid and go by names like Methylparaben, Propylparaben, and Butylparaben. They are typically supplied as powders and can sometimes be difficult to incorporate into a system due to the water solubility limitations. They only function when dissolved in water so using more than its solubility profile is a waste of money. They are effective against a broad spectrum of bacteria and fungi. They do have pH limitations and are not effective against all microbes so you usually will need an additional preservative.

It's interesting to note that the safety of parabens was recently reviewed by the SCCS in the EU



and determined to be safe when used at the levels found in cosmetics.

Paraben

Formaldehyde donors

Formaldehyde derivatives are the next most common preservative. These compounds interfere with membrane proteins which kills microbes. They are effective against bacteria, fungi, and mold. Bad press and real safety concerns have led cosmetic chemists to stop using formaldehyde. Instead, ingredients that dissociate into formaldehyde when put in a water solution are used. These are compounds like DMDM Hydantoin and Imidazolidinyl Urea. They are most often used in surfactant systems.

Phenol derivatives

Phenol derivatives have been used in cosmetics for many years and can be effective against a range of microbes. Unfortunately, they are not as effective as the previous ingredients so their use is limited. The most common examples is Phenoxyethanol. This is one of the most commonly used “natural” preservative ingredients.

Quats

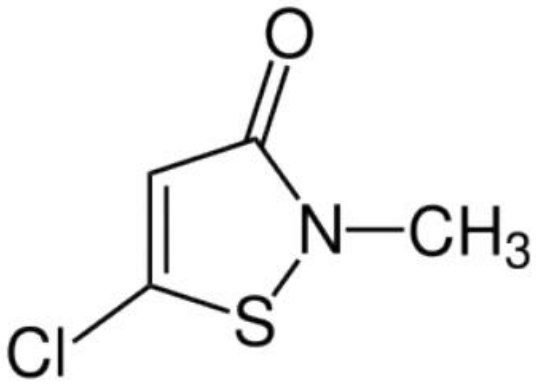
Compounds that contain nitrogen and have a positive charge when placed in solution are called quaternary compounds (or quats). Many of them demonstrate an ability to kill microbes. This includes ingredients like Benzalkonium Chloride, Methene ammonium chloride, and Benzethonium chloride. Their cationic nature makes them less compatible with anionic surfactants which limits their application & use.

Alcohol

Ethanol is a great preservative but you need to use it in high levels and it faces significant environmental restrictions. Other compounds like benzyl alcohol, dichlorobenzyl alcohol, and even propylene glycol all have some anti-microbial effect. In lower levels, these compounds are less effective at preserving products.

Isothiazolones

Synthetic compounds like Methylchloro- Isothiazolinone and Methyl-Isothiazolinone are effective at incredibly low levels. They have been shown to work at a wide range of pHs and in many different formulas. There use has been stymied however, by at least one study that suggested it could cause skin sensitization.



Isothiazolinone

Organic Acids & Others

Various other compounds are used as preservatives but all face some limitations not experienced to the same extent as the previous ingredients discussed. Some of the most important include Sodium Benzoate, Chloracetamide, Triclosan, and Iodopropynyl Butylcarbamate. Pyridine derivatives like Sodium pyrithione and zinc pyrithione are used to kill the bacteria that causes dandruff.

Why are cosmetic preservatives vilified?

More than any other ingredient, preservatives are most often called out as the worst ingredients you can use in a formula. Even people who know nothing about chemistry have likely heard about the "evil" parabens and formaldehyde.

Preservatives are designed to kill cells. That's why they are effective. Unfortunately, that's also why they are potentially hazardous. They don't easily discriminate between good human cells and bad microbial cells. But ultimately, the risk from using preservatives is significantly lower than that of using unpreserved cosmetics. There are safe levels of "toxic" chemicals. All chemicals can be deadly if you're exposed to a high enough level. How many people die from water exposure (ie drowning)?

Remember, it's the dose the matters!

Certainly, cosmetic science research is ongoing in the field of preservatives since many things previously deemed safe have been reclassified as hazardous. Suppliers who can come up with even safer preservatives will likely make a lot of money. Hopefully, they'll do it soon but there do not appear to be any promising materials on the horizon.

The most important thing to remember is that your formula MUST be adequately preserved. It's okay to try out new, alternative preservatives but understand that you are taking a risk. The alternative preservative may not work as well, may break down over time, and may have some unknown health risks.

Natural preservatives

I know many people are interested in "natural" preservatives and although this course is not meant to focus on natural formulating, I will include some options in this chapter.

Here is a list of some options that could work. However, it will take a high level to get them to function properly so they would be impractical for most cosmetics.

- Alcohol
- Benzoic acid and its salt Sodium Benzoate
- Boraxitrus seed extracts
- Copper salts
- Fragrance oils
- Glycerin
- Hinokitiol
- Honey
- Japanese Honeysuckle extracts
- Melaleucol (Tea Tree) oil

- Perillic acid
- Salicylic acid
- Salt
- Silver Chloride
- Sodium Gluconate
- Sorbic acid
- Sugar
- Usnic acid
- Wasabi extract
- Zinc Salts

Thickeners

One of the requirements of most cosmetic products is that they have an appealing rheology. This means that you as a cosmetic formulator you are going to have to figure out a way to control the viscosity (or thickness) of your products.

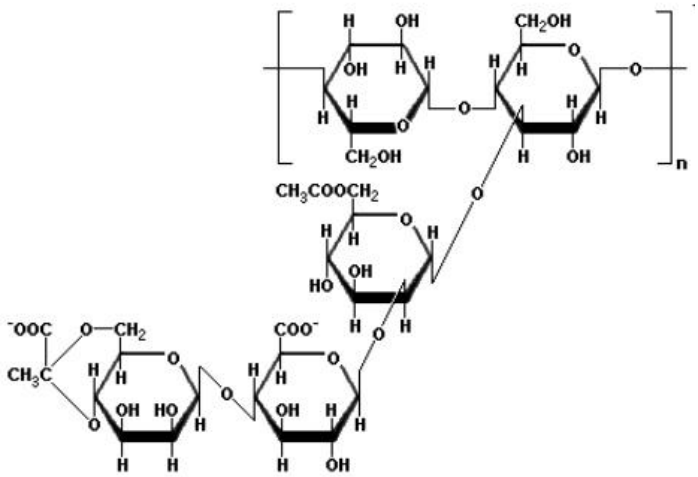
There are a number of ingredients that are used for this purpose. Each kind has applications to different formulation types. These include lipid thickeners, naturally derived thickeners, mineral thickeners and acrylic acid thickeners. You should also remember that salt can be a thickener in surfactant systems as we discussed previously.

Lipid Thickeners

Lipid thickeners are primarily composed of lipophilic materials. They work by imparting their natural thickness to the formula. Typically, these materials are solids at room temperature but are liquified via heat and incorporated into emulsions. They are used most often in creams and lotions. Some common types include Cetyl Alcohol, Stearyl Alcohol, Carnauba Wax, and Stearic acid.

Naturally derived thickeners

Various thickeners are found in nature or are derivatives of natural thickeners. These ingredients are polymers that work by absorbing water to swell up and increase viscosity. Cellulose derivatives like Hydroxyethylcellulose are frequently used in liquid cleansing products such as shampoo or body wash. Guar gum is another example of a naturally derived thickener. Others include Locust Bean Gum, Xanthan Gum, and Gelatin. These thickeners can be used in any formula that contains a high level of water. Unfortunately, they can be inconsistent, cause clear formulas to become cloudy, and feel sticky on skin.



Xanthan Gum

Mineral thickeners

Mineral thickeners are naturally occurring, mined ingredients that can absorb water or oils and boost viscosity. They give a different kind of viscosity than the natural gums. Materials include Silica, Bentonite, and Magnesium Aluminum Silicate. These thickeners can be used to thicken oils as well as water-based formulations.

Synthetic thickeners

Perhaps the most versatile of all thickeners are the synthetic molecules. Carbomer is the most common example. It is a water-swellable acrylic acid polymer that can be used to form crystal clear gels.

The way it works is that it is an acid and free flowable material when dissolved in water. At a low pH the compound remains flowable. But when you neutralize the formula (raise the pH) with something like Triethanolamine, the polymer creates cross-linked bonds between itself which makes the system incredibly thick.

They have a desirable feel which makes them superior to other thickening agents that leave a sticky feel. Carbomer thickeners also can suspend materials in solution so you can have low viscosity formulas with large particles suspended. These thickeners also help to stabilize emulsions and are frequently used in lotion and cream products.

Fragrance

Although some people show allergic sensitivity to fragrance ingredients, fragrances remain a standard ingredient found in nearly all cosmetics. The simplest reason is because people are more prone to buy cosmetics that smell good than to buy unfragranced or scent free products. The reality is that without fragrance most cosmetics would smell unpleasant and deter usage.

Fragrances are used in cosmetic formulas to improve the scent of either the formula or the surface to which they will be applied. In this way, fragrances can be thought of as both an aesthetic modifying ingredient and a functional ingredient. Fragrances are included here because unless the cosmetic is specifically a perfume or cologne, fragrance is added to the formula simply to modify the aesthetics of the formula.

Fragrances are a complicated blend of anywhere from 75 to 150 ingredients. A wide variety of ingredients are used to create the different notes including essential oils, natural musks and resins, and synthetic ingredients. Creating fragrances is a specialty that requires years of training. In fact, some call it more of an art than science. Perfumers who create fragrances train through an apprenticeship program and take up to ten years to become a full-fledged perfumer.

Fragrances are made up of both natural and synthetic ingredients. The natural ingredients are primarily derived from plants although some fragrance materials may be animal derived. For the most part, alternatives to the fragrance notes that are created with animal ingredients have been developed.

The challenge of working with plant-derived ingredients is that they can be highly variable depending on the soil and growing conditions of the plants. One harvest a natural ingredient might have one odor and a slightly different odor in another harvest. This makes it difficult to produce a fragrance with consistent quality.

Natural ingredients are also more expensive because it is much more complicated to create and isolate them. Supply is also variable due to the dependency on weather. Natural ingredients require land to grow and sometimes the crops compete with other, more profitable crops so they can be difficult to obtain. These challenges are what spurred the development of synthetic aromatic compounds.

Despite the challenges, a number of fragrance ingredients come from natural sources. These include resinoids, mosses, essential oils, and herbal extracts. It's interesting to note that

ingredient extracts do not necessarily smell like the plants from which they are derived. For example, strawberry extracts do not smell like strawberry. In fact, most every strawberry scent that you have smelled is produced using synthetic compounds.

The modern fragrance industry would not have nearly as diverse a pallet of scents if it wasn't for the creation of synthetic ingredients. These are volatile, organic compounds created in the lab based on scientific principles. There is a host of materials like aldehydes, ketones, esters, ethers, and more that trigger different sensations of scent. A number of these materials have been created to duplicate difficult to obtain natural materials. This makes them an important secondary source. Synthetic materials also tend to be much more consistent in quality, easier to obtain, and are less expensive than natural ingredients. You'll find that these benefits of synthetic ingredients are true for most cosmetic ingredients.

When a fragrance is created it is a blend of ingredients with differing volatility (the tendency to evaporate). They are loosely classified as top notes, middle notes, and base notes.

The top notes are the first thing that you experience when you smell a fragrance. These ingredients are the most volatile and they quickly evaporate once you open the container. It is these ingredients that create your first impression of a fragrance. If the consumer doesn't like the initial notes of a fragrance, they typically won't like the fragrance. Top notes are typically citrus or fruity scents.

Next, we have the middle notes, also known as the heart or body of the fragrance. They are what you smell after the top notes dissipate. Middle notes are typically made up of floral notes like rose or lily.

Finally, there are the base notes or bottom notes. These compounds take some time to emerge so are not immediately noticeable. However, they are the ones that last the longest so when your product is applied to a surface like skin or hair it will be these notes that people continue to smell hours after application. The bottom notes add depth and complexity to the fragrance. The most common types of base notes are woody or musky scents.

Just a note about fragrances and the list of ingredients. When you use a fragrance in a formulation you are only required to put the word “Fragrance” or “Parfum” to represent the ingredient. As you realize however, different fragrances can be made up of vastly different compounds. Putting the term “fragrance” on the label doesn't give consumers much information about what is in their product. Since there are some ingredients in fragrances that are known allergens there is the requirement in the EU (and arguably in the US) that you list those known allergens if they are in your fragrance.

This allows people who know they are allergic to a material to stay away from a specific product. But this requirement to only list *Fragrance* to represent all fragrances has led some to push for new legislation that lists all the ingredients in the fragrance. I'm not sure if that would be helpful to have more than a hundred ingredients on a cosmetic product label but it’s something to keep an eye on.

Fillers and appearance modifiers

Fillers are primarily found in powdered makeup products. The idea of fillers in liquid or emulsion cosmetics does not really make sense. The “filler” ingredient in these products is just the solvent. In fact, fillers can actually be thought of as powdered solvents because they have nearly the same effects as solvents. Namely, they are used to dilute the powdered colors used to create makeup. As we previously discussed just a small amount of colorant can produce a great deal of color. By using a filler, the color can be diluted and more easily spread on the surface.

Some common fillers found in cosmetics include Talc, Mica, Kaolin, Bismuth Oxychloride, and Calcium Carbonate. If you see these ingredients in a formulation, you now know why they are added. The exact filler that is used depends on the type of cosmetic you are creating and the cost of the source that you can get.

There are some miscellaneous appearance modifiers that are added to significantly change the appearance of your cosmetic formula. Pearlizing agents like Glycol Stearate or Mica are added to give the formula a swirly or pearlized look. They are often used to make clear body wash or shampoo formulas look opaque. This creates the image of a creamy, moisturizing formula.

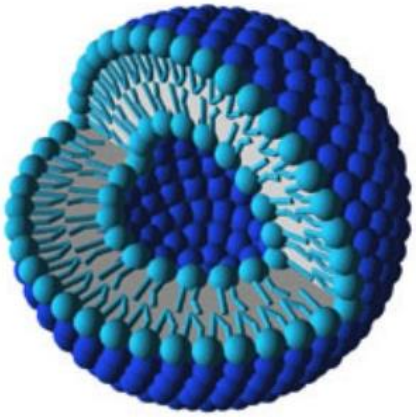
Another type of appearance modifier are encapsulated beads. These are tiny gelatin beads which are suspended throughout a formulation to make it appear as though there is some time release capsule of active ingredient in the formula. Or the beads may be added to provide something like an exfoliation effect.

Finally, there are texture modifiers which can be added to formulas to make them feel a little different during application. These are ingredients like crushed walnut shells or matrix polymers. They also can have an exfoliating effect but their main appeal is they make the formula feel different.

Specialized delivery systems

The idea behind these ingredients is that they are supposed to be able to protect your “active” ingredient from the parts of your formula in which it is incompatible to improve delivery and effectiveness of the ingredient. You would use a delivery system for an ingredient like Vitamin C in an aqueous formulation because the former is not stable in water. If the vitamin C is encapsulated it is protected from the water and can deliver its benefit when the capsules break open during application. These things work in theory but in practice it's hard to find evidence that they do.

Cyclodextrins are an interesting delivery system. They are made up of carbohydrates and have a water-soluble outer layer and a lipophilic inner core. They can be used to soak up oil on the surface of skin or deliver oil materials like fragrances to the skin. They are an interesting technology and one of the most useful of these delivery systems. Matrix polymers are another type of delivery system in which the outer part of the molecule is compatible with water while the inner part is compatible with oil. They can be used to deliver oils to the skin surface or absorb oil that is already there. They find lots of use in powdered makeup products.



Liposome

Finally, there are liposomes. Liposomes are essentially stabilized surfactant micelles. They are the same type of barrier that makes up cell membranes being created from phospholipid bilayers. In theory, they could be great and can hold both oily materials or aqueous materials inside their structure. Unfortunately, the technology is still in its early stages and there is limited proof that the liposome structure remains intact during production of the product.

Claims ingredients

To most people outside the cosmetic industry, they are unaware that these types of ingredients exist. Marketing ingredients are ingredients added to a formula for the primary purpose of supporting a marketing story. They may (or may not) have some functionality but are usually not superior in function to other materials included in the formula. They are also expensive ingredients that are cost prohibitive to add at levels that might exhibit that function. Nearly

every cosmetic company uses these ingredients because they help differentiate their formulas from other brands.

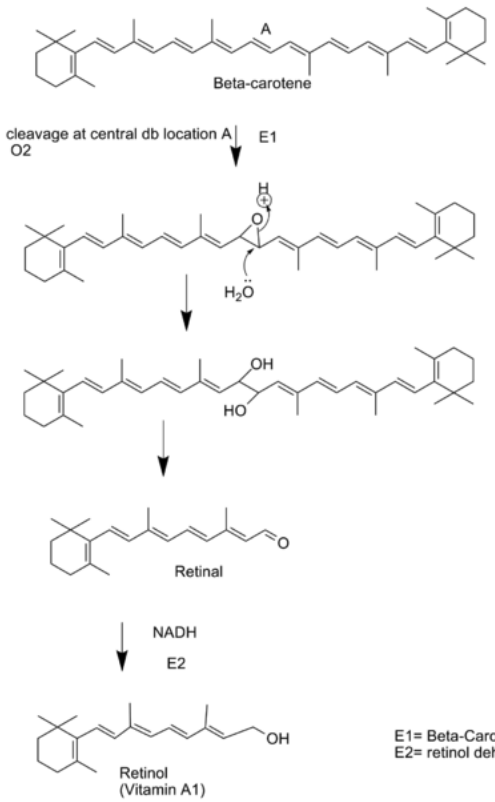
The other reason that these ingredients are used is because consumers like them. They like products that contain feature, or claims ingredients. The types of ingredients that serve as claims ingredients can vary but the ones that work best are those that are recognizable by consumers and offer some perceived benefit.

The primary types of marketing or claims ingredients include:

- Vitamins / Anti-oxidants
- Botanical Extracts
- Proteins
- Anti-aging ingredients

Vitamins/anti-oxidants

Of all the marketing ingredients, Vitamins are the best known and liked by consumers. Most consumers already believe that vitamins are good for their health so it is not a stretch for them to believe that vitamins in their cosmetic products will have benefits to their skin and hair. Unfortunately, with a few exceptions, vitamins have not been demonstrated to have a significant impact on the condition of skin or hair. They are primarily added to formulations because they support effective marketing stories.



The primary vitamins you will find in cosmetic products include Vitamin A, Vitamin B, Vitamin C, Vitamin E, Vitamin D, Essential Fatty Acids, and Vitamin K.

Of all the vitamins, by far the most effective one when delivered from a topical cosmetic is Vitamin A. It is derived from beta carotene and is part of a more general class of ingredients called Retinoids. This includes ingredients like Retinoic acid, Retinaldehyde, and Retinol. All of these ingredients have some function on skin but the most functional is Retinoic Acid. In fact, it

is so good at treating skin conditions that it is classified as a drug in the US and you need a prescription from a doctor to use it at effective levels. The other ingredients are added to cosmetics and have demonstrated some minor effects with reducing wrinkles and removing age spots however, they are not nearly as effective which is why this ingredient is classified as a claims ingredient. Many cosmetic companies will put a low, non-functional level of the ingredient in the formula just to be able to make the claim that Vitamin A is in the formula. Consumers know that Vitamin A works and are more compelled to buy the product no matter what level of the vitamin is actually in the formula.

One of the drawbacks of using Vitamin A in a formula is that it is difficult to stabilize. This is another reason that products that say they contain Vitamin A don't necessarily give you the benefits you would expect from having the ingredient.

The next type of vitamin commonly used in cosmetics is Vitamin C. It is a proven anti-oxidant who's chemical name is Ascorbic Acid. Vitamin C has definite health benefits when ingested in food but it's effects when topically applied are less proven. One of the biggest benefits to formulators in using Vitamin C is that it is an ingredient well-known to consumers. People find it easy to believe that Vitamin C has beneficial effects in their cosmetic formulations. There is some evidence that it can reverse UV damage by squelching free radicals caused by sun exposure. It is also thought to have some bleaching effect on age spots.

However, Vitamin C is a water-soluble ingredient that quickly oxidizes when placed in a water-based formula. If you are using a water-based cosmetic with vitamin C, you can be certain that it is not functional by the time it gets to the store shelves. The product may have all the standard effects of regular moisturizers, just don't expect the vitamin C to be doing anything.

Another common vitamin used in cosmetics is Vitamin E. This ingredient belongs to a class of compounds called Tocopherol and is a potent anti-oxidant. It also has some evidence that when applied topically it can have some beneficial effects on skin. It has been shown to improve moisturization, increase skin softness, and increase skin smoothness. Unfortunately, it doesn't have more of an effect than other moisturizing ingredients like Petrolatum or Mineral Oil. Another reason that vitamin E is added to some formulas is to stabilize them by preventing rancidity of oils. It is particularly effective when you have unsaturated oils like Olive Oil in your formula. But for the most part, there are other ingredients that function better than Vitamin E in all categories so that is why we list it as a marketing ingredient.

The final vitamin we will cover is Vitamin B5, also known as Panthenol. This is an ingredient that has been shown to work well as a moisturizing ingredient. It is a humectant and has the ability

to absorb a good amount of water. Of all the vitamins used in haircare products, this one has the most evidence of some functionality. In fact, there is evidence that Panthenol can actually strengthen hair strands, although the effect is small.

While Panthenol is an effective ingredient it is also water soluble which means if you are using it in a water-based, rinse off formula it will simply run down the drain and not have any function. If you are using Panthenol in a product be sure that it is a leave-on product.

There are a number of other vitamins that could be mentioned but there is even less evidence that they do anything when applied topically. If you are working on a project in which you want to include a vitamin to support your marketing story ingredients like Vitamin D, Vitamin K, and Vitamin H might be just what you need - just remember that they are claims ingredients only.

Botanical extracts

Perhaps the most common of these types of marketing ingredients are botanical extracts. It makes sense because consumers generally have a positive view of plants and there is a lot of folkloric information that supports their use. Unfortunately, there is very little scientific evidence that these ingredients have much beneficial effect when used in products like skin creams or hair products.

While anecdotal evidence of their effectiveness abounds, there are very few botanical extracts that have been shown to do anything beyond moisturization. This effect can be nice but from a formulation standpoint it makes more sense to use an ingredient that shows the best moisturizing effect in the most efficient way and then add a small amount of a botanical extract to support the marketing story. This is what is most often done in the cosmetic industry. If the ingredients could be shown to be more effective than other ingredients, they would get more use. But so far, the evidence is just not there.

You can buy any manner of herbal extracts from companies like Carrubba or Active Organics (owned by Lubrizol). They are typically supplied as solutions of the extract in a solvent like propylene glycol. This is one of the reasons that propylene glycol is found on a number of cosmetic labels. It is the solvent for the herbal extract.

The typical use level of an herbal extract when used in a cosmetic is below 0.1% and sometimes as low as 0.001%. There are no specific concentration limits you are required to meet when claiming that an ingredient is in your product. However, you have to have some amount of the ingredient in the formula.

Proteins

Proteins are most commonly hydrolyzed proteins derived from plants. Proteins are incredibly versatile ingredients and are the primary construction of all living things. They are complicated polymers made up of amino acids. When in their native state they can create structures like hair or blood. However, when they are used in cosmetics they are typically chemically hydrolyzed to break down their natural structure. This leaves straight chains of amino acids and essentially removes any kind of activity the protein had. Hydrolyzed proteins work as humectants and emollient ingredients but that's about it. However, there is some evidence that they may help to increase the strength of hair or nails but it is weak. Formulators should not expect proteins to have a significant impact on the way that their products function. They are typically added to the formula because they look good on the ingredient label.

Anti-aging ingredients

One of the primary promises of skincare products is that it will have some type of anti-aging effect. There are lots of ingredients that promise to work as antiaging ingredients but the reality is there is limited data to prove they actually work. We've already mentioned Vitamin A, E and C and how there is some evidence those can work as anti-aging ingredients when topically applied. The following ingredients also have shown promise.

Niacinamide

Niacinamide is a version of vitamin B3 (Niacin) which can brighten the complexion, erase wrinkles, reduce trans epidermal water loss, improve elasticity, and fight inflammation. There is some explanation of why it would work but the mechanisms are not fully understood. It is believed that Niacinamide has the ability to increase the antioxidant capacity of skin. It works by reducing (the opposite of oxidizing) NADP. Niacinamide may reduce water loss by increasing production of lipids and ceramides and by increasing cell turn over. It may reduce wrinkles by increasing collagen production. Finally, it lightens age spots by reducing the amount of pigment transferred from melanocytes to keratinocytes.

It has been demonstrated to penetrate the skin and several studies indirectly proved penetration by measuring increased NAD in cells after topical application (which increases due to the skin metabolizing vitamin B3.) This suggests that niacinamide is an effective anti-aging ingredient.

Soybean extract

These ingredients consist of two active ingredient types (isoflavones and protease inhibitors) which neutralize free radicals, stimulate collagen production, increase skin moisture, and reduce hyperpigmentation. There is some suggestion that it works as an antioxidant but it is uncertain whether it can penetrate the skin. If it can't penetrate, it won't have an effect on the

aging of skin. There have been a couple of in vivo tests which demonstrated some skin lightening effects however, the evidence of these products working as anything more than a claims ingredient are scant.

Green Tea

Another ingredient that has gotten a lot of press are green tea extracts. These contain polyphenols which are known to be potent antioxidants that may protect against UV damage and help photo-aged skin. There is a mechanism by which it might work and there is no doubt that green tea extract is an effective antioxidant which works by quenching several reactive oxygen species. It is also capable of limiting enzymes which cause collagen breakdown and to increase synthesis by fibroblasts, but this was only in laboratory testing.

The challenge with isoflavones as an anti-aging ingredient is that they are not able to penetrate the skin to be effective. So, their use in topical skincare products is currently little more than a claims ingredient.

Hyaluronic Acid

This is an ingredient found naturally in the skin and is a potent antioxidant. Unfortunately, it is too large of a molecule to penetrate skin when topically applied so there is little benefit to actually including in the formula except that it is recognizable and holds high consumer appeal.

Stem Cells

These are the hot new ingredient in the anti-aging arena and they have an interesting story. Most are from cells derived from apple or another plant. They say these stem cell extracts have the ability to restore lost youth for skin. Unfortunately, these ingredients can't possible work as advertised. First, plant stem cells are not the same as animal stem cells so they are not compatible with human skin cells. Second, it is technologically out of our reach at the moment to create stable stem cells in a product that can be sold on a store shelf. Consumers and cosmetic marketers might find these ingredients compelling but there is no science to back them up.

Purchasing raw materials

Often you can buy a single ingredient but you can also buy ingredients that are sold as blends. This might make sense for you as it can be less expensive and requires less inventory for you to maintain. However, this also makes you vulnerable to price changes and supplier availability. Don't get into a situation where you are reliant on a single supplier for a key raw material in your formulation. If they go out of business then you go out of business!

To finish up this chapter on raw materials I wanted to briefly mention “natural” raw materials and natural cosmetic products. When large companies are producing cosmetics, the cosmetic chemists are tasked with the job of creating the best formulations possible. This means that they create formulas that actually work as well as they can. If there is a natural ingredient that can perform as well or better than current synthetic ingredients, a cosmetic formulator from a big corporation would not have any problem using it. But the reality is that many of the best performing ingredients are synthetically derived. In fact, almost all cosmetic chemicals can be considered synthetically derived because there are actually very few natural ingredients that are used exactly as they are found in nature. There is always some level of processing that is required.

This brings us to the primary challenge for people who want to formulate “natural” cosmetics. In the cosmetic industry the term 'natural' does not have a specific meaning. Anyone can pretty much call any product they produce natural. This makes it challenging for people who are adhering to some standard to compete. Generally, synthetic ingredients are more consistent, easier to obtain, and functionally superior.

There are a few things to understand about natural ingredients. First, you need to decide what you mean when you are talking about natural ingredients. If your goal is to get your products sold into Whole Foods, then you will have to follow their Allowed Ingredient list. This makes it easy to define natural. However, their list isn't scientific and a better one may be the Ecocert standards published in the EU. Again, these limit a lot of ingredients you can use but at least it's a guideline.

If you do limit yourself to natural only ingredients don't expect the formulas to perform as well as standard products. Also, you should expect to charge a premium for your products. Natural based cosmetics are more expensive. Finally, don't expect consumers to continue to buy your products if they are unsatisfied with the way they perform. While consumers might say they want natural cosmetics, they ultimately want beauty products that work.

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Chapter 4

Types of Cosmetic Formulations

Types of Cosmetic Formulations

While there are thousands of different types of cosmetic products, there are only a limited number of different types of cosmetic formulas. You can categorize them in a few different ways but for the purpose of this book we'll consider the following eight basic cosmetic product forms. We will go over what they are, when and why they are most often used, and how they are made.

8 Cosmetic Product Forms

The basic categories for cosmetic formulas include:

- Solutions
- Creams / Emulsions
- Lotions
- Gels
- Ointments / Pastes
- Sticks
- Powders / Tablets
- Aerosols

Solutions

Solution cosmetics are the simplest type of formulation because they are just homogeneous mixtures of soluble ingredients. Nearly all their ingredients are wholly compatible with all the other ingredients.

When are they used?

The solution formulation type is used for a wide range of cosmetic products. This includes a wide range of products such as shampoos, body wash, hand cleansers, colognes, perfumes and more. They have several advantages to their use including:

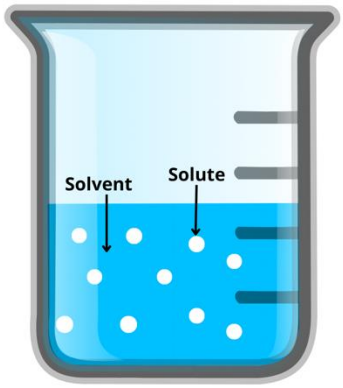
1. Fast and Easy to make
2. Relatively inexpensive
3. Highly stable

The primary difficulty with using solutions as your main product form is that the number of ingredients you can use in the formula are limited. If they are not compatible with your main solvent, you can't really use them. This makes it more difficult to create a unique and aesthetically pleasing product.

Solution cosmetic forms are made up of various ingredient types. There are the functional ingredients like cleansers, fragrances and conditioning agents. There are the aesthetic ingredients like thickeners, emulsifiers, preservatives, colorants, and adjustment ingredients. And there are the marketing ingredients too.

Science behind the formulation

Now let's talk a little about the science of solution formulations. Solutions are made up of solvents and solutes. The solvent is the material that makes up the bulk of the solution while the solutes are ingredients that get dissolved by the solvent. When I say "dissolved" that just means that the molecules of the solvent are less than 2nm in diameter. They're really small.



Solution

To give you a sense of the size, a glucose molecule is about 1nm in diameter. When you have a sugar solution in water, the glucose molecules are pretty much floating around either by themselves or loosely associated with another glucose molecule. It's notable that the human eye cannot see anything smaller than 100 nm.

In Figure 1, the solvent is the Alcohol while the solute is the Fragrance oil. When you mix the system, the fragrance oil molecules get intertwined with the alcohol molecules and create particles that are so small you can't see them anymore. If you look at it on a molecular scale the alcohol molecules surround the fragrance oils and keep them separated and suspended in the solution.

Figure 1: Perfume

Formula Name *Women's Perfume*

Batch size 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Solvent	Alcohol, denatured	75	375
2	Provide odor	Fragrance oil	25	125
		TOTAL	100	500

Procedure:

1. Add item #1 to container and begin mixing
2. Add item #2 and mix for 10 mi Appearance
3. Check batch versus specificat Odor

Specifications

Clear, water-thin, slightly yellow liquid

To match standard

For a system like a perfume this is not complicated. As long as the ingredients are soluble in alcohol then you'll have no problems. However, for most formulas not every ingredient is soluble in the primary solvent. Also, alcohol is expensive and flammable so using it as your sole solvent is not always ideal.

Figure 2 is quite similar to the previous formula (Figure 1) except that it contains 15% water. The addition of water helps reduce the formula cost and increases the safety of manufacturing. The problem is that typically water is not compatible with fragrance oils. Most of the fragrance oil ingredients are hydrocarbons which are insoluble in water.

Figure 2: Cologne

Formula Name **Batch size**

Men's Cologne 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Solvent	Alcohol, denatured	80	400
2	Provide odor	Fragrance oil	5	25
3	Solvent	Water	15	75
		TOTAL	100	500

Procedure: **Specifications**

1. Add item #1 to container and begin mixing
2. Add item #2 and mix for 10 mi Appearance — Clear, water-thin, slightly yellow liquid
3. Add item #3 slowly and mix fo Odor — To match standard
4. Check batch versus specifications

But the fragrance oils are soluble in the alcohol so in this formula you can mix the fragrance oil with the alcohol first to make the tiny particles. Then you slowly blend in water to dilute those particles further. You need to add it slowly so a big slug of water doesn't send the small fragrance particles crashing into each other to create larger, insoluble “blobs:”. Even if you are careful, there will be some creation of larger insoluble fragrance oil blobs which is why there is the filtering step. What you are left with is a stable solution of water/alcohol/fragrance molecules.

Colognes and perfumes primarily use alcohol or water/alcohol solvents. However, there are also formulations in which the solvent is an oil. This works well for any kind of formula that has water-incompatible ingredients. A common example of this formula is a bath oil (Figure 3).

The solvent is mineral oil and also included is an oil compatible emollient, Isopropyl Myristate. The fragrance is an oil so there are no compatibility issues with this ingredient. The Laureth-4 is a surfactant added to the formula specifically to help the formula disperse in the bath tub. If you did not include a surfactant / emulsifier like this when the consumer put the product in a bathtub, they might have a tough time removing it and it may also just float on the surface of the tub. Whenever you are formulating you should always consider how the product is going to be used and where it is going to go after it's been used.

Figure 3: Bath Oil

Formula Name **Batch size**

Blooming Bath Oil 500 grams

	Purpose	INGREDIENT	%	Amt. In Batch
1	Solvent / Emolli	Mineral Oil	61	305
2	Emollient	Isopropyl Myristate	25	125
3	Emulsifier	Laureth-4	10	50
4	Provide odor	Fragrance	4	20
5	Provide color	Color		0
6				0
		TOTAL	100	500

Procedure: **Specifications**

1. Begin mixing item #1 in container.
2. Add item #2 - #4. Mix 10 min Appearance — Thin, clear, liquid
3. Add item #5 to color level des Odor — Compare to standard
4. Compare formula to standard

Finally, we will briefly cover cleansing formulas. They will be covered more thoroughly in the hair and skin formulation chapters but we wanted to introduce them here because solution formulations will be used over and over. A good example is a shampoo.

Simple shampoos are essentially a mixture of a solvent, a surfactant (detergent) and aesthetic modifying ingredients. They can contain many more ingredient s but let's just look at a simple formula (Figure 4).

Figure 4: Normal Shampoo

Formula Name | **Batch size**

Normal Shampoo | 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Diluent	WATER (AQUA)	62.744	313.72
2	Color	YELLOW 6 (CI 15985)	0.003	0.02
3	Adjustment agent	TETRASODIUM EDTA	0.044	0.22
4	Adjustment agent	CITRIC ACID	0.06	0.3
5	Detergent	SODIUM LAURYL SULFATE	28	140
6	Detergent	SODIUM LAURETH SULFATE	1	5
7	Secondary surfactant	COCAMIDOPROPYL BETAINE	6.5	32.5
8	Solubilizer	POLYSORBATE 20	0.005	0.03
9	Preservative	DMDM HYDANTOIN	0.2	1
10	Fragrance	FRAGRANCE (PARFUM)	0.244	1.22
11	Adjustment agent	SODIUM CHLORIDE	1.2	6
		TOTAL	100	500

Procedure:

1. Begin mixing item #1 in container.
2. Add item #2 – 7
3. Premix #8 & #10 and add
4. Add #9 & #11
5. Mix for 30 min
6. Mix until cool. Check pH and viscosity. Adjust as necessary

Specifications

pH = 5.0 – 6.0

Viscosity = 4000 – 6000

In this formulation water is the primary solvent and makes up the majority of the formulation. The other ingredients are nearly all water-soluble ingredients. There is the color which is a water-soluble dye. The adjustment agents Tetrasodium EDTA and Citric Acid are also both water-soluble. Then there are three water soluble surfactants which make up the cleansing / detergent system. DMDM Hydantoin (preservative) is water soluble and salt or sodium chloride is also water soluble. The one ingredient that is not water soluble is fragrance. In this case the fragrance is pre-mixed with Polysorbate. As discussed in Figure #2, the fragrance is first solubilized with a compatible ingredient (polysorbate) then it incorporated into a water-based formulation.

Creams / Lotions and Emulsions

These are colloidal solutions or emulsions and are pseudo stable mixtures of immiscible liquids dispersed in another liquid. Or put another way, creams are thickened mixtures made up of incompatible ingredients. They are called emulsions because they are held together with emulsifiers.

Creams find a wide variety of uses including products like skin moisturizers, make up, hair conditioners, sunscreens, and pretty much any other application where you need to deliver a water incompatible material to the skin or hair.

Many conditioning / moisturizing ingredients are not compatible with water so a cream makes an excellent delivery vehicle.

What is the science behind them?

There are three primary parts of a cream or emulsion formulation. They include the internal phase, the external phase and the emulsifiers. The internal phase is made up of tiny particles discretely distributed throughout the mixture. It is also called the discontinuous phase because the various internal particles are not connected but rather separated into individual particles.

The external phase is made up of the primary solvent and is also known as the continuous phase. This is because it runs throughout the mixture filling in all the space between the particles of the internal phase.

The emulsifier is a specialized surfactant that keeps the oil phases separated from the water phases. The better job you do at picking the right emulsifier for the internal phase of your emulsion, the more stable and effective your cream formula will be. To become a good formulator, you need to get good at creating stable emulsions.

There are a number of configurations an emulsion can take and formulations are classified by these. There are Oil in Water emulsions, Water in Oil emulsions, and Multiple emulsions. Each of these use a different concentration of water, oil and emulsifiers. They also have different characteristics and are better for different applications.

Oil in water emulsions – These are the most common types of emulsions used in cosmetics. The internal phase is made up of lipophilic compounds and the external phase is water- and water-soluble ingredients. The oil in water emulsion has a number of benefits. First, it has a light feel when applied and does not leave the skin feeling greasy. Most consumers do not like

their hands to feel greasy after they've applied a skin cream. Next, oil in water emulsions have the nice ability to spread easily. This is more desired by consumers also. Since water is the external phase when you apply an oil in water emulsion there is a natural cooling effect as the water evaporates which most consumers like. Finally, these formulations also tend to be less expensive than a similar water in oil emulsion. This is because water is an incredibly inexpensive ingredient and oil in water emulsions tend to have more water in them. All-in-all, this is an excellent formulation form for you to use.

However, there is one significant drawback to using oil in water emulsions. They don't tend to work as well to moisturizer skin. This is because it's more difficult create a continuous film when the product is spread on the skin. They also tend to require a higher level of preservative which many people who are looking to create “natural” and low preservative systems might not like.

Let's take a look at a simple oil in water skin lotion example (figure 5).

Figure 5: Oil in Water Emulsion

Formula Name **Batch size**

Oil in water emulsion 500 grams

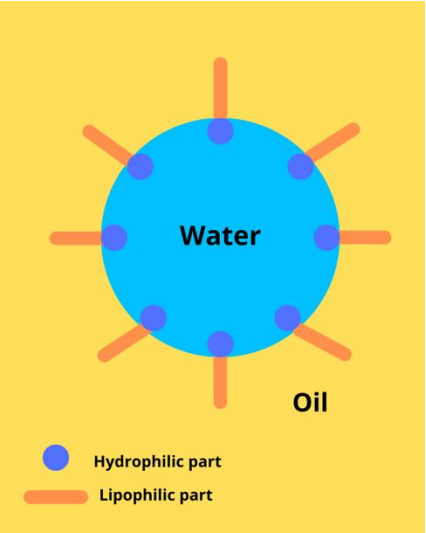
	Purpose	Ingredient	%	Amt. In Batch
1	Solvent	WATER	73.7	368.5
2	Humectant	PROPYLENE GLYCOL	5	25
3	Adjustment Agent	POTASSIUM HYDROXIDE	0.4	2
4	Emollient/emulsifier	STEARIC ACID	8	40
5	Emollient/emulsifier	STEARYL ALCOHOL	4	20
6	Emollient	BUTYL STEARATE	6	30
7	Emulsifier	GLYCERYL STEARATE	2	10
8	Preservative	METHYLPARABEN	0.2	1
9	Preservative	DMDM HYDANTOIN	0.2	1
10	Fragrance	FRAGRANCE (PARFUM)	0.5	2.5
		TOTAL	100	500

Procedure:

1. Begin mixing item #1 in container.
2. Begin heating to 75C and add items #2 & #3
3. In a separate container heat together items #4, 5, 6, & 7 to 75C
4. When oils are at 75C and clear, add items #7 & 8.
5. Add oil phase to water phase and mix at 75C for 20 minutes
6. While mixing, cool to 35C. When batch is at 40C add items #9 & 10.

This is an oil in water formulation. The first clue is that it contains nearly 75% water. Typically, the ingredient that is used in the highest quantity is going to be the external phase. In the procedure to make this formula you blend the water-soluble ingredients like propylene glycol and potassium hydroxide in the water phase. Separately, you mix your oil soluble ingredients including Stearic Acid, Stearyl Alcohol, and Butyl Stearate. Both phases get heated up to a temperature at least 5C higher than the melting point of the highest melting point solid. In this

case Stearic Acid has a mp of 69C so we heat the batch up to 75C. When both phases are heated, they are mixed together to form the emulsion. Typically, you add the oil phase to the water phase. Mixing for 20 minutes should ensure that the oil particles are suitably broken up to create a stable emulsion.



Water in Oil Emulsion (figure 6) – In these types of emulsions, the internal phase is made up of water & hydrophilic materials. The external phase is oil and lipophilic ingredients. These are less often used but they do have some advantages. They can provide better coverage of occlusives on skin so they tend to be more effective and better moisturizers overall. They also need less preservation because of their lower, discontinuous water content.

Unfortunately, they have a few drawbacks which make them less desirable. They feel heavier, tackier and greasy when applied. They tend to be more expensive to produce due to the higher level of oil. And they can be harder to stabilize since the standard suspending ingredients (like Carbomer) can't be used. However, if you are looking for the most effective cream these types of emulsions are a good choice.

Figure 6: Water in Oil Emulsion

Formula Name — **Batch size**

Water in Oil Emulsion — 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Solvent	WATER	73.7	368.5
2	Humectant	PROPYLENE GLYCOL	5	25
3	Adjustment Agent	POTASSIUM HYDROXIDE	0.4	2
4	Emollient/emulsifier	STEARIC ACID	8	40
5	Emollient/emulsifier	STEARYL ALCOHOL	4	20
6	Emollient	BUTYL STEARATE	6	30
7	Emulsifier	GLYCERYL STEARATE	2	10
8	Preservative	METHYLPARABEN	0.2	1
9	Preservative	DMDM HYDANTOIN	0.2	1
10	Fragrance	FRAGRANCE (PARFUM)	0.5	2.5
		TOTAL	100	500

Procedure:

1. Begin mixing item #1 in container.
2. Begin heating to 75C and add items #2 & #3
3. In a separate container heat together items #4, 5, 6, & 7 to 75C
4. When oils are at 75C and clear, add items #7 & 8.
5. Add oil phase to water phase and mix at 75C for 20 minutes
6. While mixing, cool to 35C. When batch is at 40C add items #9 & 10.

Multiple Emulsion – These emulsions are characterized by having more than one internal and external phase. You can think of them like one of those toy dolls that have a doll within a doll. There can be a wide variety of these types. For example, there is the Water in Oil in Water emulsion (WOW). Then there is the Oil in water in Oil emulsion (OWO). Finally, you can have an even more complicated structure where there are multiple types of emulsion particles within a single formula. The primary benefit to these types of emulsions is that they can give you all the benefits of a water in oil emulsion without the drawbacks of the formula feeling taking and greasy. Unfortunately, these are much more difficult to produce in a consistent way, especially on a large scale, so companies generally avoid this type of emulsion.

To create a multiple emulsion, you typically have to first create a standard emulsion (O/W or W/O) and then blend it in to another external phase hoping your new emulsifier doesn't disrupt the first emulsification system. It can be complicated but it can be done.

More emulsion Science

While emulsions can be classified by the composition of their internal and external phase, they can also be classified by the size of their internal particles. As we have mentioned previously, when a mixture has a particle size that is smaller than 2 nm it is classified as a solution. These are stable, clear formulas. When the particle size is a little larger 2-10 nm, the particles are arranged in micelles. This is still considered a solution. When the particles are sized 10 – 100 nm, you have a microemulsion. These are clear, stable formulations and would be an ideal delivery form if you could make them. Unfortunately, most mixtures do not lend themselves to this type of particle size.

Most creams and lotions have particle sizes that are larger than 100 nm. Above this size they are considered macroemulsions. They are opaque because at 100 nm or bigger the particles can be seen by the human eye. Macroemulsions are inherently unstable and will eventually separate. Your job as a formulator is to ensure that the separation doesn't happen within the lifetime of the product you are making.

There are a number of factors that influence particle size including:

- **Amount of agitation** – This is very important
- **Temperature** – The temperature at which the emulsion is created. Higher is generally better
- **Component concentration** – The amount of oil, water, and emulsifier is important
- **Type of emulsifier & oil** – These have the biggest influence on particle formation

In general, the smaller the particle size the more stable your emulsion will be.

Emulsion Instability

While we're on the subject of emulsion particles it makes sense to discuss why or how emulsions tend to separate. It takes energy to create the particles in an emulsion (agitation and heat specifically) but unless you are able to make the particles small enough, it will not be enough energy to make them stable like a solution or microemulsion. Over time, the particles can go through four types of destabilizing processes. They can flocculate, coalesce, experience creaming, and ultimately inversion.

Flocculation is a process by which two small particles get close enough to “stick” together. It's a bit like when you blow bubbles and two of the bubbles stay together. These flocculated particles are larger and have a higher chance of bumping into other particles and undergoing more destabilizing processes.

When the particles are “stuck” together like this the barrier between them can get squeezed out and the two particles then coalesce to form one larger particle. Again, think of what happens to bubbles that are stuck together. The middle barrier often breaks before the entire bubble.

As particles begin to coalesce, they start to separate based on their size, density and buoyancy. This can lead to a situation called creaming where particles of different sizes occupy different layers in the sample. This is a process that non-homogenized milk experiences when the cream rises to the top.

Eventually, these separations and enlarged particles can coalesce so much that the formula goes a process of inversion where the internal phase completely separates out from the external and you are left with two or more phases in the sample. You can often see this with formulas for sale.

Emulsion Ingredients

Creams or emulsions are made up of two different phases, the water phase and the oil phase, held together by an emulsifier. In most emulsions the two phases are kept separate until they reach the appropriate temperature. They are then combined, mixed for an appropriate amount of time and cooled to form the final formula. The ingredients that go in the oil and water phase are different.

The water phase is where you add the water-soluble ingredients. This includes things like:

- Thickeners
- Humectants
- Colorants
- Batch adjustment agents
- Preservatives
- Secondary emulsifiers
- Feature ingredients

In the oil phase you have your lipophilic ingredients. For creams this includes things like:

- Occlusive agents
- Emollients
- Fatty acids / alcohols, waxes
- Preservatives
- Secondary emulsifiers
- Feature ingredients
- Silicones

Silicones are not necessarily soluble in oil but they are usually more easily dispersible in this phase so that is why they are included. However, if you are working with a silicone like Dimethiconol which is specifically designed to be water soluble, it would be added to the water phase.

There are a variety of emulsifiers and emulsion types that are used when creating creams. For most skin cream formulas, you are going to want to use nonionic emulsifiers. Two of the most common types are Glyceryl Stearate and PEG Sorbitan Fatty Acid Esters. The specific type you use will depend on the type of oil phase that you are creating.

Anionic and cationic emulsifiers are also commonly used for cream application. By far the most common anionic surfactant used is Stearic Acid. To create stable emulsion formulas with an anionic surfactant also contain an alkaline neutralizer which reverts the acid to a salt form. For cationic creams Dicetylmonium Chloride can be used. This ingredient also needs to be neutralized when using it as an emulsifier.

The most recent development in emulsion technology is the introduction of Polymeric emulsifiers. These ingredients are not technically surfactants but they are able to create structured internal films that help prevent internal particles from coalescing. Polymeric

emulsifiers include ingredients like Acrylates/C10-30 alkyl acrylate crosspolymer and Hydroxypropyl Methylcellulose. They are particularly popular for sunscreen formulations.

To complete our discussion on ingredients used in emulsions, we should mention that there are some ingredients added to the formulations after the emulsion is formed. These include things like fragrances, preservatives and any other heat sensitive ingredients. The reason these are included later is because if they were added when the batch was hot, they may chemically break down or change (for fragrances, the notes with the highest volatility can evaporate away). Typically, ingredients like these are added during the cool down phase at temperatures below 40C.

HLB Method

Figuring out what emulsifier to use in any specific formula will be a challenge you'll face as a cosmetic formulator. One of the techniques that can help substantially when you are putting together an emulsion is to follow the HLB method. HLB stands for Hydrophile Lipophile Balance and it was introduced by William Griffin in 1949.

The goal of the HLB method is to help you figure out what non-ionic emulsifiers you need to use for any given oil phase. It primarily applies to nonionic (uncharged) surfactants although attempts have been made to broaden the concepts to other surfactant types including silicone surfactants. Using the HLB system to create emulsions is quite simple. You need to calculate the HLB number of your surfactant, then the Required HLB for the oil phase and match the two numbers.

The HLB numbers are calculated both theoretically and experimentally. You can find a list of these numbers in the resources page. Basically, higher HLB numbers = More water soluble. The highest HLB value of any material is 20 and the lowest value is 0. To give you an idea of HLB numbers, Cocoa butter has an HLB value of 6. Stearyl Alcohol which is more water soluble has an HLB value of 15.

Using the HLB method to create emulsions

Here is a four-step method for calculating the required HLB of your formulation.

Step 1: Find the HLB value of the oil phase of your formula

Step 2: Calculate the required HLB number

Step 3: Pick emulsifiers which are 2 units above and below that number

Step 4: Create prototypes to determine the amount of emulsifier needed

Determining the HLB of an emulsifier

A typical nonionic emulsifier (eg Laureth-4) contains an ethylene oxide group or polyhydric alcohol hydrophilic portions with a fatty alcohol hydrophobic portion. The HLB for a nonionic surfactant can be calculated as follows:

- HLB = Weight % Hydrophile / 5
- HLB calculation for Laureth-4
- Molecular weight of ethoxylate portion = 176
- Molecular weight of lauryl alcohol = 186
- Wt. % Hydrophile = (176/(176+186)) x 100 = 48.6%
- HLB = 48.6/5 = 9.7

Based on the calculation, surfactants with high HLB values will be more water soluble and those with low HLB values are more oil soluble. Division by 5 just allows for a compact, easy to use scale. The calculation is simple, but you won't usually have to figure it out since most surfactant HLB values are readily available through literature references and surfactant suppliers.

Calculating HLB of oil phase

Each lipophilic ingredient in the oil phase has its own required HLB. Required HLB values for some common oil phase ingredients are available to the formulator in literature. The HLB values are approximate and can vary by about ± 1 unit. It is also important to keep in mind that cosmetic emulsions often have complex oil phases with several components. The required HLB of an oil phase mixture can be calculated by first calculating the percent of the oil phase each ingredient contributes. This percentage is then multiplied by the required HLB for each of those ingredients and the results are summed.

Calculation of required HLB for an oil phase mixture

The oil phase is 10% of the total formulation and consists of:

- 4% Shea butter, 40% of the oil phase. Required HLB of 8.
- 3% Jojoba oil, 30% of the oil phase. Required HLB of 6.5.
- 3% Sunflower seed oil, 30% of the oil phase. Required HLB of 7.

Total required HLB:

- Shea butter contribution 0.4 x 8 = 3.20
- Jojoba oil contribution 0.3 x 6.5 = 1.95

- Sunflower oil contribution 0.3 x 7 = 2.10
- Total Required HLB = 7.25

You can now select emulsifiers to match the required HLB of the oil phase and create an emulsion. A blend of high and low HLB surfactants is often used to achieve the desired value in part because of demonstrated effectiveness and efficiencies in packing at the interface. The HLB for the surfactant blend is calculated in same manner as the required HLB for a blend.

Calculation of HLB for a surfactant mixture

The surfactant mixture is a 70/30 blend of Steareth-2 and Steareth-21.

Total HLB:

- Steareth-2 contribution 0.7 x 4.9 = 3.43
- Steareth-21 contribution 0.3x 15.5 = 4.65

Total HLB = 8.08

In order to match the HLB of a particular oil phase, it is easiest to set up a spreadsheet with the calculation and vary the percentages of each emulsifier in increments of 5% to find the right ratio.

Limitations of HLB

Although a very useful tool, the HLB system does have some limitations. For example, additional water phase ingredients are not considered but still may impact the stability. The method also does not provide information as to how much surfactant is needed, but 2 to 4% surfactant is a good starting point to begin further optimization for stability. It is important to keep in mind that the HLB system is not absolute in prediction of your formulations behavior, but a very good starting point for achieving emulsification.

Lotions

Creams are not always appropriate for some applications because they can be too heavy or greasy. In these cases, the lotion form is used. They are used for facial moisturizers, leave-in hair conditioners, moisturizing cleansers, foundation and a variety of other applications.

In practical terms, lotions are essentially thin creams. In fact, the term lotion and cream are often used interchangeably in the cosmetic industry. Since these are emulsions, you make them

the same way you would a cream. They are a bit easier because you do not have to worry about the emulsion getting thick enough as it cools down. Often the challenge with lotions is that you need some way to suspend the particles in a thinner liquid so that they don't settle to the top or bottom of the formulation. This is done using a suspending polymer.

The primary difference between a cream and a lotion is the level of the oil phase. In lotions, there much less of the oil phase.

Suspending science – Yield Value

Since lotions are flowable they are necessarily thinner than creams, therefore more mobile and more apt to migrate to the top or bottom of the sample. This can often lead to quicker separation. To prevent this, you need a suspending polymer that has a sufficient yield value.

The term yield value is defined as the initial resistance of a material to flow caused by shear applied stress. Essentially, a product can appear very viscous but will move easily when a force is applied. When a material has a yield value that is high enough to overcome the force of gravity, particles will be suitably suspended in the lotion. This is independent of the thickness of the product. You can have a thick formula in which the particles settle or a thin one in which the suspended particles never move.

The most effective ingredient for producing a yield value appropriate for lotions is Carbomer. At low levels this can be used to stabilize most any formula. For a natural option, Gum Tragacanth (about 3%) can be used to produce permanent stabilized suspensions of particles.

We will cover more specific emulsion formulations in upcoming chapters on skin, hair, and color cosmetics.

Gels

These are thick products, typically clear, that have a property known as “shear thinning”. This means they stay thick until you apply a force which makes them thin and flowable. If you have ever tried to get ketchup out of a bottle, you’ll understand this concept. Gels are used for hair products, body washes, shaving products, and in toothpaste. They are made by using a gelling agent such as an acrylic polymer, a natural gum or a cellulosic thickener.

Gel Thickening - Rheology

In the previous chapter we introduced the various thickening agents used in making gels. The primary ones

include naturally derived thickeners and synthetic thickeners.

The science of thickened cosmetic products is called rheology. More technically, rheology is defined as how materials deform and flow under the influence of some external force. The force is applied over a certain area and is referred to as “shear stress”. The ratio of the size of the force versus the rate of force is known as viscosity. It's a bit complicated but in practical terms, viscosity is a measure of the thickness of a system. This is one of the main characteristics that you will pay attention to in your formulations.

The viscosity of cosmetics is typically talked about in terms of “poise” or Centipoise. The thickness of most cosmetic products is in terms of how they compare to water. Water has a viscosity of 1 centipoise. A product like Honey on the other hand has a viscosity of approximately 10,000 cps. That should give you a sense of the scale. We'll talk about this in a later chapter but it's worth noting that the viscosity values cannot always be directly compared unless you know the conditions under which the reading was taken. For example, you could have a cream with a viscosity reading of 20,000 cps taken under one set of conditions and a viscosity reading of 30,000 cps taken under a different set of conditions. Always keep that in mind when you see viscosity values in raw material sales literature.

Different kinds of fluids

Formulations can be classified by the response of their viscosity when a shear force applied to them. In these terms formulations can be:

- Newtonian
- Plastic
- Pseudoplastic
- Dilatant

The viscosity of Newtonian fluids remains constant no matter how much shear is applied to them. Water and mineral oil are examples of this type of fluid. Most solution formulations are also Newtonian fluids.

Formulations like creams, lotions, and gels are examples of non-Newtonian fluids. This means that when you apply a force to them you actually change the viscosity. Some products like Gels are classified as Plastic fluids because they are thick and have a high yield value but when a significant enough force is applied to them their viscosity is drastically reduced and they flow. Ketchup is another example of this type of fluid.

Pseudoplastic fluids also get thinner as more force is applied but they do not have a yield value so they start to flow immediately. This is typical of some thin lotions.

The final category, dilatant fluids, exhibit the opposite effect of Plastic fluids. When a force is applied, they actually get thicker. Silly putty is an example of this type of fluid.

Another term you will hear related to viscosity is the term Thixotropic. These fluids behave just like Pseudoplastic materials in that when a force is applied, they experience a reduction in viscosity. However, when the force is removed the viscosity of a pseudoplastic material will quickly recover to the point where it started. A Thixotropic material will only slowly recover its viscosity when the force is removed. Most cosmetic gels, emulsions and cream systems (especially ones thickened with clays) will exhibit this characteristic. This is why when you produce a cream or gel it will typically build viscosity over time.

Gel Ingredients

Now that we've discussed the viscosity and rheology let's get back to formulating gels. Creating gels is a lot like creating solution cosmetics. If you are trying to create a clear gel you need to work with compounds that are all compatible. The primary components of a gel include:

- Solvent
- Thickening Polymer
- Neutralizing ingredient
- Functional Ingredients

For most cosmetic gels the solvent you will use is water or a mixture of alcohol and water. Alcohol is a good choice as it makes the system compatible with more hydrophobic materials and it works as a preservative if used at a high enough level. However, far fewer formulations are using alcohol these days because it is classified as a volatile organic compound (VOC) and faces use restrictions in many markets.

By far the most common thickening polymers used to create gels are acrylic polymers. Carbomer is an example. It is typically supplied as a polymer and is compatible with water. When you incorporate it into water (and this can be a big challenge as it takes a long time to fully hydrate) the solution it creates has an acid pH and is easily flowable. When you add a neutralizing agent like Triethanolamine you increase the pH of the system and cause the -COOH groups within the molecule to chemically react to produce covalent bonds between the polymer strands. More specifically it results in a C-O-C linkage. This creates a molecular “netting” effect which results in the thickening even when used at low levels. The reason acrylic acid polymers are so often used in cosmetic gels is because they create crystal clear formulas and have no sticky feel.

For more naturally based gels formulators use ingredients like Hydroxypropylmethylcelluose. Locust Bean Gum or Xanthan Gum. These are also polymers but they are polysaccharide polymers with a number of -OH side groups on their molecules. These ingredients have the ability to absorb water which swells the molecule and creates the thickening effect. The thickening is a result of Hydrogen bonding between the -OH groups on the polymeric chains. To increase the thickness of the formula you have to increase the amount of the material used. However, there is a limit to the viscosity that can be achieved with these types of thickeners.

While effective, these types of thickeners have some drawbacks that make formulating with them a challenge. First, it is difficult to create clear, thick formulas. Since the viscosity of these thickeners depends on the amount of material added and these materials produce slightly hazy formulas, the thicker you make it the hazier it gets. Second, these formulas can also feel sticky and the more you put in your formula the stickier your formula will feel. You can add emollients to offset this effect but it can be difficult to get many systems clear and non-tacky.

In addition to the thickening system and solvent any number of functional ingredients can be used in a gel formulation. This is going to depend on the specific application but will include things like styling polymers, surfactants, emollients, etc.

Sticks

When you need to create a product that the consumer won't necessarily want to touch, for example, lipstick or underarm deodorant, a stick is ideal. They are solid delivery forms that deliver active ingredients through a rubbing action. The way you create them is by using mostly materials that are solid at room temperature. The ingredients are heated until they melt, mixed, and poured into either a mold or the final container. When they cool, they take the shape of their packaging.

There are basically four types of stick formulations produced for cosmetic products classified by the solidifying ingredients. These include:

- Fats, Wax and Oil mixtures
- Solidified Soaps
- Fatty alcohol / Silicone mixtures
- Dibenzylidene sorbitol

Fats, Waxes and Oils

To create lipsticks or other solid color products waxes, fats and oils are used. The specific ingredients incorporated into the formula are chosen to impart structure and rigidity to the formulation. Fats are solid triesters of glycerin. The molecular structure of these molecules is such that they are solid at room temperature. Ingredients like Cocoa Butter and Shea Butter are examples of solidified fats. Other materials like coconut oil, solidified vegetable oil and palm kernel oil can also be solid at room temperature. In addition to these natural materials, there are some synthetic triglyceride materials like Glyceryl Tristearate that can be solidifying agents.

In general, the longer the hydrocarbon chain the higher the melting point and the more solid it will be at room temperature. However, this assumes that the hydrocarbon is fully saturated. If there is a double bond in the molecule then the product tends to be liquid at room temperature. For example, Steric Acid which has an 18-carbon chain backbone is solid at room temperature. Oleic acid which is also an 18-carbon chain backbone is liquid at room temperature because it contains a double bond between two carbons in the chain.

Waxes are another type of solidifying material. These are a blend of hydrocarbons that are solid at room temperature. There are 4 types of waxes used for making cosmetics including

- Animal waxes
- Vegetable waxes
- Mineral waxes
- Synthetic waxes

While most people try to avoid animal products in cosmetics there are still two ingredients that you find including Beeswax and Lanolin. For making solid products Beeswax is used. It is produced by bees and is made up of mostly esters (myristyl palmitate) and other hydrocarbons. When used in a stick formula it can help provide some structure and flexibility.

Vegetable waxes are more frequently used to make lipsticks. These include Carnauba wax and Candelilla wax. Carnauba wax has a high melting point so you can make rigid sticks. Candelilla wax has a lower melting point so the sticks tend to be slightly softer and less grainy. Typically, a blend of both Carnauba wax and Candelilla wax are incorporated into stick formulas.

There are a number of mineral waxes that you will find in stick formulas. These include petroleum derived waxes including Ozokerite, Ceresin, and Paraffin wax. These materials have a number of advantages since they are consistent, easily obtained, provide greater flexibility in formulating and are less expensive. However, they are not considered natural by most people so some formulators will be unable to use them.

Solidified soaps

Another type of solid formula that you will find in cosmetics are solidified soaps. Most commonly used is Sodium Stearate. This ingredient is the basis of most soap bars but it also makes a good base for a deodorant. The soap remains hard but with the addition of a humectant solvent like Propylene glycol or PPG-Myristyl Ether it can be made to glide on smoothly. These formulas can also be made translucent.

Fatty alcohol / silicone mixes

For some applications stearate soaps do not work as well so you can use a fatty alcohol solidifier with a silicone added for slip instead. These types of solid formulas work well for antiperspirants. Ingredients that work well are those with a melting point somewhere in the range of 50C – 70C such as Cetyl Alcohol, Myristyl Alcohol, or Stearyl Alcohol. This is because the formula will soften at body temperature and aid in application.

Dibenzylidene Sorbitol

The final solid form that we will cover is Dibenzylidene Sorbitol formulas. DBS is a known gelling agent for many hydrocarbon solvents but it also has a thickening effect in silicones. It can be used at low levels and if formulated properly can create a clear stick formulation. Here is an example of a clear stick formula made with Dibenzylidene Sorbitol.

Figure 7: Dibenzylidene Sorbitol Solid

Formula Name **Batch size**

Dibenzylidene Sorbitol solid 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Active ingredient	Aluminum Zirconium tetrachloro	50	250
2	Solvent	Propylene Glycol	33.5	167.5
3	Solvent	Dipropylene glycol	10	50
4	Emollient	Glycine	1	5
5	Emollient	Diisopropyl sebacate	2	10
6	Slip agent	Dimethicone Copolyol	1.5	7.5
7	Solidifying agent	Dibenzylidene sorbitol	2	10
		TOTAL	100	500

Procedure:

1. Begin mixing item #1 in container.
2. Begin heating to 75C and add items #2 & #3
3. In a separate container heat together items #4, 5, 6, & 7 to 75C
4. When oils are at 75C and clear, add items #7 & 8.
5. Add oil phase to water phase and mix at 75C for 20 minutes
6. While mixing, cool to 35C. When batch is at 40C add items #9 & 10.

The formula contains 50% of the active antiperspirant ingredient plus two types of humectant solvents, Propylene Glycol and Dipropylene Glycol. To aid in slip / feel the formula also contains a small amount of Dimethicone Copolyol. To get the solidifying effect, 2% dibenzylidene sorbitol is used. Unfortunately, DBS is unstable in the presence of acids and it lacks good solubility in many cosmetic solvents.

Ointments / Pastes

These are super thick products used for things like hairdressing and medicated skin products. Since this is more of a marketing term than strictly scientific there are a wide range of formulations that can be considered ointments or pastes. For our purposes we will confine our discussion of ointments that are anhydrous (contain no water) and are sticky and greasy.

This formulation type is much like the solution formulas we discussed at the start of this chapter. The primary difference is that their solvent is some type of hydrocarbon like petrolatum, mineral oil, lanolin or a silicone like dimethicone. The benefit to this type of formulation is that preservation is not usually required as with no water in the formula no disease-causing microbes will grow. The downside is that these formulas do not provide the best feel during use.

Making them is a simple matter of heating up the raw materials and rapidly mixing them until they are dispersed. The key is to use ingredients that are compatible (not all hydrophobic materials are compatible) and to get suitable mixing without blending air into the formula.

Here is an example of a typical ointment:

Figure 8: Hairdressing Ointment

Ointment form – Hairdressing 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Solvent	Mineral oil	25	125
2	Emollient	Petrolatum	23	115
3	Emollient	Lanolin	18	90
4	Emollient	Paraffin	15	75
5	Spreading agent	Isopropyl Myristate	9	45
6	Emollient	PEG-8 Dilaurate	4	20
7	Spreading agent	Propylene Glycol	4	20
8	stabilizer	BHT	0.5	2.5
9	Fragrance	Fragrance	1.5	7.5
		TOTAL	100	500

This product is a thick, greasy formulation which if packed full with oily materials. In fact, it can be difficult to remove from hair as it is so hydrophobic. The formula is made pretty simply, just heat the mixture and blend the ingredients. The fragrance is added at the end.

Powders – Loose & Pressed

One of the most common types of product forms for color cosmetics are powders. Powders are also used for products like make-up, baby powder and foot powder. They are mixtures of solid raw materials blended together into a fine powder. Often specialized equipment is needed when making these products as the fine powder can be dangerous.

Powder Ingredients

There are a few types of ingredients used to produce powdered cosmetic forms. The ingredient that makes up the bulk of the powder formula is the diluent or filler which has the same role as the solvent in a liquid formula. The functional ingredients will depend on the purpose of the formula but for color cosmetics they

are usually pigments and solid dyes. Other ingredients include binders to hold the powders together (in the case of pressed powders), preservatives, fragrances, and other miscellaneous ingredients.

One of the most frequently used ingredients is Talc. Chemically, it is Magnesium Aluminum Silicate and is the major component of standard pressed powder color cosmetics. It is useful because of its white color, good surface coverage and spreadability. Another popular filler is Kaolin also known as Aluminum Silicate. It is a little less flexible than talc but it is compatible with oil and water ingredients, has good coverage of the surface, adheres nicely to the skin and has a smooth feel. Mica is also a popular choice for a filler / extender in a powdered product.

Since powders have an earthy odor, a fragrance is often used. The fragrances are oils so they also have an added effect of being a binding agent to hold the pressed powders together. In addition to the fragrance other binding oils may be used to hold the formula together. However, care must be taken not to use too much binding agent as you still want the formula to spread as a powder not an oil.

Powder cosmetics don't contain water so they are not typically at risk for growing microbes. However, it is advisable to include a preservative in these products because it is simple for consumers to transfer microbes from their skin to the surface of the product. This is also a good reason why you should never share someone else's powdered cosmetic products. The preservatives commonly used include parabens and imidazolidinyl urea.

Tablets & Capsules

It is worth noting that there is also a tablet and capsule form that is used for creating cosmetics. These are physically blended solids that are held together by being pressed into shape. Since the powdered ingredients are pressed together so tightly these really become nearly impossible to produce in a lab without special equipment.

Aerosols

Aerosols are actually more of a packaging product form than a specific formulation type. In fact, you could probably create an aerosol out of almost any cosmetic formulation if you have the right can, propellant, and nozzle set-up.

In the cosmetic industry, aerosols are considered any cosmetic delivered from a pressurized can. They are most commonly used for hair styling products (hair finishing spray), sunscreens, shaving creams, and antiperspirants. Other applications include some color cosmetics, self-tanners, and medicated powder sprays.

Aerosol ingredients

Aerosol formulations can come out in a number of forms. For products like hairsprays and antiperspirants a standard spray mist is desired. For powdered products aerosols can also deliver a cloud of fine powder. Shaving creams come out as stable, formed foams or they may be delivered as gels that spontaneously foam when they are spread on the skin. In both cases they contain a surfactant that helps create the foam. Aerosols can also be made to come out as creams though this is less often seen on the market.

Aerosol cosmetics are composed of a concentrate and a propellant. The concentrate can be made up of any of the ingredients that we have already discussed. There will be functional ingredients like styling polymers, emollients, and active ingredients. There will also be aesthetic ingredients, adjustment agents and marketing ingredients too.

The distinguishing feature of aerosols is their propellant. A propellant is a compound that can provide the energy required to force the formula out of the container. It is a compressed or liquified gas that expands rapidly when exposed to atmospheric pressure. This is done when the can is opened by pressing the button. For an aerosol to work properly the can needs to be properly pressurized well above atmospheric pressure.

Liquified propellants and compressed gas propellants work slightly different in the formula. A liquified propellant is actually dissolved in the concentrate so the pressure can be maintained throughout the life of the product. A compressed gas does not combine with the concentrate rather, it exists as a gas in the volume above the concentrate. This has the effect of losing pressure over time. You may have noticed this in products like aerosol sunscreen that use compressed air as the propellant. Over time they just do not spray out as hard as when you first got them.

There are four types of propellants used in formulating aerosols. These include:

- Hydrocarbon
- Hydrofluorocarbons
- Dimethyl Ether
- Compressed gas

Hydrocarbon propellants include compounds such as Propane, Butane and Pentane. They are good choices because they have no odor, have very low toxicity, and are compatible with nearly all organic solvents. The primary disadvantage is that they are flammable, can be dangerous to use and are subject to VOC limits. Dimethyl ether is another hydrocarbon type propellant but it has the advantage of being compatible with water. So, it's useful when you are creating low VOC aerosol products.

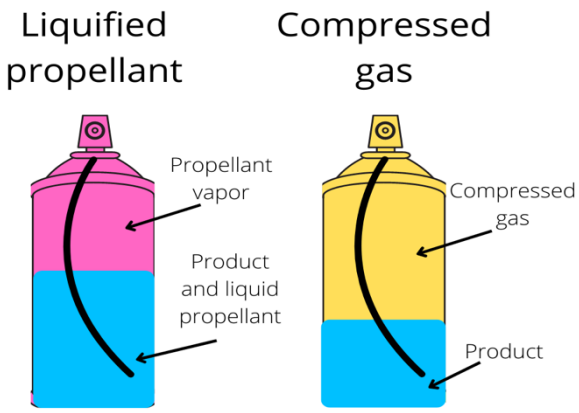
Hydrofluorocarbons include ingredients like Difluoroethane, Tetrafluoroethane, Hexafluoroethane. These ingredients tend to be more expensive than hydrocarbon propellants but they are more compatible with emulsion-based concentrates, they are not corrosive, and they aren't subject to the same VOC limitations.

Finally, there are compressed gas aerosols. These include ingredients like Carbon Dioxide, Nitrogen, and Nitrous Oxide. They have the advantage of being compatible with most any formulation, low cost, non-VOC, and non-flammable. The biggest disadvantage is that the pressure in the formula tends to reduce as the product is used.

Aerosol Technology

When you create an aerosol product you first make the formula as you would any other cosmetic, then fill it into the can. You seal the can and pressurize it using the appropriate propellant. Each aerosol can have specific parts that allow it to function properly. This includes:

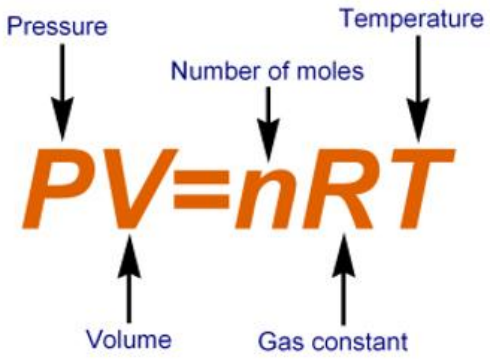
- Actuator
- Valve
- Dip Tube
- Can



The actuator is the button at the top of the container which the consumer presses to dispense the product. The valve is what goes on top of the can to seal in the product & propellant and also create the hole for the actuator to rest upon. The dip tube is a plastic straw that runs from the top of the valve to the bottom of the product. This ensures that the product delivered is forced down from the top of the can thereby allowing pressure to be maintained throughout the life of the product.

The way it works is that the can is pressurized when it is filled with the concentrate and propellant. It is sealed with the valve and actuator. When you open the valve (by pressing the actuator) the pressure difference between the inside of the can and the standard atmosphere forces liquid up the tube and through the nozzle of the actuator. The spray pattern and amount of product delivered depends on the shape and size of the nozzle.

If you are curious about the science, just remember the ideal gas law:



The consequence of this law is that as pressure decreases, volume increases. So, when you press the actuator button and reduce the pressure, the volume of the product expands. Since the only place the expanding liquid can go is up the tube and out of the container, that's where it goes.

Aerosol formulations

As we mentioned previously aerosol formulations are made up of a concentrate and the propellant. Here is a typical aerosol formula for a spray.

Figure 9: Hair Spray

Formula Name **Batch size**

Basic Hair Spray 500

	Purpose	Ingredient	%	Amt. In Batch
1	Solvent	SD Alcohol	20	100
2	Solvent	Water	31.68	158.4
3	Neutralizer	AMP	0.97	4.85
4	Fragrance	Acrylates/C1-2 Succinates/hydr	11.7	58.5
5	Neutralizer	MEA Borate & MIPA Borate	0.25	1.25
6	pH adjustment	Ammonium Hydroxide	0.25	1.25
7	Fragrance	Fragrance	0.15	0.75
8	Propellant	Dimethyl Ether	35	175
		TOTAL	100	500

Procedure:

1. Begin mixing item #1 & #2
2. Add item #3 – 7 in order
3. Fill in can and add propellant under pressurized conditions

This has a solvent system of alcohol and water to be VOC compliant. Since there is water in the can there is also a corrosion inhibitor added. The key point to notice in this formula is the ratio of concentrate to propellant.

Chapter 5

HAIRCARE PRODUCTS

Haircare products

The haircare market makes up about 22% of the cosmetic industry. The products are designed to solve consumer problems with hair and to make it easier to wear the hair styled in the way that they want.

After completing this chapter, you will understand the challenges consumers report with their hair and the strategies cosmetic formulators employ to try and solve these problems. You will also learn how to formulate a variety of different haircare formulas.

In this chapter we are going to cover all the most important types of haircare formulas in detail including:

- Shampoos
- Conditioners
- Styling Products

And we will also briefly cover the chemistry and formulating of specialty hair products such as:

- Hair Color
- Relaxers
- Permanent Waves

Haircare market

Haircare makes up about 22% of the total cosmetic market but here is the breakdown of that market in terms of the products that are sold.

As you may have guessed, shampoo is the largest share of the market making up about 35% of the entire haircare market. Usage of shampoo is nearly universal across the globe. Conditioners are next with 26% of the market followed by styling products including gels, mousses, putties, etc. representing 19% (these are rough estimates). The home hair coloring makes up about 21% of the haircare market. Home hair color saw a big boost as a result of the COVID-19 pandemic and has increased share in the last few years.

These numbers are related to the dollar share and they would be slightly different if we considered just volume. From a volume standpoint (that is the number of bottles sold) shampoos are number one but conditioners would be the second most popular product type followed by hair styling products. Hair colors are generally more expensive than conditioners thus a smaller volume can dwarf the less expensive, higher volume conditioner market.

Here are some of the top global haircare manufacturers. Large companies really dominate the market but growth of smaller brands has outpaced larger manufacturers in recent years, indicating lots of room for growth. The current global haircare market is estimated at nearly **$94 billion** (though estimates range greatly).

- L'Oreal
- Coty
- Henkel AG
- Procter & Gamble
- Revlon
- Kao
- Unilever
- Johnson & Johnson

Shampoos

Shampoos are usually solution cosmetic formulas designed to clean hair and leave it in a more manageable state. These are one of the simplest cosmetic formulations which means that shampoos are relatively easy to create.

There are literally thousands of different shampoos available in most markets but there are very few different types of formulas. Here is a list of the major types of shampoos you can find in most markets:

- Normal
- Extra Body (volumizing, thickening, etc)
- Moisturizing (smoothing, restoring, shine, etc)
- 2 in 1 Conditioning Shampoos
- Strengthening
- Color-treated
- Color-enhancing
- Baby shampoos (tear free)

Of course, there are “natural” versions of many of these types of formulas. While companies call products natural there are not actually any naturally occurring surfactants that would be suitable for turning into a shampoo so products that are marketed as natural actually have a significant level of chemical processing to get them to perform.

There are also some specialty shampoos that in some markets are also considered drugs because they treat a disease. These include:

- Anti-Dandruff shampoos
- Anti-Lice shampoos
- Hair loss treatment shampoos

There are also niche shampoos that aren't in the standard solution form. These include powdered shampoos which are actually powders you sprinkle on the hair and brush out. Also, there are no-rinse shampoos which are low solids surfactant solutions that are rubbed into the hair and towel dried out. Finally, there are conditioner type shampoos which are actually more like hair conditioner emulsions that don't foam while they work. These specialty formulations represent a small segment of the market but are a significant niche that a small brand may be able to make some significant sales.

People use shampoos to solve a number of problems including:

- Clean hair
- Remove odors
- Moisturizing
- Easier to comb/manage
- Prevent frizz
- Improve Shine
- Increase volume

Then there are the medical conditions that specialty shampoos solve including:

- Dandruff
- Lice
- Hair loss

It is the job of the cosmetic formulator to create shampoos that can solve these primary problems which consumers report. Plus, you need to do it in a way that provides for a good marketing story.

To fix these problems cosmetic chemists have come up with a number of different technologies. For cleaning hair and removing dirt and oil the most effective technology are cleansing surfactants. Cleansing surfactants also can remove hair odors and can even create a volumizing effect from the formula.

To solve other problems associated with hair products there are a wide range of different compounds that are incorporated into shampoos. These include conditioning agents like cationic polymers, silicones, and humectants. For shampoos charged ingredients like cationic surfactants and hydrophobic materials like occlusives and emollients have limited effect.

Shampoo formulations

Shampoo formulations are rather simple to create. They are primarily surfactant solutions and have a limited number of characteristics that can be modified. One of the main characteristics to think about when formulating is formula aesthetics. This includes appearance and thickness.

The appearance of the shampoo can be either clear or opaque (pearlized). A clear formulation subtly communicates to the user that it is going to be a highly cleansing formula. When you are developing a normal, extra body, or volumizing shampoo formula you will typically go for clarity. However, if you want to make a moisturizing formulation then you usually will create an opaque or pearlized version. This is helpful because sometimes it is difficult to make formulations with conditioning ingredients crystal clear. Certain conditioning polymers or fragrances can cause the formula to be hazy.

Another aesthetic characteristic that can be controlled is the viscosity of the shampoo. Most shampoos fall in a viscosity range of 4000 cps – 15,000 cps. Normally, a thicker viscosity communicates a more moisturizing formula.

When creating a formula, the amount and type of surfactant you choose will affect the type of foam that is generated. Most consumers want a shampoo which produces lots of thick, creamy foam. A thinner, lacy foam communicates a lower quality, less cleansing formula. This is despite the fact that the foam of a shampoo is in no way indicative of how well the product cleans. **Remember, foam and cleansing power are not necessarily related.**

The amount and types of surfactants that you choose will affect the perceived harshness of your shampoo formula. In general, the more surfactant you use the harsher your formula will feel. This is true no matter what type of surfactant you use so even so-called mild surfactants

can result in a harsh feeling formula if you use too much. Incidentally, when I call a formula harsh what I mean is that it is irritating to the skin or drying to the hair or skin.

You can control the perceived harshness of your formula in a number of ways.

Pick a less irritating surfactant – Perhaps the most irritating surfactant that is normally found in shampoos is Sodium Lauryl Sulfate. Using ingredients like Sodium Laureth Sulfate or Sodium Lauryl Sarcosinate can reduce the irritation potential of your formula. This will typically increase the formula cost and may reduce the quality of the foam so it's a balancing act to get just the right performance with low enough irritation potential.

Use a lower level of surfactant – The more surfactant you use the harsher it will be. But using a lower level will impact foam quality, viscosity, and cleansing ability. Remember you need your formulas to perform well but they can't be irritating to too many consumers.

Add ingredients to reduce the irritation level of your surfactant. - You can make a milder shampoo based on Sodium Lauryl Sulfate by including Cocamidopropyl Betaine which will offset the irritation level of the overall formula.

One other characteristic you can control is the conditioning ability. The more conditioning materials you add the greater the conditioning effect. But these materials will also affect the foam quality, thickness, and cost.

Ideally, you'll strive to find that perfect balance of high foam, low irritation, adequate conditioning, clarity (or opaqueness) and good thickness.

Shampoo Ingredients

When you are creating a shampoo formula there are a number of different ingredients that you will need to make a working formula.

- **Water** – This is the main solvent for solution-based shampoos. Deionized water is preferred as it will not contain metal ions that can interfere with the functionality of the surfactants.
- **Primary Surfactant** – This is the ingredient that will provide the functionality in terms of cleansing and foaming. For standard shampoo formulas this will be some type of anionic surfactant. This will also normally be the ingredient that makes up the bulk of the formula after water so it has a big impact on formula cost.

- **Secondary Surfactant** - Since blends of surfactants can create better foam characteristics it is always a good idea to add a secondary surfactant to your formula. These are normally nonionic or amphoteric surfactants that have the added benefit of modifying the viscosity and reducing irritation.
- **Conditioning agents** – If you make a shampoo that only contains a detergent you run the risk of leaving the user's hair feeling dry, unmanageable and static prone. For this reason, it is advisable to add some type of conditioning agent. The type and amount you include will depends on the marketing position of your formula however. For a volumizing shampoo you might use a low level of conditioning ingredients. For a moisturizing shampoo, you'll use a relatively high level of conditioning ingredients.
- **Color** – The natural appearance of most surfactants is a light-yellow color. Unfortunately, this doesn't work with most marketing stories so it's advisable to add some type of artificial color to your formula. In the US colorants in cosmetics are highly regulated and there are specific ones that are allowed.
- **Fragrance** – The natural odor of most shampoo formulas is a light waxy odor. It's not an unpleasant smell but it is not particularly appealing either so fragrances are added to make the shampoo formula more appealing.
- **Preservatives** – Whenever you have water in a formula you have the potential for microbial growth. For this reason, your shampoo formulas will always require a preservative. There are a number of effective options depending on what other ingredients are in your formula.
- **Formula adjusters** – In a shampoo it's helpful to include ingredients that can be used to adjust the pH and viscosity. This would include things like salt, acids, and bases. Additionally, chelating agents may be added to improve the function of the preservatives.
- **Feature ingredients** – The other type of ingredient you'll add to your formulas are the feature ingredients like vitamins, proteins, and herbal extracts. These ingredients aren't expected to have an effect in the formula but they do help sell the product by supporting the marketing story.

Here is a list of the most common types of shampoo formulas.

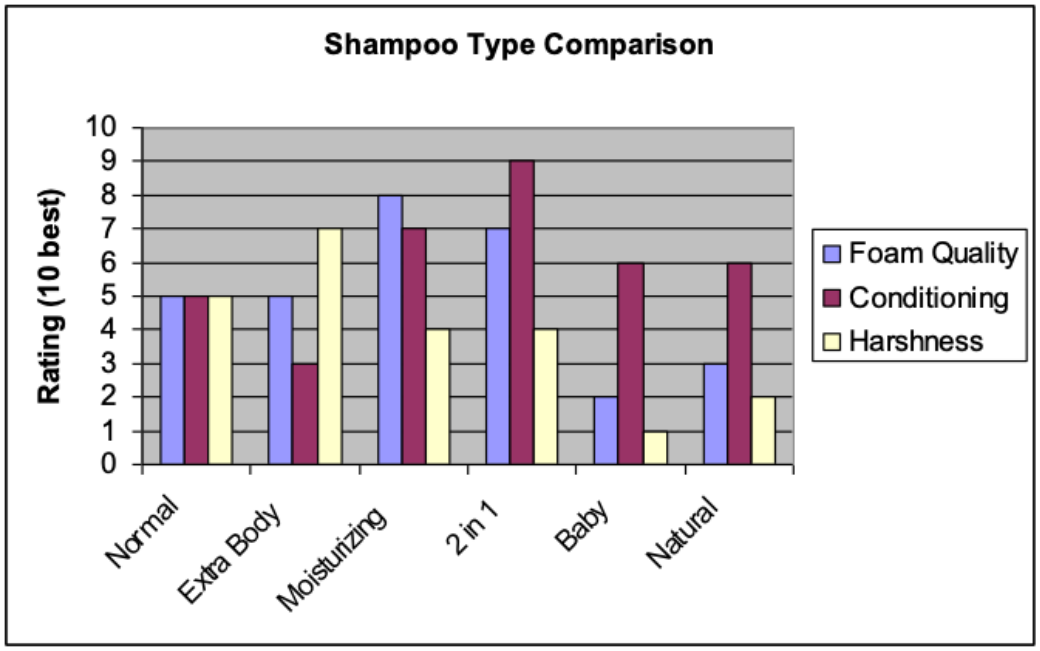
- Normal
- Extra Body/Volumizing
- Moisturizing
- 2-in-1
- Baby
- Natural

It is important to note that these names are traditional terms, but different companies or marketing departments will call products different names. For example, Moisturizing formulas may be called Restorative, Damage Repair or Shine Enhancing.

Shampoo factor comparisons

In the chart below we compare the key characteristics of the different types of shampoo formulations. If we take the Normal shampoo formula as the average rating for each factor, you can see how the other types of formulas compare.

Figure 10: Shampoo Type Comparison



From the standpoint of foam quality (a measure of the creaminess of the foam) both Normal and Extra Body formulas are expected to have average foam quality. The Moisturizing formula should have the best foaming feel as should a 2 in 1 formula. This better communicates the idea of moisturization during use. Baby shampoos are formulated with nonionic surfactants and are not expected to foam as well as standard shampoos. Natural shampoos are not formulated with standard surfactants so it can be more difficult to produce a formula with luxurious foam.

Conditioning is another characteristic in which we can compare formulas. Extra Body formulas are not expected to conditions as well as normal formulas and they don't due to their higher level of surfactant. Moisturizing formulas are expected to be more conditioning than Normal formulas while 2-in-1 formulas are designed to have the most conditioning delivered from a shampoo. Both Baby shampoos and Natural formulas are typically a more moisturizing than Normal. This is because they do not use surfactants that are as harsh. This also means that they don't clean the hair as well as normal shampoos.

The final factor to consider is harshness. By this I mean the level of potential irritation that the user might experience after using the product. The ratings are mostly a function of the amount and type of surfactants used. No company tries to create a harsh formula so even ones with a slightly higher “harshness” rating are not particularly problematic for most consumers. However, formulas with low harshness ratings like Natural and Baby shampoos are specifically designed to minimize this characteristic. Formulas with a higher harshness rating are more concerned with completely cleansing the hair. In general, the better the cleaning ability of the formula, the harsher you can expect it will be.

We should also talk about what is meant by “active surfactant.” This term refers to the amount of actual surfactant that is in the raw material you buy. When you buy an ingredient like a surfactant it is often sold as a diluted solution. For example, Ammonium Lauryl Sulfate is frequently sold as a 28% solution. This means in a 100g sample of Ammonium Lauryl Sulfate, 28g will be surfactant while the remaining 72g are water. Therefore, the ALS is said to be 28% active.

When you are formulating if you add 20% of this ALS in your formula you are not actually adding 20% surfactant. You are adding 28% x 20% = 5.6% surfactant.

As previously mentioned, normal shampoos have a range of 10 – 15% active surfactant. If you wanted to fall within that range in your formulation using the 28% ALS sample, you would need to add a total of 35.7% of the material into your formula.

It's also worth noting that when you see the term “% Active” that is usually synonymous with the term “% Solids”.

Normal shampoos

A normal shampoo is designed to remove dirt and oil from hair while also providing a small level of conditioning / moisturization. Depending on the brand positioning the formula can be either clear or opaque.

The level of surfactant in a normal shampoo formula varies but it typically falls within a range of 10 – 15% active surfactant.

Figure 11: Clear Cleansing Shampoo

Formula Name

Basic Clear Cleansing Shampoo

Batch size

500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Diluent	Water	54.631	273.16
2	Colorant	Color	0.001	0.01
3	Sequesterant	Disodium EDTA	0.100	0.50
4	Primary Surfactant	Ammonium Lauryl Sulfate (28%)	32.143	160.71
5	Secondary Surfactant	Sodium Laureth Sulfate (25%)	4.000	20.00
6	Foam stabilizer/Thickener	Cocamidopropyl Betaine (35%)	7.143	35.71
7	Fragrance	Fragrance	0.500	2.50
8	Preservative	DMDM Hydantion (55%)	0.182	0.91
9	pH adjuster	Citric Acid	0.300	1.50
10	Thickener	Ammonium Chloride	1.000	5.00
		TOTAL	100.00	500.00

Procedure:

1. Begin mixing item #1 in container - warm to 45C.
2. Add items #2 and #3
3. Slowly add items #4-#6
4. Cool batch to 25C
5. At 30C, add items #7-#9
6. At <30C, add item #10. Mix for 10-15 minutes
7. Check pH and viscosity. Adjust as required

Specifications

pH = 5.0-5.5
Viscosity = 4000-7000 cps

Water makes up the largest volume of this formula followed by the surfactant. In this case the primary surfactant is Ammonium Lauryl Sulfate which is used at about 32%. On an actives level that is 9%. Also included as a secondary surfactant is Sodium Laureth Sulfate. This is included to help improve the foam characteristics and reduce irritation. Cocamidopropyl Betaine is included for similar reasons. It also has an impact on the formulation viscosity. If you add up the % activity of the surfactants you will see that this formula has a total of 12.5% surfactant. This would be 9% from ALS, 1% from SLES, and 2.5% from Cocamidopropyl Betaine.

The other ingredients are fairly straightforward including fragrance for odor, DMDM Hydantoin for its preservative effect, and citric acid to allow for some pH adjustment. Note that for a shampoo, 0.5% of the fragrance is typically used. This helps give the product a pleasant odor while also ensuring that it remains clear.

Volumizing Shampoos

Volumizing, Thickening or Extra Body shampoos are designed to clean hair and make it look like you have more fullness. There are two strategies that formulators can use to achieve this goal. First, you can increase the amount of surfactant in your formula. By increasing the surfactant, you increase the amount of dirt and oil removed from hair. If there is no oil weigh hair down it will be in the most voluminous condition that it can. The other strategy is to add a conditioning polymer which can coat hair and make it look slightly thicker. A polymer like Guar Hydroxypropyltrimonium Chloride or Polyquaternium-10 is frequently used.

Moisturizing Shampoo

The purpose of a moisturizing shampoo is to clean hair but also to provide a low level of conditioning. To achieve this we use more mild, less aggressive detergents. By doing this you reduce the amount of oil that is removed from hair and you make it easier to deposit the conditioning ingredients that are included in the formula. In addition to the milder surfactants, moisturizing shampoos can contain conditioning ingredients like Cationic Polymers, Humectants and Silicones.

Photo by Erick Larregui on Unsplash

Often, formulators will include an even milder surfactant like Sodium Lauryl Sarconsinate instead of ALS. The downside of this approach is that it will not foam as well and might also require you to add an additional thickening system as salt thickening may not be adequate.

Moisturizing formulas can be either clear or pearlized. To make it opaque consider including 1% Ethylene Glycol Monostearate (EGMS).

2-in-1 shampoo

These shampoos were created to eliminate the need for a conditioner after shampooing. It has been difficult to create a good working 2-in-1 formula because the way shampoos and conditioners work are opposite. When you shampoo, you are trying to remove oils from your hair. When you condition you are trying to leave oils on your hair.

The standard conditioning ingredients like cationic surfactants, humectants and emollients are not generally effective for a few reasons. Cationic surfactants are not compatible with anionic surfactants. Humectants are water soluble and just rinse away while emollients are oils which get removed with all the other oils during washing.

The first ingredient tried was cationic polymers. The most effective was Polyquaternium-10 and it is still used in many 2-in-1 formulas today. However, it was not nearly as conditioning as a standard conditioner plus it had a tendency to build up over time. The next ingredient tried was silicones, or more specifically, Dimethicone. When formulators were able to stabilize this ingredient the 2-in-1 formula was born.

Baby Shampoo

Baby shampoos are designed to be cleansing without being irritating to skin. They also must be tear free. These are challenging for the standard surfactants used for formulating shampoos however, many nonionic surfactants will work. PEG-80 Sorbitan Laurate is an effective surfactant for a baby shampoo. It will not foam as well and will also be less cleansing but babies don't usually have a lot of hair or need deep cleaning and consumers don't expect the same functionality from a baby shampoo as they do from a standard shampoo.

Since salt can be irritating to eyes it cannot be used for thickening. Instead, a surfactant thickening polymer such as PEG-120 Methyl Glycose Trioleate is used. Still, these formulas tend to be thinner than standard shampoos. Fragrance levels are also lower in baby shampoos to minimize irritation.

Natural Shampoo formula

The final type of shampoo we'll discuss is a so-called Natural formula. It is difficult to include this formula because everyone has their own ideas of what “natural” really means. In the United States, there are no rules regarding the use of the term “natural” or “green”. Any of the previously discussed could be marketed as a “natural” formula if it’s given the right name and put it in the right packaging.

However, there are some groups that have tried to create “natural” standards and it is useful to look at a shampoo formula that would follow some of the more common standards. These standards could include:

1. Sulfate free formulas
2. Gentle preservatives – (no parabens, no formaldehyde donors)
3. Natural extracts
4. Synthetic free fragrances

The formulas presented thus far are market-proven formulations and with some minor adjustments they can be sold as actual products. However, as a formulator you may want to experiment with your own versions because you may have access to different surfactants or you want some other type of foam or feel.

Here are some of the variables you can change to make these formulas your own:

Aesthetics – The easiest way to create a “new” formula is to change the color or the fragrance. These have a huge impact on the consumer's perception of the product while having little impact on the product stability and cost. That is not to say there will be no impact as different colors can fade more easily and some fragrances will interfere with foam and performance, however, these are some of the easiest, most-impactful changes to make.

Marketing ingredients – I didn't include them in most formulas but when you sell a shampoo (or most any other cosmetic) you are going to want to add some claims ingredients. These include herbal extracts, vitamins, proteins or “new” technology. It really depends on the marketing story but it's good to include these at low levels (eg 0.05%). They can help sell your product without interfering too much with the stability or performance.

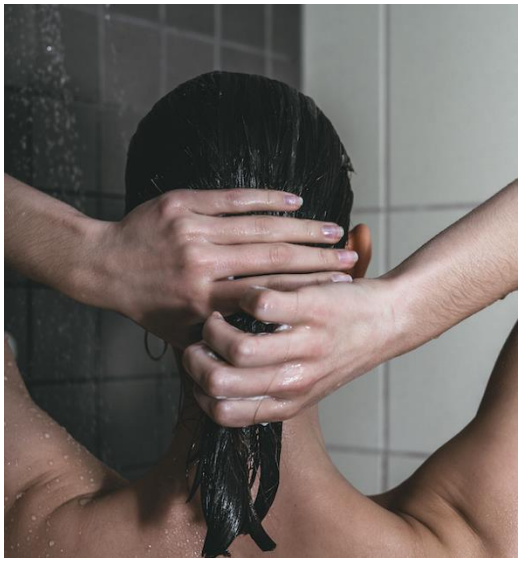
Surfactant Substitutions – If you want to experiment you can swap out some of the surfactants mentioned in the previous formulas. There are literally thousands of different surfactants you can use and some may work differently than others. The reality is that most shampoos in the world are based on some type of alkyl sulfate and this is because they have been shown to work the best. Yes, you can use Taurates or Polyglucosides but they are more expensive and less effective. But I look at it like making an omelet. There are hundreds of different egg choices you can use to make an omelet but nearly everyone uses chicken eggs because they are the most effective. However, as a formulator you should become familiar with all the other options as there may be some subtle differences that you can use to make your formulas stand out.

Conditioning agents - The other thing you can do to modify these formulas is to try different conditioning or moisturizing ingredients. For the most part you will find that cationic polymers and silicones are the most effective but you can try adding different humectants or even emollients to see whether there is some noticeable effect.

Of course, you can also try adjusting the levels of the different ingredients suggested. Since everyone will have access to slightly different raw materials and manufacturing facilities the level of the ingredients may be different for you.

We will discuss this more in a future chapter but when you make changes try to keep changes minimal (only make one change per formula) and test the new prototypes on a blinded basis. For a shampoo the key things to test are foam and feel. Ideally you will have someone else create the samples and you can try them to see if there is any difference. Often, we notice differences where there might not actually be any. It's also a good idea to test your prototypes with people who are unfamiliar with the project.

Conditioners



Although shampoos are the largest market for hair products, conditioners are also a significant segment and have outperformed shampoos in terms of sales growth in recent years. In fact, nearly all shampoo brands offer a companion conditioner.

Unlike shampoos, conditioner formulas are almost always simple emulsions instead of solutions. They contain more oil-based ingredients and are meant to leave something behind on the hair surface rather than remove anything. They are primarily designed to reduce the forces associated with combing and styling hair. They also help reduce damage caused during the grooming process.

Another characteristic of conditioners is that they are almost always applied after shampooing.

Types of conditioners

Just as with shampoos there are a number of different types of conditioners on the market. For the most part these formulas work the same way but they are marketed to appeal to a different set of consumers.

The most common type of conditioner is the rinse-out conditioner. These are meant to be applied after shampooing to improve combing, manageability, and any other claim there might be. Here are the most commonly marketed rinse-out conditioners:

- Moisturizing
- Volumizing
- Smoothing / Straightening
- Color preserving
- Shine
- Strengthening

Conditioners are sold in much the same way that shampoos are sold. In fact, there is usually a companion shampoo with these conditioners. So, a volumizing conditioner will be sold with a volumizing shampoo. This works well for the marketer since many consumers believe that if they buy one type of shampoo, they should buy the companion conditioner. In reality, there is little evidence that using a conditioner from the same brand will have an additional benefit.

Since conditioners are seen by consumers as therapeutic the market has spawned more intensive versions or conditioning treatments. These go by a wide variety of names but they all promise to condition hair in a more intense way. Some typical examples include:

- **Hairdressing** – These are oil-based formulas that are meant to be left in hairdressing
- **Protein Packs** – These are thicker products which contain protein. They are meant to be left on the hair for a number of minutes then rinsed out.
- **Hot Oils** – These are conditioners meant to be applied prior to shampooing and rinsed out. Interestingly, they don't typically contain any actual oil.
- **Capsules** – These are gelatin capsules that hold liquid oils which are meant to be left in hair.
- **Serums** – These formulas are leave-in products like the ones found in capsules but they are delivered from an eye dropper bottle.

Finally, leave-in sprays are liquid forms of conditioners. These are solution formulas that contain humectants, silicones and emollients mixed with water. These are sometimes sold as detanglers.

What makes conditioners interesting are the vast array of claims that are made in an effort to sell them. Here are some of the most common claims you'll find on conditioners. Let's review how they are achieved:

- **Easier to comb** - This is the primary reason conditioners are used because without them hair can pull and snag during the styling process. Conditioning agents solve this problem.
- **Rinses completely** - One of the concerns consumers have with their conditioners is that it will leave the hair feeling heavy. By making formulas that rinse out easily using cationic surfactants you can minimize this issue.
- **Doesn't weigh hair down** - This is a different way to say the formula rinses out completely. Marketers are clever in their ability to say the same thing a number of different ways.
- **Protects hair from breakage** - Many consumers are concerned with spilt ends and frizzy hair. For this reason, claims about protecting hair are compelling. Standard conditioner ingredients can help satisfy this claim.
- **Contains vitamins**- Vitamins (with the exception of Panthenol, vitamin B5) do not do much for hair products. However, just adding a vitamin to your formula makes it more compelling to most consumers.

Purpose of Conditioners

While the primary reason that people use shampoo is to clean their hair, conditioners are used for a number of different reasons. Here are the most common problems for why consumers use conditioners:

- **Hair is hard to comb** – When you use a shampoo you remove most of the natural lubrication between the fiber. Since they easily tangle while cleaning having some kind of lubricating coating will make it much easier to comb. Most shampoos cannot do a good job of both cleaning and conditioning so conditioners are needed.
- **Hair feels dry** – Damage caused by the styling and grooming process leads to hair that feels more like straw. Conditioners are designed to offset that dry, straw-like feeling.
- **Hair frizz** – Frizz is characterized by single stray hair that seem to go in a direction different from the bulk of your hair. This is the result of unequal water absorption and can be helped by the use of a conditioner.
- **Dull looking** – Consumers want hair that looks shiny and conditioners or treatments are a way for them to get that.
- **Too flat** – Consumers with fine thin hair seek products that make it look like they have more hair than they might. Volumizing conditioners can sometimes help solve this problem.
- **Hard to style** – Hair that is not conditioned can be more difficult to conform to the shape that you desire. A conditioner can give the consumer an even coating on each strand and make styling easier.

Hair Damage

The primary reason consumers use conditioners is because hair naturally gets damaged. Damaged hair directly results in many of the previously mentioned challenges consumers experience.

There are two types of hair damage including Physical damage and Chemical damage.

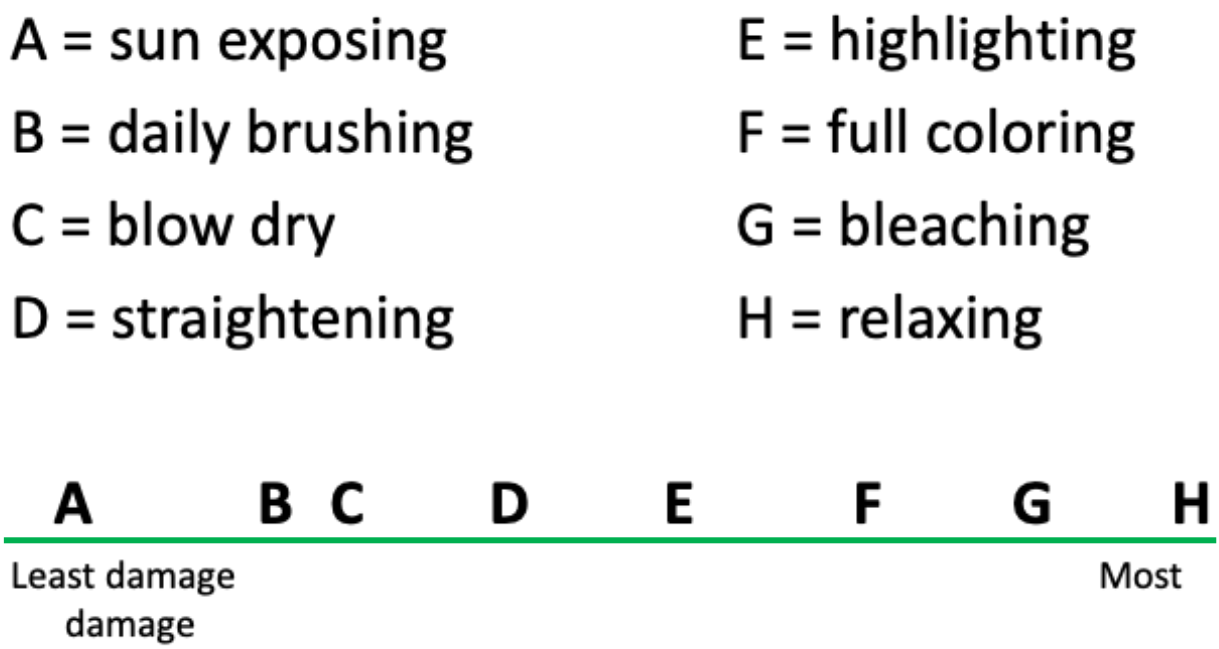
Physical hair damage is caused by a number of things that consumers **do** to their hair including:

- Washing and drying
- Combing and brushing
- Heat styling with curling and flat irons

Additionally, hair can be damaged on a chemical level where the protein strands that make up the hair fibers are damaged. Chemical damage is caused by UV exposure or any of the various chemical hair treatments such as relaxers, hair colors, bleaching, or perms.

To give you a sense of how much each of these different factors damage hair, below is a chart that will be helpful.

Figure 12: Factors that contribute to hair damage



You can see that sun damage is the least problematic damage as far as hair goes. If you artificially color hair it can be a problem but not for breakage or frizz. Daily brushing causes a minor amount of damage but this can build up since you do it every day. This is the primary reason that people should use conditioners. Blow drying is only slightly more damaging but the heat added to the brushing that goes along with it can really contribute to worsening hair. Moderate damage can be caused by using something like a flat iron which can actually melt the hair fibers.

But you can see that chemical treatments are much more damaging than physical damage. So, highlighting or coloring hair will produce a moderate amount of damage while things like bleaching and relaxing are the most damaging thing that can be done to hair. Fortunately, these chemical treatments are not done frequently so it's okay to do them occasionally as long as the consumer uses a conditioner.

Here are some of the different types of physical hair damage as characterized by scanning electron microscopy.

Some time back the raw material supplier company Croda commissioned a study to visualize hair damage. They found five different types of damage including:

- **Buckling** - This is where the cuticles get loose and lift up off the surface. Buckling fibers pull off the hair and can cause snagging, tangles and broken fibers.
- **Abrasion** – In this damage the cuticles are worn off the surface. Abrasion the cuticles are rubbed off. This can result in weakened hair that can more easily break
- **Cracking** – These are long, lengthwise cracks in the hair fiber - caused by chemical and physical factors and represents the start of a split hair.
- **Crazing** – When this happens the cuticles are fused to the surface and are easily broken off. Crazing is much like Abrasion but is caused by heating the hair too much. Cuticles don't flex as well with the hair and can chip off.
- **Blistering** – This is caused by heat styling and looks like tiny bumps on the hair. Blistering literally looks like there are blisters on the hair. Eventually, these bubbles can “pop” and cause split hairs.

Hair conditioner formulas

The primary ingredients that are included in conditioner formulas are very similar to the shampoo ingredients and include a solvent (water), functional ingredients (conditioning agents), aesthetic ingredients (thickener, opacifier, emulsifier, preservative, color, and fragrance) and marketing ingredients.

The formula below is a very simple hair conditioner. It contains a cationic surfactant at 1% (cetrimonium chloride) to provide the primary conditioning effect. For help in emulsification and to make it look consistently opaque, Cetyl Alcohol is used at 2.5%. This level of the ingredient will give an adequate product thickness. Then another 1% of the formula is used for the preservative, fragrance and feature ingredients. The rest of the conditioner is made up of 95% water.

Cetrimonium Chloride	**1.0%**
Cetyl Alcohol	**2.5%**
Cellulose	**0.5%**
Fragrance, preservative, acid	**1.0%**
Water	**95.0%**

Factors formulators can control

When creating a shampoo the control you have over the formula is limited to aesthetic characteristics such as color, fragrance, and thickness plus functional items like foam quality and cleansing properties. For a conditioner you have the same kind of control of the aesthetic characteristics (although you typically can't make a conditioner clear). You also have control over hair feel when the conditioner is removed. This is controlled by the type and amount of conditioning ingredients you use.

While there are a number of different conditioners on the market, there are really only a few types of cosmetic conditioner formulations including:

- Moisturizing - A formula that goes along with moisturizing shampoos – Heavy conditioning
- Volumizing - Designed to be paired with extra body shampoos – light conditioning.
- Intense - A treatment product meant to be used once a week
- Natural - An option for a natural conditioner
- Leave-in - A formula meant to remain in hair
- Serum - A specialty formula meant to treat a specific problem

Moisturizing Conditioner

Below is an example of a standard moisturizing conditioner. It features water as the primary solvent and it happens to make up over 90% of the formula. Conditioners are mostly water. The Hydroxyethylceullose is included to provide the appropriate thickness to the formula. Other ingredients that add to the thickness include the Cetyl Alcohol and Stearyl Alcohol.

Figure 13: Moisturizing Conditioner

Moisturizing Conditioner 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Diluent	Water	91.600	458.00
2	Thickener	Hydroxyethylcellulose	0.500	2.50
3	Adjustment Agent	Disodium EDTA	0.200	1.00
4	Humectant	Glycerin	1.000	5.00
5	Conditioning Agent	Cetrimonium Chloride	1.500	7.50
6	Preservative	Methylparaben	0.100	0.50
7	Conditioning Agent	Hydroxypropyl Guar Hydroxypropyltrimonium Chloride	0.300	1.50
8	Conditioning Agent	Dimethicone Copolyol	0.200	1.00
9	Adjustment Agent	Citric Acid	0.300	1.50
10	Opacifier	Cetyl Alcohol	2.000	10.00
11	Opacifier	Stearyl Alcohol	1.000	5.00
12	Emulsifier	Glyceryl Stearate	0.500	2.50
13	Preservative	DMDM Hydantoin	0.200	1.00
14	Fragrance	Fragrance	0.600	3.00
		TOTAL	100.00	500.00

Procedure:

1. Begin mixing item #1 in container.
2. Add items #2 - begin heating to 75C
3. Add items #3-#9
4. At 75C, add items #10-#12
5. Mix for 30 mins and begin cooling to 30C
6. At <40C, add item #13 and #14
7. Mix until cool. Check pH and viscosity. Adjust as necessary.

Specifications

pH = 3.5-4.0
Viscosity = 15,000 - 20,000 cps

The primary conditioning agent is Cetrimonium Chloride (a cationic surfactant). Dimethicone copolyol and a Guar polymer are also included for additional conditioning. These ingredients are only going to provide a small amount of conditioning if any. However, the Dimethicone copolyol may impart some additional shine. This is an emulsion product so Glyceryl Stearate is included as the emulsifier.

To get adequate preservation the formula includes both Methylparaben and DMDM Hydantoin. You may not require both of these in your formula but for emulsions a blend of parabens and DMDM Hydantoin can often get better results than a single preservative.

This is a white, opaque formula so there is no added color. To create a less yellow tint you might want to include a small amount of Blue 1.

This formula will provide good detangling and some softening of the hair however, it will not be incredibly effective on really damaged hair. For that, you will need to add a higher level of conditioning ingredients.

Volumizing Conditioner

These formulas are intended to help detangle the hair without weighing it down. Consumers who want volume do not want anything will weigh down their hair.

To achieve this, you can switch out the primary conditioning ingredient to an amphoteric surfactant with a lower level. You can also increase the level of the cationic surfactant to further reduce static flyaway which is a problem with this type of hair. The rest of the formula remains similar to the Moisturizing conditioner.

When creating varieties of a formula it is good to start with a standard formula and then make only slight modifications. This makes it easier to produce on a large scale and can also give you a sense of what ingredients have the most impact on the final formulation.

Intense/deep Conditioner

For people with severely damaged hair the conditioners we've discussed thus far will likely not be adequate. To treat this type of hair there are intense conditioners. Many of the products marketed as intensive conditioners are really just thicker versions of standard conditioners. In this way they are more marketing stories than products that actually work different. This is because standard conditioners work well but consumers like the experience and promise of an intensive treatment.

The primary differences in this type of formula are the inclusion of a different conditioning system. Dimethicone is used at a 1% level and Quaternium-18 is included at a level of 2% to reduce static while providing a protective coating. Stearamidopropyl dimethylamine and Dimethicone copolyol are also included to round out the conditioning. While the Stearamidopropyl Dimethylamine will have a noticeable effect it is unclear whether you really need the Dimethicone Copolyol as it will mostly get rinsed away and you've already got the Dimethicone. However, this ingredient was included in the other formulas and there is no good reason to remove it.

If this were going to be used as an Intensive weekly conditioner you would want to include some kind of protein like Hydrolyzed Keratin to help support the story of a protein treatment. It may have some humectant effect but not much. This type of product could be used for a good daily conditioner too though it may be too thick. To reduce the thickness a lower level of Cetyl or Stearyl Alcohol is used. To increase the thickness, you could double the amount of those ingredients.

Natural Conditioner

Unlike shampoos, there are a number of naturally occurring conditioning ingredients. A number of vegetable oils like Coconut Oil, Sunflower Oil, or Palm Kernel oil can provide a conditioning effect. Unfortunately, these ingredients used on their own do not produce an aesthetically appealing product. Consumers generally prefer emulsion-based conditioners better than completely natural ones. However, there is demand by some in the marketplace to have a formula they can call “natural” and adhere to some standard.

The inclusion of natural extracts also supports the natural narrative. The exact ones that you use will depend on the marketing story that you want to pursue.

Leave-in Conditioners

Rinse-out conditioners may be perceived as too heavy and leave too much of a coating on hair for some consumers. However, they still want detanglers or products to make hair shiny so the leave-in conditioner was introduced.

Leave-in formulas are typically solution-based formulation although they could be thin emulsions. These formulas typically contain Humectants, a cationic surfactant and a silicone.

The silicone is added for shine and slip while the humectant is able to attract moisture and keep hair moisturized. A cationic surfactant is included to reduce static charge and thereby prevent frizz and fly-away hairs. It's notable that Cetrimonium Chloride has a maximum use level in a leave-on product of 0.25% (in the US). This is because it has been shown to be irritating to most people at higher levels. For this reason, you might consider substituting this ingredient with another conditioning ingredient such as a cationic polymer.

Oils and emollients are not used in this formula because they can weigh hair down and attract dirt and oil. Also, to incorporate them into the formula you would need an emulsifier which might turn the product white. People typically do not like to spray a non-clear formula into their hair.

Hair Serum

These formulas are typically simple blends of silicones including Dimethicone which can coat and seal the hair and Cyclomethicone which helps reduce the viscosity of the serum and improve the feel. There is also the option of adding claims ingredients like vitamins and a fragrance. Neither of these are required to produce a functional formula however.

Conditioner Modifications

The formulas presented here are basic formulas which can be modified in a variety of ways. You can make changes to the aesthetics of the formula by changing the color or the fragrance. Also, you can include any type of marketing ingredient to support the product positioning.

To make functional changes you can modify the conditioning ingredients that you choose. Try to replace the silicones that were mentioned with other types of silicones. You may also substitute different humectants, cationic polymers or cationic surfactants. You may also try to incorporate natural oils to determine whether they have any noticeable impact on the formula.

If you want to experiment with a different texture, you can incorporate some thickening ingredients in the formula such as Carbomer, Hydroxyethylcellulose or other thickeners mentioned in chapter 3. Also, the texture can be adjusted by modifying the level of the Cetyl or Stearyl Alcohol you use.

No matter what types of changes you make be sure to test your formulas on a blinded basis to determine whether you've made an improvement or not.

Styling Products

Hair styling products are formulations designed to help shape and maintain the shape of hair. They are typically leave-in products that feature a styling polymer or other ingredient which can hold the hair in place.

Hair styling product types

While shampoos and conditioners are mostly the same type of formula (solutions or emulsions) styling products take on a number of different forms.

- Gels – Viscous clear liquids the spread easily when a force is applied
- Waxes - These are opaque greasy products that can be created in a variety of ways.
- Pomades - Emulsion based waxes meant to create a movable style
- Putties - Like pomades but typically anhydrous and slightly greasy
- Aerosols - pressurized systems that deliver product in a spray of foam form
- Mousse - Foam formula that provides hold and some hair conditioning
- Hair spray - Spray formula that "glues" hair in place
- Creams - These are similar to pomades & putties but are less greasy and look more like hand creams

In addition to the styling product forms, they can also vary by the level of hold that they impart in hair. Strong hold or Maximum hold formulas are intended to provide a stiff hold and keep the hair in place. Medium hold products keep hair feeling a little less stiff but still provide some level of hold while flexible hold allows that hair to move naturally. Offering a spectrum of hold levels ensures that you are reaching the most consumers, as preferences vary greatly from person to person.

In general, to create different levels of hold the styling polymer used is increased to give more hold or decreased to produce less.

Styling Product Claims

When formulating styling products there are three types of claims you will have to create formulas to support. These include:

- **Hold claims** – which refer to the level of hold, how long it lasts, or whether it is sticky or not.
- **Conditioning claims –** which refer to conditioning claims like shine, frizz reduction and hair protection
- **Other claims –** which refer to how the product works (eg speed of drying, no build-up)

Consumer styling problems

There are a number of factors that conspire to change the shape of hair once it has been styled including:

- Entropy - The tendency for ordered things to become disordered.
- Humidity - Water in the air gets absorbed by hair and causes a change in shape
- Gravity - This constantly pulls hair down and can destroy an updo style.
- Compression (sleep or clothes) - Resting on hair can rearrange hydrogen bonds and cause hair to change shape.
- Wind - Wind and other environmental effects change hair color
- Combing - Combing can damage hair causing future manageability problems
- Touching – Just touching hair can ruin a hair style

To solve these problems a number of technologies are available but they basically work in the same way. To keep hair into a fixed shape styling polymers are used. They can coat the hair shaft, block out moisture, and stick together to keep hair into shape. Conditioning ingredients may also be added to provide protection during the styling process.

Styling product ingredients

As mentioned previously, there are a wide variety of styling product forms available on the market. We will discuss the ingredients found most commonly and then review some specific styling product formulations.

This list of ingredients used in styling products may look familiar to you because it is the same type of ingredients used to make the other cosmetic products we've discussed. These include:

- Solvents
- Styling polymers
- Conditioning ingredients
- Thickeners
- Film modifiers – Plasticizer / Neutralizers
- Propellant
- Batch adjustment agents
- Preservatives / Colorants / Fragrance
- Feature ingredients

Styling Polymers

Styling polymers are often referred to as 'resins' in the cosmetic industry. The most common type of resin is Polyvinylpyrrolidone or PVP. This ingredient is easily soluble in water or alcohol,

can be easily sprayed, the film it forms can be easily modified, the film is clear, it sticks well to keratin, and it is compatible with cationic antistatic agents. It is supplied in different grades with PVP K30 and PVP K90 being the most popular. In this case, the number is related to the molecular weight of the polymer.

While PVP has excellent features it has a couple of drawbacks including being sticky when it gets wet and absorbing water from the atmosphere to reduce holding effectiveness. For this reason, manufacturers have introduced a wide variety of styling polymers.

The most popular of these is a copolymer with PVP and Vinyl Acetate (VA). PVP-VA is more resistant to absorbing moisture and thus will hold its shape better in humid conditions. It is also significantly less sticky. However, the introduction of the VA made the molecule less water compatible so formulating with it can be more of a challenge.

There have been a number of new styling polymers introduced aimed at making the hold more flexible, easier to wash off, and longer lasting. PVP/DMAPA acrylates copolymer is a recent introduction that is designed to be more compatible with today's lower VOC requirements.

Neutralizers

To ensure that styling polymers can be removed during washing and to adjust the characteristics of the styling film you need to include a neutralizer in most styling formulas. Neutralizers are compounds that interact with the polymer film and make them more compatible with water. Without a neutralizer the styling resin will adhere too strongly to the keratin and it would be difficult to be removed. The most commonly used compounds for neutralizing include Aminomethyl Propanol (AMP) and Triethanolamine (TEA).

Plasticizers

Another important ingredient included in styling products are plasticizers. These ingredients are added to change the flexibility of the polymer film. Without plasticizers the styling film is too brittle and it can “break” when touched or otherwise impacted. This can create unsightly flakes and ruin the hair style. The plasticizers help loosen the bonds between the polymer strands. Some common examples include Propylene glycol, Glycerin, and some silicones.

Formulating options

As a cosmetic formulator there are a number of variables that you can modify in a styling formula to create different products. As with shampoos and conditioners you can change the following:

- Aesthetics – color, clarity and fragrance
- Thickness – thin liquid to thick gel
- Feel of the hold – hard or soft
- Tackiness of the film
- Length of time the curl lasts – curl retention

These characteristics are modified by increasing the level of functional raw materials and experimenting with different blends of ingredients. In the following formulas we will provide some basic styling products which can be modified to suit your needs.

Styling Formulations

The basic styling formulations in this section include:

- Normal Hold Gel
- Extra Hold Gel
- Pourable Gel
- Setting Lotion
- Styling Cream
- Pomade
- Mousse
- Hair Spray (covered in previous chapter)

Normal Styling Gel

The formulation begins with the main solvent which is blended with the thickening system (Carbomer). Carbomer takes a long time to hydrate in water so it's added early in the process. In fact, if you work with Carbomer often it is worth creating a 1% solution so you can make prototypes faster.

Figure 14: Styling Gel

Formula Name

Normal gel

Batch size

500 grams

	Purpose	Ingredient	%	Amt. In Batch	Phase
1	Solvent	Water	72.180	360.90	a
2	Thickener	Carbomer	0.500	2.50	a
3	Adjustment Agent	Disodium EDTA	0.200	1.00	a
4	Humectant	Glycerin	0.500	2.50	a
5	Stabilizer	Benzophenone-4	0.020	0.10	a
6	Preservative	Dazolidinyl urea & iodopropynl butylcarbamate	0.100	0.50	a
7	Solvent	Water	20.000	100.00	b
8	Styling Polymer	PVP K-90	2.000	10.00	b
9	Styling Polymer	PVP/dimethylaminoethylmethacrylate copolymer	3.000	15.00	b
10	Solubilizer	Oleth-20	0.800	4.00	b
11	Fragrance	Fragrance	0.200	1.00	b
12	Neutralizer	Aminomethylpropanol	0.500	2.50	b
		TOTAL	100.00	500.00	

Procedure:

1. Begin mixing item #1 in container.
2. Add items #2 slowly to prevent clumping
3. Add items #3-#6
4. In a separate container mix item #7
5. Add items #8 and #9
6. Premix #10 and #11. Add to polymer mixture
7. Add item #12 and mix until clear.
8. Mix polymers with Carbomer solution. Mix 30 minutes until clear.
9. Take pH and viscosity readings.

Specifications

pH = 6.0-6.2
Viscosity = 25,000 - 35,000 cps

This formula is designed to provide hold to hair without significant flaking. For this reason, we use the standard styling resin PVP K-90 and also PVP / DMAPA which will reduce water uptake. The total styling polymer level is 5%. Since it is easier to work with these polymers in a water solution they are mixed apart from the main batch.

The fragrance is preblended with a solubilzer (Oleth-20) to ensure that a clear product can be made. The neutralizer is also added to the polymer phase so that when the two phases are combined at the end, the Carbomer is neutralized with minimal mixing after to prevent air entrapment in the gel.

This formula is relatively easy to make and highly stable. It also provides a long-lasting hold to hair due to the blend of styling polymers.

Extra Hold Gel

For some consumers, the previous styling gel would not provide enough hold which is why extra hold formulas are available. The formula is nearly identical to the normal gel formulation except for the amount of styling resin and the level of humectant. The increase in Glycerin is needed to maintain the plasticizing effect of the increased polymer level. To increase the level of hold we incorporate 7% of the styling polymers in the formula. This may not seem like a large increase but in terms of a styling film that is less than millimeters thick it has a notable effect.

The challenge with creating a formula like this is that if you add too much styling polymer the consumer starts to experience “helmet head” in which hair is too stiff and flaking can occur. You have to experiment to find the hold limits of your polymer blend.

If you wanted to create a more flexible hold formula (or get a cost reduction) you could experiment with reducing the level of styling polymer in these formulas. Say flexible hold with 2% styling resin.

Pourable gel

For people who don't like the texture of gels and prefer the spreadability of a liquid product a pourable gel features a Hydroxyethylcellulose thickening system with a light level of styling polymer hold at 1.5%.

These formulas also contain conditioning ingredients to help reduce static and add some flexibility to the resulting polymer film. Overall, this formula will provide less hold but more conditioning. It functions very much like a mousse.

Setting Lotion

When creating shape in the hair using curling irons/curlers, gels are not the best option because you need something that is easily spreadable and can coat the whole hair fiber. Setting lotions are the best for this application. Below is a simple setting lotion that can be used for achieving a curled style.

Figure 15: Setting Lotion

Formula Name **Batch size**

Simple Setting Lotion 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Solvent	Water	93.3	466.5
2	Styling polymer	PVP K 30	5	25
3	Plasticizer	Glycerin	0.5	2.5
4	Conditioning	Cetrimonium Chloride	0.2	1
5	Solubilizer	Oleth-20	0.2	1
6	Fragrance	Fragrance	0.6	3
7	Preservative	DMDM Hydantoin	0.2	1
		TOTAL	100	500

Procedure:

1. Begin mixing item #1
2. Add in order items #2-4
3. Premix items #5 & 6. Add to batch
4. Add item #7. Mix 10 min then check specifications

It features a PVP styling polymer and Glycerin as the plasticizer. An additional amount of conditioning is derived from the cationic surfactant used. In this case the PVP K30 is used so the user has the option of spraying the product on hair. If the PVP K90 were used the product would be too stringy and you would not be able to deliver it from a pump spray.

Styling Cream

We move off gels and on to a cream-based styling product. In reality you can solve many styling problems that consumers experience by using variations of the formulas above. However, both marketers and consumers like new products so there is a constant need for different options. Some people just don't like gels or don't believe that they are conditioning or protecting enough for hair. For this consumer, a styling cream works better.

Styling creams are an emulsion with a weak emulsifier (Cetyl Alcohol) and a strong suspending agent / thickener Carbomer. It has a very low level of styling polymer just 0.5% and is designed more as a heat protecting formula rather than a high hold formula. The protective agents include a high level of silicones including Dimethicone, Cyclomethicone, Dimethicone Copolyol, and Phenyl Trimethicone.

These silicones will provide shine and heat protection but will also help to plasticize the film created by the styling polymer. Since there is a low level of styling polymer this formula also provides a style that can be re-worked. If hair starts to fall it can be restyled to regain its shape.

Styling Pomade / Hairdressing

Photo by Nati Melnychuk on Unsplash

For those that don't like the crunchy feel or rigidness of styling polymer there are anhydrous hairdressing options. Formulas range but simple pomades usually feature a large amount of petrolatum. After application, the petrolatum will help hair stay in place via hydrophobic effect although it will not provide a large degree of hold. This formula works well for a slicked back look however. Triglycerides are added to give some flexibility to the formula and a fragrance is included to offset the odor of the petrolatum.

These formulas do a good job of protecting the hair from styling damage and will keep the hair feeling moisturized. However, it will quickly attract dirt and hair will feel heavy. The user may also have a hard time washing it out of their hair as Petrolatum can be particularly tough to remove with a shampoo.

Styling Mousse

Styling mousses were first made popular in Europe then brought over to the United States. They are essentially setting lotions put into an aerosol container and made to foam. They are easier to spread than most standard setting lotions and many consumers find them fun to use.

Figure 16: Hair Mousse

Formula Name **Batch size**

Basic hair mousse 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Solvent	Water	78.6	393
2	Styling polymer	Polyquaternium-11	10	50
3	Solubilizer	Oleth-20	1	5
4	Fragrance	Fragrance	0.2	1
5	Preservative	DMDM Hydantoin	0.2	1
6	Propellant	Isobutane & Propane	10	50
		TOTAL	100	500

Procedure:

1. Begin mixing item #1
2. Add item #2
3. Premix items #3 & 4. Add to batch
4. Add item #5. Mix 10 min then check specifications
5. Fill in can and add propellant under pressurized conditions

This is a very simple formula featuring the styling polymer Polyquaternium-11 at 2% active. This ingredient creates a flexible film but also has a conditioning feel. In fact, many consumers don't realize that a mousse is giving them as much hold as it does. The Oleth-20 helps to solubilize the fragrance but also increases the amount of foam when the product is dispensed.

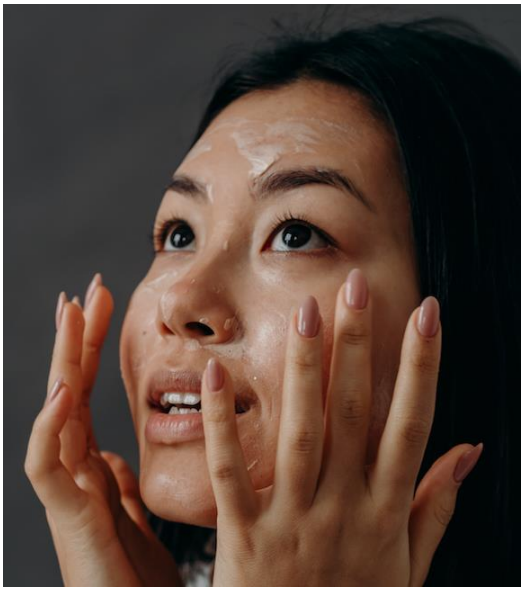
What did we leave out?

We've covered the top three haircare product markets including shampooing, conditioning and styling. However, we have left out some significant topics include chemically reactive products like hair colors, hair relaxers and hair perms. These are specialty products that require significantly different chemistry and tools and will be covered in a different book.

Chapter 6

SKINCARE PRODUCTS

Skincare Products



In this chapter we are going to look at skincare products and the skincare market. We will cover a wide variety of product types, the consumer problems they are trying to solve, and how to formulate. Additionally, we'll cover the science behind some of the technology in these products.

Market Data

Numbers vary widely depending on who collects the information or what products are included, but it is estimated that the global skincare market represents more than $130 billion in sales (2020 estimates). It is the largest of the cosmetic market segments and includes categories such as:

- Cleansers (eg body wash, bar soap, facial cleansers)
- Moisturizers
- Anti-aging products
- Anti-acne products
- Sunscreens
- Shaving products

In the US market, the largest segment of the skincare market are cleansers and breaks out roughly as follows:

- Body wash - $4.0 billion
- Facial cleansers - $2.9 billion
- Bar soap - $1.5 billion
- Liquid hand soap - $1.5 billion
- Hand sanitizers - $895 million
- Bath products - $511 million

Similar to haircare, some of the top cleanser manufacturers include Unilever, P&G, Henkel, Colgate-Palmolive and Johnson & Johnson. Due to the COVID-19 pandemic, segments such as liquid hand soap and hand sanitizers saw sales skyrocket during 2020, and have since fallen but are still outpacing pre-pandemic growth. Bath products have also been successful in recent years as more consumers focus on self-care and holistic wellness.

The US moisturizer/lotion segment is valued at roughly $5 billion and includes body care and facial moisturizers. Again, Unilever, P&G and Johnson & Johnson are leading manufacturers though L'Oréal, Beiersdorf and Sanofi-Aventis are significant competitors.

The Anti-aging market is separate from the cleanser and moisturizer segments and focuses on facial care. It represents a large segment of the US skincare market and is valued at roughly $2.7 billion in sales in 2020. This segment includes a wide range of formats such as moisturizers, serums, masks, etc. It also should be noted that many "traditional" facial skincare products include anti-aging ingredients making it increasingly difficult to segment anti-aging products separately from traditional skincare. There is also a move away from the term anti-aging as more inclusive and "pro-aging" language is being embraced by the beauty industry. Leading brands in the US anti-aging market include:

- Olay
- L'Oréal
- Neutrogena
- RoC

The US Sunscreen market is valued at $1.6 billion in yearly sales as of 2021.

Some of the top US brands include:

- Coppertone
- Banana Boat
- Private Label
- Sun Bum
- Neutrogena

You'll notice that Private Label is a top brand. Private Label refers to store brands and not something produced by one of the leading cosmetic manufacturers. Store brands are typically produced by a contract manufacturer and made to the specifications of the retailer that is selling them. You'll find private label brands in nearly all categories. They typically position their marketing such that they look like a market leading product but the packaging is slightly different and the price is less. High price points associated with sunscreen make private label an especially appealing option for cost-conscious consumers.

Skincare formulations

We'll cover the variety of product types currently being sold, the consumer problems trying to be addressed, the science and technology used to solve the problems, and then example formulations.

The primary segments we will cover include:

- Cleansing
- Moisturizing
- Sun protection
- Anti-aging - Cosmeceuticals
- Sunless Tanners
- Skin Lightening
- Shaving

Cleansing products

Since it is the largest segment, we'll begin by discussing the skin cleansing market. All consumer products are designed to solve some type of consumer problem and these products are no different. Of course, the main problem that cleansing products attempt to solve is to remove oil and dirt from the skin.

Consumer problems

Skin gets dirty due to a number of factors. First, based on the way that skin grows it naturally gets covered with oil (sebum) and dead skin cells. When these build up on the surface of skin they can attract other types of dirt such as small particles from the air, chemical vapors, pollen, or dust. Skin can also get dirty due to whatever activity the consumer may be engaged in like eating food, painting, applying makeup or even gardening. Additionally, skin is home to a large population of microorganisms that eat, reproduce, and create waste that is left behind. This can lead skin to feel greasy, dry, grimy, and even smell. People have long sought products that would remove dirt and restore skin to a more appealing state.

The first products created to solve the problem of dirty skin were soaps. No doubt the method from producing them was accidentally discovered in some ancient fire pit where our ancestors were cooking animal meat. The fat from the meat likely dripped onto some wood ash (which contains alkaline ingredients like sodium or potassium hydroxide) and reacted to form a solid soap. The first cosmetic formula for soap was recorded on a Babylonian clay tablet dating from 2200 BC.

While soap is a good technology for cleaning the skin and it's still used today, it can also lead to problems associated with dry skin. These include symptoms such as

- Tightness
- Roughness
- Itching
- Flaking, scaling or peeling
- Fine lines or cracks
- Redness
- Deep fissures that may bleed

Later in this chapter we'll talk more about the issues of dry skin, but for skin cleansing products it is not enough for formulators to create a product that just cleans the skin. It has to clean the skin without irritation. And there are a number of other stipulations that your formula must usually have. It also needs to rinse off quickly and easily. Additionally, you're going to want to create something with a luxurious foam to signal to the consumer the idea of skin moisturization (even if it's not really doing that). Finally, in today's world the product should also be suitably biodegradable.

Skin Cleansing Formats

There are a wide range of skin cleansing formats which are marketed in different ways. The largest segment is body wash which are very much like shampoos when it comes to formulation. The marketing of these products focuses less on the cleansing aspect of the formula and more on what it will do to skin after using it. Popular body wash types include those that are focused on skin moisturizing. These are also referred to as Hydrating or Nourishing or some other similar language. Then there are “experiential” body washes. These are designed to give the consumer a pleasing experience while using the product. They are often driven by fruity or floral scents that are appealing to consumers. There are also products that focus on “gentleness” such as baby body washes or those for with sensitive skin.

Some body washing focus more on their cleaning ability and specifically the antibacterial claim which many consumers find appealing despite the lack of evidence that antibacterial ingredients in body wash have any additional benefit over standard formulas.

Recently, there has been a push to sell anti-aging body washes or body washes that are designed to support anti-aging products. There is little evidence you can get anti-aging benefits from a body wash but it's another way to differentiate products.

Finally, there are multi-purpose body washes that double as both shampoos and body washes. The products can be very similar and in fact, when the company I used to work for launched their first product in the body wash market, they simply took one of our standard shampoo formulas and added additional conditioning ingredients.

Another significant type of product in the cleansing field are liquid hand soaps. These products are pretty much the same formulations as body washes but they are marketed slightly different. Most of them are sold in pumps or as concentrates that get put into pumps. The focus of the marketing stories is also on more functional aspects such as odor reducing or antibacterial products but there is also an emphasis on hand moisturizing. Additionally, pump versions which come out as a foam to help reduce water use and speed up application are popular. Big brands tend to dominate this market including Dial and Softsoap. However, there are a number of smaller, "natural" brands that have carved out significant market share. In the US these include brands like Method, Kiss My Face, and Seventh Generation.

While hand and body cleansers can be used anywhere on the body there is also a significant market for products targeted specifically for the face. Facial wash products are theoretically milder but also designed to provide additional benefits such as anti-acne, exfoliation or anti-aging benefits.

In the US, bar soaps are not classified as cosmetics unless they make some type of cosmetic claim. This is due to some quirk in the legislation that created the framework for the regulation of the cosmetic industry. However, most of the solid cleansing products sold in the US are not strictly soap bars because they make cosmetic claims. If you make any claims that would be considered cosmetic such as "moisturizing", "hydrating" or "fresh feeling" your product would then be considered a cosmetic and subject to FDA regulations. Solid cleansing products like these are typically referred to as bath bars or beauty bars.

One newer area for skin cleansing are hand sanitizers. This market has grown significantly since the mid 1990's and now represents more than $800 million in the US alone. The products are basically gelled versions of alcohol or some type of leave-on foam product. The focus on hand cleanliness as a result of the pandemic has elevated hand sanitizers into a must-have for many consumers.

Skin Cleansing Technologies

Before we talk about specific formulations let's review the types of technologies that are used to make skin cleansing formulas. Generally speaking, skin cleansing formulations take the form of liquid solutions, loose emulsions or solid bars with liquid solutions being the most common.

Cleansers – Body Washes & Liquid soaps

As you might imagine the primary technology driving skin cleansing formulations is surfactants. In previous chapters we talked about the science of surfactants and the way that they remove dirt from surfaces. One of the key aspects of surfactants used in skin cleansing formulas is the requirement that they must be mild. Or more specifically, the end formulations have to be mild.

Making formulations mild

Mildness basically means that the formula is able to perform its primary function without causing unacceptable negative side effects. This means that the formula must be non-irritating, cause no allergic reactions, and be non-sensitizing. Since we are all genetically different and react to chemicals in different ways, it's practically impossible to create a product that is mild for every consumer. The best you can hope for is making a product that is mild to the vast majority of users. To do that you can first choose mild surfactants as your primary functional ingredient in the formula.

Mild surfactants can be either anionic, amphoteric or nonionic. As with shampoos, anionic surfactants are the most often used ingredients for body washes and liquid soaps. That is because they clean the best, foam well, are easily rinsed, and are less expensive. There are a number of different anionic surfactants you can use for formulating body washes. Here are some examples along with their irritation potential.

Surfactant Irritation Potential

- Acyl Phosphates - Low
- Acyl Polypeptides - Low
- Acyl Sarcosinates - Extremely low
- Acyl Taurates - Low
- Alkyl Ether Sulfates - Mildly irritating
- Alkyl Sulfates - Higher
- Isethionates - Low
- Soap - Higher

Of course, these are only approximate irritation scores and the irritation potential of your formula will depend on the other ingredients in the formula. You can make a perfectly fine,

non-irritating cleanser using Alkyl Sulfates if you include other ingredients to offset the irritation. The term “Acyl” refers to the structure of the molecule. It is any molecule that features a hydrocarbon chain reacted with a C=O but missing the C-O bond that would create a carboxylic acid.

As far as what is used, the most successful and best-selling cleansing products use mild anionic surfactants as their base formula.

Another strategy for making mild cleansing products is to use **Amphoteric** and **Nonionic** surfactants.

Amphoterics are fairly good cleansers, have minimal irritation potential, and are thought to be substantive to skin so they can provide some conditioning effects. Typically, they are blended with anionics to produce a superior effect that can't be achieved using either surfactant alone. Common examples include Cocamidopropyl Betaine and Sodium Lauriminodipropionate.

Nonionic surfactants are good for cleansing but are not particularly good for creating the flash foam that consumers expect. For this reason, they are used as secondary surfactants except in formulations in which foam is not the primary driver of purchase (eg natural formulas).

There are three types of nonionic surfactants used in cleansing formulas including Alkyl Glucosides, Amine Oxides and Poloxamer. The alkyl glycosides like Decyl Glycoside or Lauryl Glucoside are fully biodegradable, have adequate foam and are good cleansers. They are less stable at lower pHs so when you formulate with them you need to keep your pH higher than most cleansing formulas. Amine oxides like Lauramine Oxide are good foam boosters. Poloxamers are actually block copolymers that have foaming properties and function in the same way as other surfactants. They are typically combined with other surfactants to improve mildness and help stabilize foam.

In addition to choosing milder surfactants, conditioning ingredients are also used when formulating body washes and other skin cleansers. To improve foam fatty alcohols such as Cetyl or Stearyl alcohol are used. To add conditioning effects any number of humectants, occlusive agents, emollients and polymers can be used.

Some common examples include:

- Humectants like Glycerin and Propylene Glycol
- Occlusives like Petrolatum & Mineral Oil – although these are tricky to include in a body wash because they will significantly reduce foam
- Emollients such as Shea Butter or Dimethicone
- Polymers like Guar Hydroxypropyltrimonium Chloride

Cleansing Products – formulation controls

As you may have guessed formulating body washes and liquid soaps are very much like creating shampoos. That means you will have control over characteristics such as:

- Appearance – both color and opacity
- Thickness
- Odor
- Cleansing effectiveness – how stripping it will be to skin
- Skin feel – what skin feels like after using the product

That also means that you will use pretty much the same type of ingredients to make the formula including:

- Diluent (water)
- Surfactants
- Thickeners
- Conditioning ingredients
- Aesthetic modifiers - Color, Fragrance, Preservatives
- Feature ingredients

Skin Cleansing Formulas

In this section we will cover a basic body wash, a moisturizing body wash, a baby or gentle formula and one that could pass for a natural formula. We will also cover a bubble bath formulation.

Normal Body Wash Formula

Below is an example of a basic body wash. It is a solution formulation and is made by simply combining the ingredients while mixing. The surfactant system is a combination of anionic surfactants (ALS and ALES) plus some nonionic and amphoteric surfactants to reduce irritation and improve the creaminess of the foam. Also, to offset some of the surfactant harshness a large level of Glycerin is included. Most of this will be washed away so it won't have much effect on the skin after feel. To improve that Polyquaternium-7 is included. It is a cationic polymer which will be left behind on the skin after rinsing.

Figure 17: Clear Body Wash

Formula Name

Basic Clear Cleansing Body Wash

Batch size

500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Diluent	Water	64.499	322.50
2	Conditioning Agent	Polyquaternium-10	0.400	2.00
3	Colorant	Color	0.001	0.01
4	Humectant	Glycerin	3.000	15.00
5	Adjustment agent	Tetrasodium EDTA	0.100	0.50
6	Primary surfactant	Ammonium Lauryl Sulfate (28%)	13.000	65.00
7	Primary surfactant	Ammonium Laureth Sulfate (25%)	15.000	75.00
8	Secondary surfactant	PEG 5 Cocamide	0.500	2.50
9	Foam stabilizier / Thickener	Cocoamidopropyl Betaine	2.000	10.00
10	pH Adjuster	Citric Acid	0.500	2.50
11	Preservative	DMDM Hydantoin	0.200	1.00
12	Fragrance	Fragrance (parfum)	0.800	4.00
		TOTAL	100.00	500.00

Procedure:

1. Begin mixing item #1 in container.
2. Add items #2 and #3. Begin warming to 45C.
3. Slowly add items #4-#10
4. Begin cooling batch to 25C
5. At 35C, add items #11 and #12
6. Mix for 10-15 minutes longer
7. Check pH and viscosity. Adjust as required.

Specifications

pH = 6.0-7.0
Viscosity = 4,000 - 7,000 cps

This formula is created to have good flash foaming and clean rinsing. It is clear and has a high level of fragrance so it can support a number of marketing positions, particularly ones that would be classified as “experiential.”

Moisturizing Body Wash Formula

Moisturizing body washes feature different surfactant systems such as the anionic Sodium Laureth Sulfate and Sodium Cocoylglycerylether Sulfonate as the primary surfactants plus Cocamidopropyl Betaine and Sodium Lauroyl Sarcosinate as the secondary surfactants. These latter surfactants will reduce the irritation potential of the first and boost foam. They will also provide a moisturizing, creamy feel during formula use. Higher levels of Glycerin can be used to also offset the surfactant harshness and to boost the moisturized feel of the product on the skin. For a good after feel a cationic polymer Polyquaternium-10 may be used since it won't be easily rinsed away. Glycol Stearate may be used for opacification and Xanthan Gum to help ensure it remains stable.

You can expect to get a less foam with this formula since it has a much higher level of conditioning ingredients. After using the product, the skin will feel more moisturized. You can experiment with substituting out different surfactant blends, conditioning ingredients and levels of conditioning.

Baby body wash formula

The previous formulations will be too harsh for some so it is good to have a mild formulation in your lineup. Baby or gentle formulas use milder detergents like Cocamidopropyl Betaine, PEG-80 Sorbitan Laurate and Sodium Trideth Sulfate. PEG-150 Distearate is also used to help improve foaming levels. These formulas avoid high levels of anionic surfactants and instead focuses on amphoterics and nonionics. Therefore, you can expect a lower level of foam production and a slightly moisturized feel after rinsing.

Remember formulations like this are a trade-off between foam/detergency and mildness. The milder you make something the less well it will foam or clean. Fortunately, body washes are not usually required to be ultra-cleansing.

Note *– we haven't specifically covered a Liquid Soap formulation because there really is no significant formulation difference between a liquid Soap formula and a body wash formula. You could simply use the basic body wash formula, put it in a liquid soap pump container and sell it as such.*

Bubble Bath formulation

A liquid bubble bath formula is not much different from a standard body wash however since the user will soak in the detergent for longer, lower levels of surfactants are used and it's better to use non-irritating ingredients. For example, Disodium Laureth Sulfosuccinate and Disodium Cocamido MIPA Sulfosuccinate are mild anionic surfactants which offset any irritation that goes along with Sodium Laureth Sulfate. Hydroxyethylcellulose may be included to both thicken, stabilize the foam and make it last longer. To ensure a long-lasting foam no additional conditioning ingredients are added since they can reduce foam levels and stability.

Facial wash

There are a number of different types of products that are marketed towards the care and cleansing of the face. Typically, these formulas are marketed as more mild than standard body washes or liquid soaps however if you review the products that are on the market, they use many of the same surfactants and technologies. For example, here is a popular facial cleanser marketed as a moisturizing facial wash.

Water (Aqua), Sodium Laureth Sulfate, Decyl Glucoside, Cocamidopropyl Betaine, PEG 55 Propylene Glycol Oleate, Propylene Glycol, Panthenol, Tocopheryl Acetate, Bisabolol, Anthemis Nobilis Flower Oil, Pelargonium Graveolens Oil, Glycol Distearate, Sodium Hydroxymethylglycinate, Polyquaternium 39, Laureth 10, Cocamide MEA, Sodium Chloride, PEG 7 Glyceryl Cocoate, Disodium EDTA, Dipropylene Glycol, Methylparaben

Notice the similarities? It contains SLES, Cocamidopropyl Betaine, and Decyl Glucoside. There are a number of conditioning ingredients such as Polyquaternium-39, PEG 7 Glyceryl Cocoate, and PEG 55 Propylene Glycol Oleate which we discussed before but these are standard ingredients included to both offset the harshness of the surfactants and to provide some nice skin after-feel.

This formula likely contains a lower level of surfactants than a standard body wash. Instead of the 10-15% detergent as in the previous formulas, this formula contains closer to 5-7% detergent.

Exfoliating facial wash

A popular type of facial wash is a scrubbing cleanser. This product is not expected to have a high level of foaming and can have a wide variety of thickness. Facial scrubs can be standard cleansing formulas with suspended polyethylene beads in them (these have come under fire recently for doing damage to the environment). They can also be thick paste like formulas with pumice or other scrubbing materials in them. Below is a scrubbing cleanser that is a thick paste and contains a variety of scrubbing materials.

Figure 18: Facial Scrub

Formula Name | **Batch size**

Facial scrub | 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Solvent	Water	81.980	409.90
2	Thickener	Carbomer	0.200	1.00
3	Co-emulsifier	Cetyl alcohol	1.000	5.00
4	Emulsifier	Glyceryl Stearate SE	1.000	5.00
5	Emollient	Isostearyl Isostearate	3.000	15.00
6	Humectant	Propylene Glycol	1.000	5.00
7	Scrubber	Juglans Regia (Walnut) Shell Powder	5.000	25.00
8	Surfactant	Sodium Laureth Sulfate	3.000	15.00
9	Surfactant	Cocoamidopropyl Betaine	3.000	15.00
10	Neutralizer	Triethanolamine	0.300	1.50
11	Fragrance	Fragrance (parfum)	0.500	2.50
12	Preservative	Methylisothiazolinone	0.200	0.10
		TOTAL	100.00	500.00

Procedure:

1. Add items #1 and #2. Mix until dissolved. Heat to 70C.
2. When batch is at 70C, add items #3-#7
3. After 10 mins add items #8 and #9 and begin cooling
4. At 45C add items #10-12

Specifications

pH = 5.5-6.0
Viscosity = 30,000 - 40,000 cps

The Carbomer is needed to keep the particles suspended and the Triethanolamine is there to neutralize the polymer. The primary exfoliant is the walnut shell powder although pumice could also be used. To aid in removal and cleansing there is a low level of surfactants. To help with the texture and feel of the product Isostearyl Isostearate is used plus Glyceryl Stearate.

It's worth noting that a product like this is thought to help with exfoliation but there is little published evidence that it does. There is even less evidence that products containing polyethylene beads help exfoliate any better than using a standard body wash and a wash cloth. However, consumers like these products and it makes them feel like they are doing more for their skin so that's why they sell so well. You need to be careful not to add too much scrubbing materials as it may be too harsh for people with sensitive skin.

Cleansing Cream formula

These are emulsions with a high oil phase which are applied to the face and then wiped off to remove.

These are often a water in oil formulation that contains a high level of both Mineral Oil and Petrolatum. Stearic acid and Glyceryl Stearate may be included to emulsify the system and keep it stable. Isopropyl Myristate will have an emollient effect but it will also help dissolve some of the residual oils on the face. The product is made in two phases with the water compatible ingredients mixed and heated in one vessel and the oil compatible ingredients in another. The two phases are blended when they reach the appropriate temperature and cooled after adequate mixing. The end product will be a thick, stable, white cream that is meant to be applied on dry or damp skin, wiped off with a cloth, then rinsed away.

Bar soaps

You could take an entire course on how to produce bar soaps but for our purposes we'll focus on some of the unique aspects of soap that makes it different from other cleansing formulas.

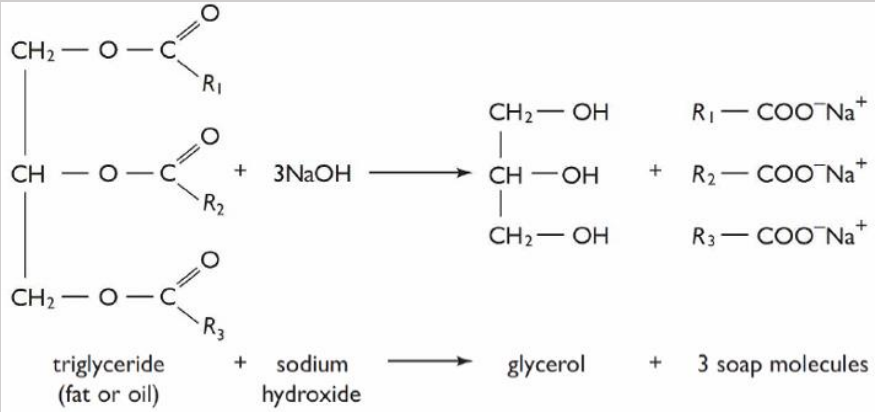
Soap is a solid cosmetic form made by reacting fats and oils with some type of alkali material. To this solid form is added ingredients that can make it more moisturizing, deodorant, or antibacterial. Soap molecules are much like synthetic detergents in that they have a fatty portion that is compatible with oil and a polar segment that is compatible with water. It is an anionic surfactant; specifically, Sodium Laurate, Sodium Palmitate, or Sodium Stearate depending on the starting oil.

The reaction that produces soap is called saponification. Essentially, a fatty acid (from a natural oil) is reacted with sodium hydroxide to form water, soap, and glycerin. For the alkaline material you could also use potassium hydroxide or triethanolamine (TEA). Potassium soaps are softer which might be desirable and TEA soaps are slightly less irritating.

But unlike synthetic detergents the head group on soap is a carboxylic acid group (COOH)-. Unfortunately, this group reacts readily with metal ions in the water to form insoluble, waxy salts. These will precipitate out of solution and can build up in a ring around your tub. Modern soap formulations are designed to avoid this problem by including synthetic detergents.

To make soap you follow some basic steps.

- Step 1 – Reduce the natural oil which is made up of triglycerides into its component fatty acids using high heat, pressure and water. This results in free fatty acids and glycerin
- Step 2 - Neutralize the fatty acids with alkali. This results in soap plus water.
- Step 3 – Vacuum dry the wet soap to 10% water to produce soap chips.



From there you can melt it, add fragrance, color, preservatives, and other ingredients then pour it into molds. In large-scale production facilities, the soap chips would be ground down to smaller pellets, blended with additional ingredients then pressed together to create bars.

Hand sanitizers

The basic technology of hand sanitizers is a simple alcohol solution thickened into a gel using an acrylic polymer. In the US, hand sanitizers are regulated as OTC drugs and have specific requirements for the levels of ingredients and the type of active ingredients that can be used.

Hand sanitizers are very simple gel formulas which include Ethyl Alcohol as the active ingredient. To dilute the product and incorporate conditioning ingredients there is a water and isopropyl alcohol blend. Carbomer is the thickening agent which is neutralized by Aminomethylpropanol (AMP). Glycerin, Propylene Glycol and Isopropyl Myristate are included to improve the hand feel after the alcohol evaporates.

Since this product has a high level of ethyl alcohol that could be flammable it is required to carry a warning label in most markets.

These formulas are interesting because many people claim that they are drying to skin. However, this has not been demonstrated under scientifically controlled conditions. It's possible that people see the product evaporating and that makes them think it is drying hands. But in reality, it is only the alcohol evaporating off. None of the oils that are naturally on consumer's hands are removed.

This is another important feature of these types of formulas. While they will kill microbes, they are generally not hand cleaners. If you have oils on your hands these products will not remove them as well as a detergent.

Moisturizers

We move now from skin cleansing to skin moisturizing. These products represent the second largest segment of the skincare market worldwide. They are a bit like hair conditioners in that they are designed to put back some of the characteristics that are removed through cleansing.

Why do consumers want these products?

Since this is such a huge market it is helpful to understand why consumers are buying these products. The reasons vary but the primary reason is because of dry skin. As we mentioned before some of the main characteristics of dry skin include:

- Dry feeling
- Scaly skin
- Itchiness
- Redness
- Skin Cracking

Typically, this problem is worse on the arms and legs. This is a result of there being a less dense amount of oil producing glands in this area.

In addition to dry skin, there are a few other reasons people use skin lotions. For example, aging skin and the things that go along with it such as wrinkles, age spots, cellulite and sagging skin also prompt people to use skin lotions. These may be preventative treatments or treatments that are supposed to repair the damage.

There are also a variety of medical conditions that prompt people to use skin creams. Conditions like Rosacea, Psoriasis, and Eczema are examples. Additionally, specialized skin creams and lotions are used for conditions like Acne, Sunburn, Rashes, Warts, and Athlete's Foot.

What causes skin dryness?

There are a wide range of things that can lead to skin dryness but the primary problem is that moisture is removed from the skin which leads to symptoms of dryness.

Water is removed from skin through a number of routes. First, it is helpful to know that your body is constantly losing moisture through your skin. Skin is permeable to water and as water flows around your body some of it moves into your skin. While in the epidermal layer this water helps make skin pliable and soft which feels good. But when the air is dry, the water molecules will naturally move to where there is less water. When it gets to the skin surface the molecules evaporate off into the atmosphere and you're left with dry skin. Incidentally, in more humid climates dry skin is rarely a problem because there is less of a tendency for water molecules to move out from your body to the atmosphere. As a result, in most areas skin lotion sales are always higher in the less humid winter months.

While there is a constant drive to remove moisture from your skin this isn't the only thing that leads to dry skin. Skin produces natural moisturizing factors that tend to be oily in nature and help hold in water to moisturize your skin. When washing skin, you remove this oily layer and accelerate the process by which water evaporates from your skin. Wash your skin too much and you'll be left with dry skin. For a similar reason being exposed to a high level of certain types of chemicals can also disrupt the skin natural moisturizing system and cause dryness.

Other causes of skin dryness include aging (your skin stops producing as much sebum as you get older), a reaction to some prescription drugs, and hormone level changes. Malnutrition also can result in dry skin.

There are varied causes of the other skin conditions that prompt people to use skin lotions. Sun exposure can damage the skin structure and cause wrinkles or sagging skin. UV light can also over stimulate the production of melanin in certain areas to cause age spots. And it can cause sunburns too.

Some of medical conditions for which people use skin lotions have known causes while others do not. Acne is thought to be a result of oil build-up plus an over active immune system. Warts and athletes' foot are caused by microorganisms that create a home on skin. The products created for these conditions are over-the-counter drugs which we will discuss later.

What ingredients are used to get skin moisturization?

Formulators have a number of options to relieve dry skin. These are the conditioning / moisturizing ingredients which we discussed in previous chapters. They include:

- Emollients – Which provide immediate relief to symptoms when applied
- Humectants – Which provide some immediate relief plus they help attract water to the skin
- Occlusive agents – Provide immediate and longer lasting skin moisturization

Emollients and occlusive agents are not compatible with water and are often sticky or unappealing as the pure raw material. Therefore, skin lotions are necessarily created in the form of emulsions. This allows you to use them to get the moisturizing benefits but also dilutes them so they feel aesthetically appealing when used.

Moisturizing product formats

The most common types of skin lotions are:

- Daily use – designed to be applied frequently
- Intensive use – designed for people with severely dry skin
- Protectants – designed to prevent future skin dryness
- Experiential – focused more on the fragrance and marketing story

Then there are lotions with specific benefits added such as:

- Firming lotions – to reduce the appearance of sagging and wrinkled skin
- Anti-aging lotions – to address problems of aging skin

- Facial moisturizers
- Eye cream – to reduce the appearance of bags or dark circles under the eyes
- Overnight lotions – to wear while you sleep

There are many words used to connote moisturizers but these are the basic formats for our purposes. All of these formulas follow a basic construction and include the following key formulation elements.

- Solvent – typically water
- Thickener
- Conditioning / Moisturizing ingredients
- Emulsifier
- Aesthetic ingredients – Fragrance & color
- Adjustment ingredients
- Stabilizing ingredients – preservatives, secondary emulsifiers
- Claims ingredients – extracts, naturals, etc.

Remember that emulsions are composed of a water phase, oil phase and an emulsifier which holds it all together.

Skin Moisturizing Formulations

Now we'll look at some standard skin lotion formulations. In this section we will give examples of the following types of lotions:

- Moisturizing (daily)
- Intensive cream
- Light Lotion (experiential)
- Cold Process lotion

The primary difference between skin lotions and creams is the amount of oil that is used. In general, a higher level of oil will produce a more effective moisturizing formula. However, there is a balance you must strike between a product that is effective against dry skin and one that feels too greasy. The more hydrophobic materials you incorporate into your formula, the greasier it will feel. While people want an effective product, they also want products to be quick absorbing.

Moisturizing (daily) formula

Below is a standard oil in water emulsion moisturizing cream. It is designed to provide immediate relief to dry skin while being non-greasy. The effect will not last as long as other formulations with higher oil levels but for an everyday lotion this will work well.

Figure 19: Moisturizing Cream

Formula Name | **Batch size**

Moisturizing Cream | Oil in Water | 500 grams

	Purpose	Ingredient	%	Amt. In Batch	Phase
1	Diluent	Water	79.650	398.25	w
2	Thickener	Carbomer (2%)	5.000	25.00	w
3	Humectant	Glycerin	3.000	15.00	w
4	Preservative	Methylparaben	0.100	0.50	w
5	Neutralizer	Triethanolamine	0.900	4.50	w
6	Coemulsifier	Cetyl Alcohol	2.000	10.00	o
7	Emulsifier	Stearic Acid	0.800	4.00	o
8	Emulsifier	Glyceryl Stearate SE	1.500	7.50	o
9	Preservative	Propylparaben	0.050	0.25	o
10	Occlusive	Isopropyl Myristate	1.500	7.50	o
11	Occlusive	Mineral oil	5.000	25.00	o
12	Fragrance	Fragrance	0.500	2.50	m
		TOTAL	100.00	500.00	

Procedure:

1. Begin mixing item #1 in container. Heat to 75C.
2. Add items #2-#5
3. Separately mix items #6-#11. Heat to 75C.
4. Slowly mix oil phase with water phase.
5. Mix for 30 mins and. Begin cooling tyo 25C.
6. At <40C add item #12.
7. Check pH and viscosity.

Specifications

pH = 5.0-5.5
Viscosity = 15,000 - 20,000 cps

The primary conditioning ingredients in this formula include Mineral Oil, Isopropyl Myristate, and Glycerin. If you wanted to substitute Mineral oil for something like Coconut Oil, Soybean Oil, or Olive Oil that should not be a problem. The formula will likely not be as effective but these things are often a matter of personal (or consumer) taste so you have to experiment. The formula uses Carbomer as the suspending agent and Cetyl and Stearyl Alcohols as opacifying agents, thickeners and moisturizing ingredients.

This formula is relatively easy to produce and is stable. Of course, product stability also depends on the quality of the starting raw materials. The formula will have a light feel and be non-greasy. You will also feel a cooling sensation when applied to skin because the external phase of the emulsion is water.

Intensive cream

Intensive creams are for consumers who have severely dry skin and are looking for something that is longer lasting. Ingredients are similar to daily moisturizers but you can experiment with modifying any number of the ingredients in the formula to produce a different feel, longer

lasting, or just to get a better marketing story. For example, you may want to try Shea Butter or Lanolin in the formula rather than Petrolatum.

Or, you could simply increase the level of Mineral Oil and Glycerin to provide additional moisturization. Petrolatum may be included as an occlusive agent to add longer lasting moisturization. To stabilize the extra oil, you'll want to increase the levels of Glyceryl Stearate.

This particular formula will feel greasier than the previous formula but it will be more effective on excessively dry skin and will last longer.

Sun protection products

In the US sunscreens are not technically classified as cosmetics since they "cure or prevent" a disease. They are over-the-counter drugs and are strictly regulated by the FDA. There is an FDA Monographs which lists exactly the active ingredients you can include and the claims you can make about the product. But before we get into the specific products and technologies, let's consider the problems that consumers are having which prompts them to purchase these products.

Consumer Problems

Too much exposure to UVB rays causes redness, tightness and even blistering if it is bad enough. Sunscreens can prevent this problem. They can also prevent other problems associated with too much sun exposure such as photosensitivity, wrinkles, freckles and skin cancer.

Sunscreen Technology

There are two ways that sunscreens can prevent the problems associated with too much sun exposure. They can reflect the UV rays away from the skin like a mirror or they can absorb the UV rays and convert the energy into heat which dissipates in the skin. To understand this a bit better we'll review the science of UV exposure.

UVB protection

For many years, most marketed sunscreens have provided protection against UVB radiation (290 — 320 nm), the rays that are responsible for sunburn. A sunscreen's sun protection factor (SPF) is the ratio of the minimum erythemal dose (MED) — the amount of UV radiation it takes to turn the skin slightly red — of skin protected with sunscreen to the MED of unprotected skin.

Higher SPFs mean greater protection against burning (and, presumably, skin cancer). This would be great but UVB is not the only type of damaging energy the sun delivers.

UVA protection

The sunscreen rules in the US are being changed and they will soon also be required to provide protection against UVA radiation (320 — 400 nm) to avoid having a warning label. UVA rays are the ones commonly known as the "tanning rays" as they stimulate the production of melanin and tanned skin. They do this because the longer wavelengths allow them to penetrate more deeply into the skin than UVB rays – through the outer layer, the epidermis, all the way to the dermis. The only visible short-term effect of UVA irradiance is skin tanning, and short wavelength UVA exposure actually has a beneficial effect in children, converting 7-dehydrocholesterol into vitamin D, thereby reducing the incidence of rickets, a bone-softening disease.

But as with UVB irradiation, long-term UVA exposure has detrimental effects. In the dermis, it degrades collagen, a critical structural component, resulting in sagging and wrinkling of skin. And UVA radiation contributes to the incidence of basal cell and squamous cell carcinomas, as well as malignant melanoma. Like UVB radiation, it decreases the number of Langerhans cells, which lowers resistance to infection.

Limiting the sun's effects

There are good reasons to limit sun tanning, and one way to do that is to apply a broad-spectrum sunscreen (one that significantly reduces the amount of both UVB and UVA rays that reach the skin). A sunscreen's UVA Protection Factor (PFA) is determined by measuring persistent pigment darkening (PPD), the appearance of brownish skin pigmentation within three hours of exposure to UVA. Products with higher PFA provide better resistance to persistent pigment darkening. Rather than using this in vivo measure of UVA protection, the FDA chose to use the critical wavelength — the wavelength at which the integral of spectral absorbance curve reaches 90 percent of the integral over the UV spectrum from 290 up to 400 nm.

Therefore, the higher the critical wavelength, the greater the level of UVA protection. The FDA's new Final Rule requires a critical wavelength of at least 370 nm (and an SPF of at least 15) for a sunscreen to be called "broad spectrum" and to avoid a "Sun Alert" warning that includes the

statement “This product has been shown only to help prevent sunburn, not skin cancer or early skin aging.”

Sunscreen technology

Sun protection includes not only classic “beach wear” sunscreens, but also the “daily wear” sun protection that is built into lip balms, color cosmetics and general skincare products. Consumer product forms from which sun protection may be delivered include creams, lotions, gels, sprays, and sticks. The most common form is creams but we will look at a variety of different forms.

The ingredients typically found in these formulas includes many ingredients we've seen before but also materials specifically included to make the sunscreen work better and last longer. A typical formula would have the following ingredients.

- Formula solvent: 50 — 80%
- Humectants: 0 — 4%
- Sunscreen Active Ingredients: 2 — 40%
- Fragrance: 0 — 0.5%
- Emulsifier: 0 — 10%
- Thickeners: 0 — 10%
- Water-Resistance Polymer: 0.8 — 2%
- Claims Ingredients: 0 — 0.5%
- Sunscreen Solvents: 0 — 10%
- Photostabilizers: 0 — 6%

FDA Sunscreen Monograph

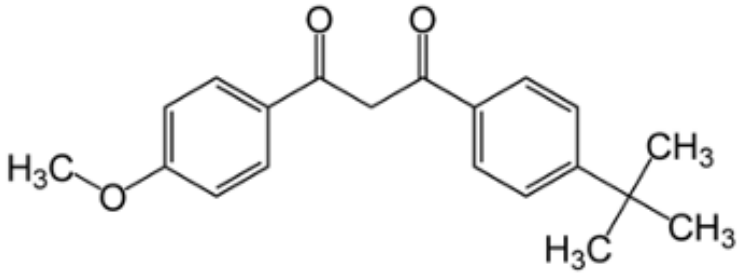
The sunscreen active ingredients are selected from the FDA monograph which are listed here. You must use authorized levels and combinations (e.g., Homosalate and Octisalate or Octinoxate with Avobenzone). Generally speaking, the higher the level of sun protection, the greater the quantity and number of sunscreen active ingredients that are needed. Zinc Oxide and Titanium Dioxide, work well for standard formulas but they are unsuitable in alcohol-based sprays because they are not soluble in alcohol, and their high densities would result in their rapid settling during storage.

Sunscreen ingredients

A water-resistant polymer, such as Acrylates/Octylacrylamide Copolymer, is required for two reasons. First, it helps retain the sunscreen on the skin and, second, it promotes uniform

deposition on the skin, preventing the sunscreen solution from pooling in crevices, which results in disproportionate protection of the crevices and a lower-than-expected level of sun protection. A uniform layer of sunscreen produces the maximum possible sun protection ratings.

When you increase the levels of solid organic sunscreen active ingredients (e.g., Avobenzone and Oxybenzone), the liquid sunscreen active ingredients may prove inadequate to keep them in solution, particularly at low temperature. If these solid sunscreen active ingredients crystallize on the skin after the alcohol has evaporated, a reduction in sun protection level and an increased potential for skin irritation will result. Consequently, addition of sunscreen solvents (e.g., Butyloctyl Salicylate, Dimethyl Capramide and/or Diisobutyl Adipate) may be required to ensure adequate solid organic sunscreen active ingredient solubility.



Avobenzone

Photostabilizers are particularly important for any sunscreen using Avobenzone as the active ingredient. This is because, although Avobenzone strongly absorbs UVA and UVB radiation, it is prone to degrading as a result, markedly reducing its UV absorbing capabilities, especially when Octinoxate, a strong UVB absorber, is also present. While solvent polarity optimization can be used to some effect (by using sunscreen solvents of higher than usual polarity, such as those listed in the previous paragraph), triplet state quenchers such as Polyester-8 and Undecylcrylene Dimethicone are frequently more effective. When Octinoxate and Avobenzone are used together, the photostabilizer of choice is singlet state quenching Ethylhexyl Methoxycrylene, which can remove the existed state energy from Avobenzone perhaps a thousand times faster than even triplet state quenchers, allowing substantial photostabilization of this notoriously photolabile combination.

Other standard ingredients like humectants are included to improve the feel of the product on skin. Fragrances are added to offset the base sunscreen odor. Then there are preservatives, adjustment ingredients, and of course claims ingredients to help with product positioning.

Sunscreen formats

Since sunscreens are regulated in both the ingredients they can use and the claims they make the varieties available are not as numerous as other types of cosmetics. As mentioned previously the forms of sunscreen products include creams, lotions, gels, sprays, and sticks. You can find an SPF range of anywhere from 4 – 100+ although the new regulations require a minimum of SPF 15 and a maximum of 50. Sunscreens also vary in how well they stay on the skin when exposed to water. There is water resistant and sweat resistant varieties.

Sunscreen Formulations

Water resistant emulsion sunscreen

This formula is a water-resistant sunscreen formula with an SPF of 18. It is a basic sunscreen cream formula that will feel lightweight while providing adequate protection. It includes Cyclomethicone which will aid in spreading and help provide a light feel. The formula is an oil in water emulsion with a high level of emulsifier (Octyl Palmitate), silicones, and emollients. To achieve the SPF rating the formula uses Titanium Dioxide and Zinc Oxide. The Ceresin wax helps to thicken the formula while also providing some film forming properties.

Figure 20: Water Resistant Sunscreen

Formula Name

Water resistant sunscreen SPF 30

Batch size

500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Diluent	Water	61.270	306.35
2	Thickener	Carbomer	0.130	0.65
3	Emulsification system	CRODASFOS CES	6.500	32.50
4	Sunscreen	Benzophenone-3	5.000	25.00
5	Sunscreen	Ethylhexyl (Octyl) Methoxycinnamate	7.500	37.50
6	Sunscreen	Ethylhexyl Salicylate	5.000	25.00
7	Sunscreen	Menthyl Anthranilate	5.000	25.00
8	Emulsifier	Octyl Stearate	5.000	25.00
9	Emollient	Jojoba oil	2.000	10.00
10	Adjusting agent	Sodium Hydroxide 10%	1.500	7.50
11	Antioxidant	BHT	0.100	0.50
12	Preservative	Germaben preservative (parabens)	1.000	5.00
		TOTAL	100.00	500.00

Procedure:

1. Begin mixing water and slowly add item #2. Mix until hydrated.
2. Begin heating. At 75C, add item #3.
3. When homogeneous, add items #4-9 each only after previous item is thoroughly mixed.
4. Mix at 80C for 20 minutes. Begin cooling.
5. At 60C add item #10
6. At 45C add items #11 and #12.
7. Cool to room temperature and check pH and viscosity.

Specifications

pH = 6.5-7.5
Viscosity = 8,000 - 10,000 cps

Sunscreen Gel formula

Not everyone likes a cream formula as they can be perceived as too thick so there are a number of sunscreen gel formulas on the market. The gel is produced the same way as other Carbomer based gels are made. You start with water and blend in the Carbomer. Then you add the other ingredients at a slightly elevated temperature and neutralize the polymer upon cooling.

Anti-aging products

One of the main drivers for consumers as they get older is to prevent the signs of aging which are particularly evident in your skin. Aging skin is a result your genetics, the amount of exposure to UV rays, chemical exposures and possibly related to diet. Products designed to be anti-aging promise to keep skin looking wrinkle free, reduce age spots, reduce sagging, and keep skin looking tight and flush. Unfortunately, there are very few products that actually have a measurable effect. However, as a cosmetic formulator you should be aware of the current science of some of these "cosmeceuticals" and what effect (if any) they might have when included in your skin formulas.

Anti-aging technology

As a formulator, you're going to hear of numerous ingredients that represent the best anti-aging technology. But how can you know whether they actually are worth including in your formulas or not?

Some years ago, the famous dermatologist and researcher Albert Kligman pondered this question and he came up with three questions about anti-aging ingredients that you should find answers to for assessing the usefulness of the ingredient.

The three "Kligman questions" to ask about any anti-aging ingredient are:

1. Based on the chemistry of the ingredient, is there any scientific mechanism that could explain why it would work?
2. Does it penetrate to the part of the skin where it needs to be in order to work?
3. Are there peer reviewed, double blind, placebo-controlled studies demonstrating the ingredient really works when applied to real people?

With these questions in mind let's review some common anti-aging ingredients for which there is proven data:

- Retinol
- Kinetin
- Niacinamide
- Soybean extract
- Green tea extracts

There are certainly other anti-aging ingredients like plant stem cells, hyaluronic acid, superoxide dismutase, and more but we'll restrict ourselves to the ingredients for which there is at least some published scientific research.

Retinol

Retinol is a vitamin A derivative which is claimed to smooth skin, unclog pores, lighten age spots and improve skin texture.

Is there a working mechanism? Yes. Retinol fades dark spots by reducing the contact time with pigment creating cells; reduces fine lines/wrinkles by stimulating synthesis of collagen and glycosaminoglycan. May also inhibit enzymes that breakdown collagen. Smooths skin by modulating genes involved in epidermal cell turn over.

Does it penetrate skin? Yes. Retinol has the right chemical structure to penetrate skin and this has been confirmed two ways: In vivo by measuring the level of a skin enzyme induced by presence of retinoic acid. (Also confirms metabolism to active version.) In vitro by measuring retinol metabolites on skin biopsies and cell cultures. There are some unresolved questions about how much bio-converts, however.

Topical application effectiveness? Yes. Retinoic Acid has undergone extensive clinical testing although fewer studies have been on the over-the-counter versions. Retinol has been shown to be effective vs placebo but not as effective when compared to retinal for wrinkle reduction.

So as far as anti-aging actives go, retinoic acid and other retinoids have some level of substantiation and are worth using.

Kinetin (N-furfuryladenine growth factor)

Kinetin is a plant growth hormone that supposedly promotes cell division and acts as an antioxidant. It nourishes skin cells to keep them healthy longer/ boosts skin's energy for increased radiance.

Mechanism of action - Testing on cultured human skin cells (lab testing aka in vitro testing) has shown kinetin can impact cell growth factors which cause age related changes, however the mechanism is not understood. Multiple studies have shown kinetin to be an effective antioxidant; it acts like Superoxide Dismutase, an natural free radical scavenger in skin. There are no reported mechanisms for how it helps wrinkles, age spots, or barrier properties.

Penetration – It's not known whether it can penetrate because no studies have been published on skin absorption of kinetin.

Effectiveness – The data on whether it is effective from a topical product is inconclusive. There's very limited research on topically applied kinetin. One study showed it can partially improve photo-damaged skin and increase skin's ability to retain moisture. Another showed that when combined with niacinamide it works synergistically to reduce hyper-pigmentation. It's questionable whether this ingredient is worth using.

Niacinamide

Niacinamide is a version of vitamin B3 (Niacin) which is thought to brighten the complexion, erase wrinkles, reduce transepidermal water loss, improve elasticity, and fight inflammation.

Mechanism - The mechanisms for ALL these proposed benefits are not fully understood. However, Niacinamide's ability to increase the antioxidant capacity of skin is well studied. It works by reducing (the opposite of oxidizing) NADP. Niacinamide may reduce water loss by increasing production of lipids and ceramides and by increasing cell turn over. It may reduce wrinkles by increasing collagen production. Finally, it lightens age spots by reducing the amount of pigment transferred from melanocytes to keratinocytes.

Penetration - Yes, penetration has been proven directly at sufficient levels in one study. In addition, several studies indirectly proved penetration by measuring increased NAD in cells after topical application (which increases due to the skin metabolizing vitamin B3.)

Effectiveness - Yes. Skin brightening has been proven in several half-face studies. Some of the studies also measured niacinamide's ability to reduce photo-aging. Based on the available evidence, Niacinamide is a worthwhile anti-aging ingredient to use.

Soybean extract

Soybean extracts consist of two active ingredient types (isoflavones and protease inhibitors) which neutralize free radicals, stimulate collagen production, increase skin moisture, and reduce hyperpigmentation.

Mechanism of action - For antioxidant: One study shows soy isoflavones work 4 ways to fight oxidation in skin. They MAY work as cell signaling molecule but no conclusive proof. Even though mechanisms are unconfirmed, evidence shows they are antioxidants. For collagen production/skin thickening: Only data on collagen is in vitro. Specific components of soy (genistein and daidzein) MAY have sufficient estrogenic activity to counter act thinning skin. For moisture increase: Appears to boost hyaluronic acid production but we don't know how. For depigmentation: appears to reduce pigment production and block transfer of pigment between cells.

Penetration - Not known for sure. There is little direct evidence the primary soy isoflavones penetrate skin. However, there is evidence that similar compounds can reach the epidermis and dermis. It is also known that penetration depends on the formula from which the isoflavone is delivered and its pH.

Effectiveness - Yes, partly. Preliminary in vivo tests confirm skin lightening benefits (undenatured only). However, anti-aging benefits related to antioxidant are unconfirmed in large scale tests on humans. This ingredient definitely has potential if the ingredient supplied is properly processed.

Green Tea

Green tea is an extract containing polyphenols which are known to be potent antioxidants that may protect against UV damage and help photo-aged skin.

Mechanism - There's no doubt that green tea extract is an effective antioxidant which works by quenching several reactive oxygen

species. It is also capable of limiting enzymes which cause collagen breakdown and to increase synthesis by fibroblasts, but again in in vitro testing.

Penetration - Probably not. The active component EGCG is water soluble so it is not well suited for skin penetration. Also, it's difficult to stabilize green tea extract long enough for it to penetrate skin. To make things worse there is little standardization about which components are contained in extracts and how much of them.

Effectiveness - Maybe, for UV prevention. At least two studies indicate at high concentrations of the active components can prevent the damaged caused by UV exposure. However, there is no comparison to indicate if it as good as conventional sunscreens. The only randomized, double-blind, controlled, clinical trial involving topical green tea extract showed no improvement in photo damaged skin from topical application of green tea extract after 8weeks. There were some trends in the data which indicate that a longer questing period might have yielded better results. But as of the now the ingredient remains unproven.

Since the active component in green tea extract is unstable and it's not easy to get the ingredient to where it needs to be work, it is doubtful that this is a worthwhile anti-aging ingredient.

Skin color

We'll turn our attention now to skin products designed to change the color of skin. Specifically, we'll look at skin lighteners and skin darkeners (self-tanning products). We'll begin with skin lightening. To understand skin lightening you first have to understand skin darkening. So let's talk about what causes hyperpigmentation.

Causes of hyperpigmentation

Hyperpigmentation (HP) means your skin produces too much melanin. Melanin is the pigment that colors your skin, hair and the iris of your eyes. It comes from the Greek term meaning "dark." Melanocytes are cells that actually create the pigment particles. Melanosomes are little vesicles, or capsules, that hold the melanin and carry them to various parts of the skin.

There are 2 basic causes of HP. Not surprisingly, both involve melanocytes which are the pigment producing cells in your skin.

1. If the melanocytes increase the amount of melanin they produce, this is called Melantotic HP.
2. If the melanocytes make the same amount of pigment but the NUMBER of melanocytes are increased, this is called Melanocytic HP. Both conditions lead to increased melanin.

HP is further classified by WHERE this excess pigment is - if it's in the outer layer it's called Epidermal HP In the middle it's called Dermal HP. There are many different types of HP including:

Freckles

Everyone is familiar with freckles but they are technically called (ephelides). These are melanotic which means your skin has a normal number of melanocytes but they produce more pigment. And the more you are exposed to the sun, the more freckles you'll get and the darker they'll become. Also, freckles are kind of the cute version of skin HP.

Age spots

Age spots are formally known as Solar Lentigines they are small brown patches on the skin. As the name implies, they are caused by sun exposure. These used to be called "liver spots" because they were associated with liver problems that occur as you age. Lentigines are melanocytic which means they are caused by the creation of MORE melanocytes. While these are triggered by sunlight, once they're formed, they usually stay stable in their color even if you get more sun exposure.

Post inflammatory HP (PIH)

This is skin darkening that occurs as a result of skin injury or trauma. As part of the healing process the melanocytes kick into high gear and produce more pigment. These spots may become darker if exposed to sunlight. Two examples: dark marks from acne. Have a zit which is infected, the trauma causes the "scar." Do you know another area of the body that's prone to PIH? Armpits! Shaving your pits causes some micro trauma which triggers melanin production. A lot of people complain about dark armpits. Even rubbing of clothing against armpits can cause this.

Melasma

Causes brown to gray-brown patches on the face. Most people get it on their cheeks, bridge of their nose, forehead, chin, and above their upper lip. It's caused by sun exposure but may be triggered by hormones so you can get it due to pregnancy or taking a contraceptive pill. In fact, it's so common that it's called "the mask of pregnancy."

Other conditions

Acral melanosis usually located on the acral areas of the fingers and toes. It is mostly seen in newborns or during the first years of life. Not very common. Tinea versicolor – typically occurs

on the chest and it is caused by yeast growing out of control. It is one of the most common skin diseases in tropical and subtropical areas of the world.

How to treat HP

For each of these conditions, treatment depends on WHERE the pigment is. For **Dermal HP** – there's not much you can do. Not much helps with this except for some lasers. You basically have to cover it up. For **Epidermal HP** – The good news is that most common types, like freckles and age spots, are epidermal so there are several treatment options.

- **Topical treatments** – creams and lotions
- **Abrasive methods** – chemical peels (combined with topical)
- **Surgical methods** - Dermabrasion, Cryosurgery, lasers

Active Ingredients

Hydroquinone (HQ), like many skin lightening ingredients, is a phenolic compound. That means it contains a 6-carbon ring with an OH group attached. This structure allows it to inhibit melanin synthesis by acting as a substrate for tyrosinase. Tyrosine, an amino acid, is acted upon by the enzyme tyrosinase to form melanin. These phenolic compounds "interrupts" this reaction by giving the tyrosine something else to attach to. That way the tyrosine never makes melanin particles.

Nothing works better than HQ – it's considered the gold standard for skin lightening. Now, that doesn't mean it works instantly – it can take several months of usage to reach maximum lightening efficacy.

What are the concerns about HQ?

There are some concerns about HQ, as you probably have heard. The reaction that's responsible for it working also causes damage to the melanosomes and melanocytes which is one of the reasons HQ raises safety concerns. And animal and cell culture studies have shown that HQ can cause DNA damage which has raised concerns about cancer. Another concern: In some people HQ causes a condition called Ochronosis which is a permanent bluish-black discoloration of the skin. This is rare and some dermatologists say it only occurs after prolonged use of high concentration hydroquinone.

HQ Safety

The studies that raised cancer concerns were based on oral or injected application and there have been no clinical studies or cases of skin cancer or any kind of internal malignancy related to topical HQ use. Therefore, the International Agency for Research on Cancer (IARC) considers hydroquinone as “not classifiable” as to its carcinogenicity in humans. As far as the Ochronosis is concerned, this is one of reasons that regulatory bodies in other countries have banned HQ for over-the-counter use. It has to be prescribed by a doctor which helps prevent the kind of long-term abuse that can lead to that permanent discoloration. In the US the FDA has even proposed banning over-the counter skin bleaching agents containing hydroquinone but as of right now it’s still available.

One important point – it’s a myth that’s HQ is “banned” in other countries; it’s really just restricted to prescription use. Europe and Asia currently allow hydroquinone at 2-5% concentration by prescription. The drug is valued worldwide but is regulated to protect against misuse and bad formulations.)

There are quite a few other ingredients which have skin lightening properties but nothing works as well as HQ (according to our research) and some of the ingredients that work pretty well have their own issues. While it’s generally recognized that HQ is the gold standard, there are not a lot of studies directly comparing all these other agents to each other so it’s difficult to rank them. But here is a quick rundown:

Mequinol

This is a derivative of HQ which According to Dr. Draelos, this outperforms OTC alternatives and is a prescription alternative to hydroquinone. Of course, as you’ll see with almost all these agents it has side effects as well which include erythema, burning, pruritus, desquamation, skin irritation.

Azelaic acid

It’s a dicarboxylic acid which occurs natural in wheat, rye, and barley. inhibits DNA synthesis in melanocytes and has a modest antityrosinase effect. According to some sources, it works better than 2% hydroquinone and about as good as 4%. The interesting thing is that its apparently safe to use during pregnancy. Side effects of itching, mild redness, scaling, and burning but overall, this is a good contender. It’s also prescription.

Kojic acid

This is a fungal metabolite and also a famous cop show from the 70s. It works by inhibiting the production of free tyrosinase. Could not find any data directly comparing it to other agents but one source considers it to be the most effective skin-lightening agent behind hydroquinone. We

do know that it can cause greater irritation, it is highly sensitizing and may be mutagenic. For this reason, it is banned in Japan, just like over-the-counter (OTC) hydroquinone.

Alpha arbutin

Arbutin is chemically related to hydroquinone and was originally obtained from the bearberry plant. Like HA it decreases melanin biosynthesis through the inhibition of tyrosinase activity. It also inhibits melanosome maturation and is less cytotoxic to melanocytes than hydroquinone. However, several studies have shown that arbutin is less effective than kojic acid for hyperpigmentation. Deoxyarbutin is a synthesized topical derivative. Studies have shown that it has an enhanced sustained improvement, general skin lightening and a safety profile comparable to hydroquinone.

Vitamin C

A study compared 5% ascorbic acid and 4% hydroquinone in 16 female patients with melasma and found 62.5% and 93% improvement respectively

Niacinamide

Works by interfering with the interaction between keratinocytes and melanocytes, thereby inhibiting melanogenesis. We've talked about this in our anti-aging show and it does work but not much data comparing it to other options.

Licorice extract

Improves hyperpigmentation by dispersing the melanin, inhibition of melanin biosynthesis and inhibition of cyclooxygenase activity thereby decreasing free radical production. Glabridin, a polyphenolic flavonoid is the main component of licorice extract. Studies have shown that glabridin prevents Ultraviolet B (UVB) induced pigmentation and exerts anti-inflammatory effects by inhibiting superoxide anion and cyclooxygenase activity. However, more studies are needed to prove its de-pigmenting action.

Retinoids

Works three ways: dispersion of keratinocyte pigment granules, interference with pigment transfer, and acceleration of epidermal turnover Something like 68% improvement (although you can't really compare numbers across studies.) Side effects: erythema, peeling, and possible post inflammatory hyper pigmentation. Can help with Melasma which is in the dermis. Works very slowly. Takes 24 weeks or more at 0.1% Need a prescription. One paper we found listed something links an additional 16 other ingredients that have some data but not enough to fully validate them.

Skin lightening vs brightening vs "imperfection correctors"

True skin lightening products are drugs and have to be labeled with very specific language. If you are selling an HQ product it has to be labeled as a "skin lightener" or a "skin bleach." If you are selling a cosmetic that uses any of the other ingredients mentioned you **CAN'T** call it a skin lightener or a bleach which is why you see products called "brighteners" or "imperfection correctors" and so forth. These are marketing terms that are NOT regulated by law which explains why they are so confusing.

Self-tanning products

Now we move away from lightening to skin darkening. Self-tanning products are designed to darken the color of skin without risking the negative health effects of UV exposure. Technology improvements in the purification of the main active ingredient and better awareness of the dangers of excessive UV exposure has led to an increase in the sales of these types of formulations.

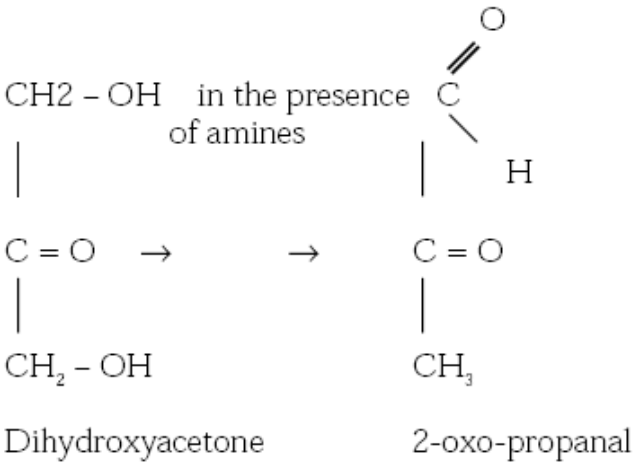
What self-tanning formulas do

Self-tanners are active cosmetic formulations that stain the outer layers of the skin and give it a more yellow/brown/orangish hue. They can be applied as a lotion or spritz and will slowly change skin color as the dye reacts with skin protein.

How do self-tanning products work

The primary active ingredient that makes self-tanners work is Dihydroxyacetone (DHA). This is a white, crystalline powder whose skin staining effect was first discovered in the 1950's.

DHA is a 3-carbon sugar that naturally forms a dimer. When heated in a solvent, the molecule can revert to a monomer which is more effective. The reaction that causes skin browning is the Maillard reaction in which the hydroxyl group on the DHA reacts with skin amino acids & proteins. It typically requires about an hour for the color change to be noticed. The color will wear off over time as the outer layers of the skin are naturally removed via exfoliation.



DHA

The delivery of DHA is typically in the form of an oil-in-water emulsion similar to a skin lotion. Since the palms will stain darkest, consumers have to wash it off or wear gloves for application to prevent unnatural looking browning on the hands. One of the biggest challenges with formulating a self-tanner is the odor of the DHA. You'll need a good fragrance to mask its slightly unpleasant smell.

It's worth noting that while there are some spray-on self-tanning products, this use has not been approved by the FDA.

Self-tanning formula

Below is an example of a self-tanning formula. It is a light lotion with a slightly acidic pH. This will help it to be easily spread and speed up the reaction of the DHA on the skin protein. In the oil phase there are some light emollients like Methyl Gluceth-20 Benzoate and Isopropyl Myristate. Cetyl Alcohol helps with thickening and emulsification but the primary emulsifier is PEG-40 Stearate. To get the self-tanning effect 5% of DHA is used. The product should also have a fragrance incorporated into it to cover the odor of the DHA.

Figure 21: Sunless Tanning Cream

Formula Name

Sunless Tanning Cream

Batch size

500 grams

	Purpose	Ingredient	%	Amt. In Batch	Phase
1	Solvent	Deionized water	72.300	361.50	a
2	Humectant	Glycerin	4.000	20.00	a
3	Active	DHA	5.000	25.00	a
4	Emulsifier	PEG-40 Stearate	8.000	40.00	a
5	Opacifier	Cetyl Alcohol	1.000	5.00	b
6	Emollient	Methyl Gluceth-20 Benzoate	6.000	30.00	b
7	Antioxidant	Tocopheryl Acetate	3.000	15.00	b
8	Preservative	DMDM Hydantoin	0.200	1.00	c
9	Fragrance	Fragrance	0.500	2.50	c
		TOTAL	100.00	500.00	

Procedure:

1. Begin mixing item #1 in container.
2. Add items #2 and #3 while heating to 70C.
3. In a separate container mix items #4-#7 while heating to 70C.
4. Blend phase A&B and mix for 20 minutes.
5. Begin cooling to 25C. At 40C add items #8 and #9. Check pH and viscosity.
6. At 45C add items #11 and #12.
7. Cool to room temperature and check pH and viscosity.

Specifications

pH = 5.0-5.5
Viscosity = 2,000 - 3,000 cps

Shaving

Shaving cream is put on the skin (primarily face and legs) to provide lubrication which helps prevent razor burn and discomfort during shaving. It comes in a wide variety of formats including creams, gels and most commonly foams.

What shaving creams do

Shaving creams are placed on the area of the skin in which shaving will take place. The cream is spread in a thick layer where it coats the hair that will be removed. One benefit of the foam is that it lets the consumer know where they still need to shave. The consumer (or operator) then takes a razor and slowly runs it through the shaving cream. This removes the cream and hair.

How shaving cream works

Shaving cream formulations have a number of different ways in which they help in the removal of unwanted hair. One function is to soften the hair via moisturization to make cutting easier. Wet hair is easier to cut. Another function is to act as a lubricant between the razor and the skin. This inhibits cuts and knicks but does not interfere with hair removal.

Shaving Cream ingredients

While shaving creams can take many forms from liquids, lotions, gels, and creams, they all contain ingredients that help soften the hair and lubricate the skin. The primary ingredients

include surfactants, solvents, humectants, conditioning agents, lubricants and aesthetic ingredients.

The most common surfactants used in shaving creams are soap-based surfactants such as Stearic Acid, Palmitic Acid, or other coconut fatty acids. These are neutralized with TEA, NaOH, or KOH. Additional foam stabilizing surfactants may also be used such as Sodium Lauryl Sulfate. The surfactant system typically makes up about 10% of the formulation.

To lubricate and moisturize the skin, humectants and other conditioning ingredients are included. These can be mineral oil, lanolin, glycerin, guar gums, or a variety of polyquaternium compounds. These ingredients make up around 5-10% of the formula.

The other ingredients include aesthetic materials like fragrance, preservatives, pH adjusting materials and sometimes colorants. For aerosol systems a propellant is needed. This can be something like Isobutane. In California, there is a 5% limit on the amount of VOC's that can be used in a shaving cream foam. Fortunately, the typical propellant level is between 3 and 4%.

Shaving Cream Formula

Below is a standard shaving cream formula which is designed to make the skin easier to shave and feel better after. It is a Stearic Acid based emulsion which includes Propylene Glycol for skin smoothness and Sodium Lauryl Sulfate for creating the foaming effect. Since Stearic Acid is a solid the formula has to be heated up to melt the ingredient for incorporation. The concentrate is put into an aerosol can and an isobutane / propane propellant blend is used. The opening of the container can be wide since the product does not have to come out in a spray so a lower amount of propellant is required.

Figure 22: Shaving Cream

Formula Name

Standard Shaving Cream

Batch size

500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Diluent	Deionized water	88.400	442.00
2	Emulsifier	Stearic Acid	5.000	25.00
3	pH Adjuster	Triethanolamine	2.000	10.00
4	Preservative	Diazolidinyl Urea	0.200	1.00
5	Foaming agent	Sodium Lauryl Sulfate	0.400	2.00
6	Lubrication	Propylene Glycol	0.500	2.50
7	Preservative	Methylparaben	0.200	1.00
8	Preservative	Propylparaben	0.100	0.50
9	Fragrance	Fragrance	0.200	1.00
10	Propellant	Isobutane (87%) and Propane (13%)	3.000	15.00
		TOTAL	100.00	500.00

Procedure:

1. Begin mixing item #1 in container and begin heating.
2. At 70C, add items #2-8. Mix for 20 minutes.
3. Cool bath. At 50C, add item #9.
4. Cool to room temperature while mixing.
5. Fill in container, add propellant and seal.

Chapter 7

COLOR COSMETICS & OTHER PERSONAL CARE PRODUCTS

Color Cosmetics & Other Personal Care Products

We are going to cover some sales information about the color cosmetics market and consumer problems. We're also going to go more in-depth with some of the ingredients and then go through the formulations. Finally, we'll cover some of the formulation topics that weren't covered in previous chapters, specifically facial masks and nail products.

Color cosmetics market

For the purpose of this book, it is helpful to define the scope of the products we are talking about. Color cosmetics are products primarily meant to temporarily impart some type of color to skin. There are permanent cosmetics which are basically tattoos but we will focus on the temporary type. These products are made and sold in a variety of forms including Powders, Emulsions, Sticks, and other solids like Compacts and Pencils. Since these are mostly solid products the packaging is a key part of the product experience because it can have a significant impact on how the product is applied.

The types of products that a color cosmetic chemist will be formulating include things like Foundation, Blush, Mascara, Eyeliner, Eye shadow, Lip sticks, Lip gloss, and Nail products. We'll go over how to formulate all of those.

The color cosmetics market can be broken down into 4 different categories including Eyes, Face, Lips, and Nail products. Of these, products for the eye comprise the largest market share representing about 38% of all sales. Facial products are next with 33% followed by Nails at 19% and Lip products at 10%. In the US, the total annual sales for the color cosmetic market was approximately $12.3 billion in 2021. The market experienced some shifts as a result of COVID-19 – both eye and nail cosmetics experienced a boost while lip products took a hit due to widespread mask wearing.

The US market is dominated by a few big companies such as L'Oréal, Coty, NYX, e.l.f and Revlon. KISS is also a big player in the nail category (known for artificial nails). Estee Lauder is a major player in the prestige sector (including brands like Bobbi Brown, MAC and Smashbox).

Facial color cosmetics

There are a variety of reasons people buy and use color cosmetics but the primary reason is to improve the way that they look and self-expression. More specifically color cosmetics are used

to cover blemishes and imperfections, enhance and highlight facial features, and for some people color cosmetics are used to make them look and feel younger.

While these products work well, there are some areas in which the products could be improved. For example, some consumers are concerned about cosmetics causing acne. There are also problems with irritation, difficulties in applying products, the length of time they last, and how easy the products can run or smear. It is in finding improvement to these areas (along with picking the right shade) that can make your formulations stand out.

The general technologies in color cosmetics that help consumers solve the problems for which they use these products are pigments and fillers. As far as other concerns that consumers are trying to solve some color cosmetics include things like UV protectants to prevent sun damage, antioxidants to reduce damage caused by free radicals, and oil absorbing powders that will help applied cosmetics last longer.

Color cosmetics ingredients

Now let's move into the specific ingredients used in color cosmetics. In chapter 3 we discussed raw materials and during that lesson we covered colorants. However, since colorants are such a huge part of formulating color cosmetics it makes sense to go over them in a bit more detail here.

Pigments are ingredients that provide color to the surface but can also provide shine, reduce shine, and cover the natural color of skin. There are two main types of coloring ingredients in cosmetics including mineral pigments and organic pigments. In the United States and around the world the types of colorants that are allowable in cosmetics are strictly regulated. This is because historically many of the colorants used in cosmetics were poisonous. For example, Mercuric Sulfide was used for its red color, Lead was used as white face paint, and Antimony compounds were also used. All of these compounds can make people sick with too much exposure. You'll find that whenever there is good evidence a compound is dangerous the government or even the cosmetic industry itself will remove it from use. Modern cosmetic companies are not in the business of poisoning their consumers.

Here is a list of common terms used in relation to cosmetic colorants:

- **Dyes** – These are color compounds that are fully soluble in the medium they are used. They are typically transparent. For example, water soluble dyes used in body wash.
- **Pigments** – These are color compounds that are insoluble in the medium in which they are used. They are typically opaque. This refers to compounds used in color cosmetics like foundation or eye shadow.
- **Lakes** – A pigment made by dissolving a water-soluble dye onto an insoluble, inorganic substance such as Aluminum Hydrate.
- **Toners** – A pigment made by precipitating a water-soluble dye as a metal salt.

- **True Pigments** – Water insoluble color compound. Chemical structure makes it insoluble.
- **Extender / Filler** – These are compounds that are used to dilute out a color and help improve coverage. Usually fillers are made from talc, clay, silica or zinc oxide.
- **Bleed** - This is a characteristic of a color additive which is slightly soluble in the vehicle used to deliver the color. If the bleed is too high it can lead to staining of skin or nails.
- **Masstone** – Refers to the ability of a color additive to improve the tone of a cosmetic product. Most relevant when making dark colored lipstick.
- **Shade** – This is the particular color that a color molecule can impart on a surface.
- **Strength** – This refers to the intensity of the color additive.
- **Transparency** - Property of color that allows light to be transmitted to the substrate (eg the skin). To get good coverage you do not want high transparency.

Pigments

There are both inorganic and organic pigments. When you hear marketing people talk about “mineral makeup” they are referring to products made using inorganic pigments. These are minerals actually mined in places around the world. They primarily include iron oxides of which there are three main types. Red, black and yellow iron oxide. There are also brown and burgundy iron oxides but they are used less often. Using iron oxides and a blend of Titanium Dioxide alone you should be able to match any human skin tone color. This is where the art of color cosmetic blending comes in. The only way you can get the exact right color is to experiment with your ratios of colors. Ideally, you'll have a consistent color source but this is not always the case.

When you purchase these ingredients, they do not go by their IUPAC chemical names but rather by the color which they can be used to produce. For example, some approved colors include materials like Blue #1, Green #3, Red #6, and Yellow #5. The numbers in this case are not indicative of anything about the molecule. They are likely just a reference to when the ingredient was registered.

Just to give you an idea about colorant comparisons, you get much more flexibility in formulating by using organic pigments. There is a much smaller range of colors that you can produce with inorganic pigments and they aren't as bright. However, they are more opaque which is good for covering natural skin colors and they are more resistant to solvents and oils so they tend to last longer on the skin. You have to decide which type (or a blend) of pigments you want to use for your formulations.

Pigment regulations

In the US, the FDA regulates all colorants that are used in food and cosmetics. The EU regulates colorants similarly and while there are minor differences the regulations for colorants mostly overlap. There are some compounds that do not require FDA certification before being used (see Resources).

But on the list of things that don't need pre-market approval to be used include compounds such as Aluminum powder, Caramel, Beta carotene, Henna, Mica, Titanium Dioxide, and Ultramarines.

But most colorants do require pre-market approval as can be seen at this link.

http://www.fda.gov/forindustry/coloradditives/coloradditiveinventories/ucm106626.htm

Most of the familiar pigments you see in cosmetics such as Red #33, Yellow #5, Blue #1, etc. Each of these compounds are inspected by the FDA after the supplier makes the product. Then when you get the raw material, you are only using certified colors. If you ever have to go through an FDA inspection, they will want to see proof that you are only using certified colors in your products.

Not only are the types of colorants you can use limited, you are also limited to where the colorants can be used. For example, there are some colorants that are allowed on the face but not in cosmetics around the eye area. Other cosmetic colorants are restricted to external surfaces so they are not allowed to be used on the lip area.

There are some specialty pigments that can be used in cosmetics. These are the pigments used to get effects like neon colors, glow-in-the-dark effects, or glitter. Pigments that change color due to pH, temperature or exposure to oxygen are ok for use in cosmetics. Composite pigments that consist of flecks of aluminum bonded to an etched plastic film are also allowed. There are only a limited number of neon or fluorescent colors that can be used such as Orange #5, 10 or 11 and Red 21, 22, 27 and 28. There are also some purple, yellow and blue fluorescent colors. The only approved glow-in-the-dark color is luminescent zinc sulfide. Tattoo pigments and liquid crystal pigments are not allowed in cosmetics.

Extenders and Fillers

These are ingredients used to extend the colors. You can think of them like solid solvents since they perform nearly the same function. The pigments themselves are powders and you only need a small amount to produce a significant effect. By using a filler, you make the pigments

easier to spread and allow the consumer to get a more consistent color. The type of filler that you use will depend on the specific type of product you are using.

One of the more common fillers is magnesium aluminum silicate also known as Talc. This is an ingredient obtained through mining processes around the world and is a major component of most face powders, eye shadows, blushes, and other powdered color cosmetics. It is used primarily because it has a nice white color, is easily spreadable, and has good slip. It also can absorb oil. Talc has come under fire in recent years due to fears about its safety however, an independent review of the scientific data on talc has demonstrated that there are no problems using it.

There are alternatives to talc and one of the main ones is Kaolin which is Aluminum Silicate. This is a white material that has good skin adhesion and provides a nice level of coverage. Coverage here just refers to its ability to cover up the underlying color of the skin. Compared to talc, kaolin provides more of a matte finish on the surface. It is also useful because it is compatible with both oil and water. This makes it useful for both powder and emulsion color products.

Some other fillers include Mica which is Potassium Aluminum Silicate. It provides a smooth feel and is more translucent than talc so you get less coverage and a different appearance on skin. Other specialty fillers that have been used as talc replacements include Bismuth Oxychloride and Boron Nitride. Both of these tend to be more expensive and less effective than talc however, they can work with some company's marketing positions.

There are some specialty secondary fillers that are added for specific purposes. For example, to get more coverage on the surface you can use Calcium Carbonate. It will also help to improve oil absorption so the color will last longer on the surface. For makeup lines in which you want to incorporate a fragrance Magnesium Carbonate can be used as a carrier. Zinc and Magnesium Stearate can also be used to improve adhesion to the skin if this is a problem in a formulation. Finally, there are a variety of polymers that have been introduced to improve the texture of makeup making it feel less grainy.

Miscellaneous ingredients

Beyond pigments and fillers there are a few other miscellaneous types of aesthetic improving ingredients used in color cosmetics. There are fragrances used to cover the natural earthy odor of the color ingredients.

There are also preservatives including parabens and imidazolidinyl urea. These are particularly important to use for any product that is going to be used around the eye area. You might wonder why a product that is mostly solid needs any preservative at all. In fact, it is difficult for microbes to grow in powdered cosmetics due to the low level of moisture. However, your skin is home to a vast array of bacteria and when a brush is used to spread the product on skin, it is dipped back into the product. This action transfers skin bacteria and spores to the surface of the powdered cosmetic. Without a suitable preservative you can spread harmful bacteria from different parts on your skin to your eyes which can lead to an infection.

Incidentally, this is the main reason that the advice to never share color cosmetics is given. Every consumer has their own unique microbial population on their skin and while it will not usually harm them to spread it around their body it may harm another person who has a different microbial ecosystem on their skin. When you share cosmetics, you share your microbes.

Other ingredients in color cosmetics will depend on the form of the product. Of course, if the product is an emulsion you are going to need things like emulsifiers, thickeners, and adjustment agents. We've spoken about these ingredients in previous chapters so we won't go into detail here.

Eye and face cosmetics formats and features

Color cosmetics come in a few different formulation forms including:

- Loose Powders
- Pressed Powders
- Emulsions
- Anhydrous formulas (pastes)
- Solids

Before we get into the specific formulas it is important to understand some of the basic concepts, terms, or jargon of creating color cosmetics. These include the terms:

- Coverage
- Finish
- Application
- Wear

The term Coverage refers to the ability of a product or ingredient to cover up the base skin color. This is important because when applying makeup, you want to have complete control over the ending colors. If parts of the skin's natural color are exposed that will make the color look blotchy and less appealing. To get coverage white pigments are used because they have

the best ability to scatter light. The amount of coverage that an ingredient can achieve is in some ways dependent on its refractive index. Refractive index is simply a measure of how light is affected when traveling through skin. Some will be absorbed and some will be reflected. The average refractive index of skin is approximately 1.62 which means you need to have a material that has at least this high of an RI to get coverage. Generally, a higher refractive index (RI) the more coverage you can get. Titanium Dioxide is an excellent material because it has an RI of 2.75. Of course, this can depend on the particle size and the smaller the particles the less effect it will have on coverage.

The next concept to understand is Finish. This refers to the appearance that the material creates on the surface when applied. Appearances can be either Matte, Moist, or Glossy. In general, to create a matte finish a powder formula is used. Emulsion products like BB creams or liquid foundations can give a moist or glossy appearance. The exact result will depend on the ingredients in the formula. Consumers who have oily skin generally look for matte finish products while people with dry skin seek moist finish products.

More than any other type of cosmetic, the method of application of color cosmetics is important. On some level it does not matter how you apply skin lotion (you just need to get an adequate level of coverage on skin). But for color cosmetics the way a product is applied can have a huge impact on the final appearance. That's why it is important for formulators to consider the application characteristics of their formulas.

When making a product the following parameters are important to control:

- **Spreadability** – This is the ability of the product to be spread across the surface. Easier spreadability is better.
- **Blendability** – This refers to the ability of the product to be blended with the natural color of skin and with other products used.
- **Play time** – This is the amount of time the color cosmetic remains workable. This needs to be long enough to allow the user to get the look they want but not too long as to let the color change after the look is achieved.
- **Adhesiveness** – This is the tendency for the product to stick to the skin. To get an unchanging look the product has to adhere to the skin but it can't stick so well that it won't be easily removed when desired.
- **Absorption** – Since skin naturally produces oil during the day the color cosmetic needs to be able to absorb a certain level of oil without a noticeable effect.

Finally, there is the concept of wear. This refers to the length of time that a color cosmetic lasts when applied. As indicated previously an oil absorbing filler added to the product will help prevent natural oil secretions from spoiling the applied look and thus increase wear time. Film

formers can also help provide a barrier that stops oil and holds the color on the skin longer. It should be noted that since oil production never stops and it tends to make the skin look shiny, products that have a matte finish will not wear or last as long as those with a glossy or shiny appearance.

Eye and face cosmetic formulations

Pressed Powder Foundation

Below is an example of a standard pressed powder foundation. The purpose of this product is to match the natural color of skin but provide an even tone and coverage of blemishes. There are two fillers included in the formula including Talc and a Mica / Methicone blend. The pigments include various iron oxides to match skin tone and Titanium Dioxide to provide coverage and skin tone matching. To improve skin adhesion powdered Zinc stearate is included and two types of powdered parabens are included for preservation. The only liquid in this formula Coco caprylate / caprate which is an emollient and binder.

Figure 23: Pressed Powder

Formula Name — **Batch size**

Pressed Powder Foundation — 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Filler	Talc	41.400	207.00
2	Filler	Mica & Methicone	30.000	150.00
3	Pigment	Titanium Dioxide	15.000	75.00
4	Pigment	Iron oxide, yellow	2.850	14.25
5	Pigment	Iron oxide, red	1.350	6.75
6	Pigment	Iron oxide, black	1.100	5.50
7	Skin adhesion	Zinc stearate	3.000	15.00
8	Preservative	Methylparaben	0.200	1.00
9	Preservative	Propylparaben	0.100	0.50
10	Binder	Coco caprylate/caprate	5.000	25.00
		TOTAL	100.00	500.00

Procedure:

1. Blend powders using mixer
2. Further disperse pigments using a hammer mill
3. Spray on item #10 with rapid agitation.

Note - for lab scale batches a kitchen blender can work

To make the formula the powders are mixed together and then the binder is sprayed on after adequate blending of the powders. On a production scale a hammer mill blender would be used. Essentially what this does is to crush the particles down to smaller sizes and in doing this it results in a much more even blend. Blending colors can be very difficult if you don't have specialized equipment. Some people have had success using high speed blenders. After the

powder is blended the binder is sprayed on slowly with mixing. This has to be done slowly or it can lead to unwanted clumping.

Foundation

The following formula we'll look at is an emulsion version of a foundation. This is an oil in water emulsion featuring Cetearyl Octanoate and Tridecyl Trimellitate as the oil phase. In the water phase there are two thickeners that are compatible with the pigments including Xanthan gum and Carboxymethylcellulose. The cellulose is used to offset the unpleasant feel that some people experience from xanthan gum. Incidentally, the Tridecyl Trimellitate will also have some thickening effect.

The emulsion is made through the neutralization of stearic acid with triethanolamine (TEA) and Glyceryl Stearate also helps stabilize it as a coemulsifier. The pigments are standard foundation pigments including iron oxides and titanium dioxide. Silica and Sericite are used to extend the pigments and the preservative system features both parabens and imidazolidinyl urea. Since this formula has a large portion of water a more robust preservative system is needed than for a powder formula.

Figure 24: Emulsion Based Foundation

Formula Name **Batch size**

Emulsion based foundation 500 grams

	Purpose	Ingredient	%	Amt. In Batch	Phase
1	Solvent	Water	58.800	294.00	A
2	Dispersant	Butylene Glycol	4.500	22.50	B
3	Filler	Magnesium aluminum silicate	0.500	2.50	B
4	Thickener	Sodium carboxymethylcellulose	0.300	1.50	B
5	Thickener	Xanthan gum	0.100	0.50	B
6	Neutralizer	Triethanolamine	1.000	5.00	C
7	Solubilizer	Polysorbate 20	0.250	1.25	C
8	Filler	Sericite	7.040	35.20	D
9	Pigment	Titanium dioxide	7.000	35.00	D
10	Pigment	Iron oxide, red	0.360	1.80	D
11	Pigment	Iron oxide, yellow	0.500	2.50	D
12	Pigment	Iron oxide, black	0.200	1.00	D
13	Filler	Silica	1.000	5.00	D
14	Emolllient	Cetearyl octanoate	10.000	50.00	E
15	Emulsifier	Stearic acid	2.500	12.50	E
16	Emulsifier	Glyceryl stearate	1.500	7.50	E
17	Emolllient	Tridecyl trimellitate	2.000	10.00	E
18	Dispersant	Butylene Glycol	2.000	10.00	F
19	Preservative	Methylparaben	0.200	1.00	F
20	Preservative	Propylparaben	0.150	0.75	F
21	Preservative	Imidazolidinyl urea	0.150	0.50	F
		TOTAL	100.00	500.00	

Procedure:

1. Pre-blend items in phase B and add to water when mixing (main batch).
2. Mix items in phase C and add to main batch
3. Pre-blend phase D items and add to main batch
4. Run mixture through a colloid mixer to fully blend colors
5. Separately mix items from phase E. Heat to 80C.
6. Heat first phase to 80C and blend with phase E.
7. Mix 15 minutes and cool. At 40C add remaining ingredients.

To make the formula you follow standard emulsion techniques in which you heat the oil and water phases separately. When the temperature reaches 75C (10 degrees C higher than the highest melting point ingredient) you blend the ingredients together and mix at high speed for at least 20 minutes. When making a foundation emulsion you go the extra step of pulverizing and pre-blending the pigments before dispersing them in the water phase.

Blush

A blush formula is not much different from a pressed powder foundation. The purpose of this product is to add a red or pinkish hue to the user's cheeks. The primary filler is Talc with Zinc Stearate added to improve surface adhesion. Titanium dioxide and red and black iron oxides are used to create the color. Additionally, Red number 6 dispersed in a barium lake is used to enhance the red shade. To off-set the odor of the pigments a fragrance can be incorporated. After the pigments are pulverized and mixed together with a hammer mill, the fragrance and a Pentaerythritol Tetraisostearate binder is sprayed onto the particles. Again, this has to be sprayed on lightly to prevent clumping.

Eye shadow

Eye shadows are products used to color the eyelid. Since it is a product that is used around the eye area the number of colorants is limited. Similar to other pressed powders, Zinc stearate is used for skin adherence. Parabens and imidazolidinyl urea make up the preservative system. Preservatives are extremely important for any product used around the eye area. Eye shadows use filler ingredients including talc, bismuth oxychloride, and fumed silica. Depending on the pigment, binders such as mineral oil and lanolin alcohol could be used.

Just like the previous powder formulas the ingredients are pulverized and blended together. Then they are pressed into an appropriate container.

Mascara

The primary purpose of this product is to highlight the area around the eyes by enhancing eye lashes. There are a number of different approaches to making mascara including liquids, creams, or cakes. In the below formula we'll look at the most common type, the emulsion cream mascara.

Figure 25: Mascara

Formula Name | **Batch size**

Emulsion based mascara | 500 grams

	Purpose	Ingredient	%	Amt. In Batch	Phase
1	Diluent	Petroleum distillate	20.900	104.50	A
2	Oil phase	Beeswax	18.000	90.00	A
3	Skin feel	PEG-6 sorbitan beeswax	6.000	30.00	A
4	Skin feel	Ozokerite	4.000	20.00	A
5	Skin feel	Carnuaba wax	6.000	30.00	A
6	Preservative	Propylparaben	0.100	0.50	A
7	Emulsifier	Glyceryl oleate & propylene glycol	1.500	7.50	A
8	Pigment	Iron oxides, various	15.000	75.00	B
9	Suspending agent	Petroleum distillate and Quaternium 18 hectorite & propylene carbonate	12.500	62.50	C
10	Diluent	Water	15.000	75.00	D
11	Preservative	Methylparaben	0.300	1.50	D
12	Preservative	Sodium borate	0.600	3.00	D
13	Preservative	Quaternium-15	0.100	0.50	D
		TOTAL	100.00	500.00	

Procedure:

1.Combine ingredients #1 - #7. Blend and heat to 80C.
2. Blend pulverized pigment (item #8) into Phase A.
3. Add item #9 and mix.
4. Pre-blend items #10-#13 and add to main batch. Mix for 20 minutes at 85C.
5. Cool to room temperature (RT)

This formula is a water in oil emulsion featuring a high level of an oil phase made up of petroleum distillates, beeswax, ozokerite, and carnauba wax. The waxes have the added benefit of thickening the eyelashes when applied. Glyceryl oleate is the emulsifier and the main pigments include a blend of black iron oxides. This formula also has standard preservatives that have been proven safe for the eye area.

The product is made like any other emulsion in which the oil and water phases are blended separately, heated and combined when they reach 80C. They are mixed together at a high temperature to create the emulsion then cooled down to finish the product.

Lip cosmetics

Lipstick is a solid delivery system of pigment for the lips. It is typically made of an oil and wax base combined with a high level of lip-approved colorant.

Marketing of lipsticks is primarily driven by different shades and wear (ie long-lasting). Claims are made about the vibrant color of the products and another important feature is how long lasting the color is. Some products also refer to how the product provides an additional benefit like moisturizing lips, providing UV protection or even having an anti-aging effect. Skincare benefits are becoming widespread in the color cosmetics category.

Related to lipsticks are lip gloss. This is a liquid version of lipstick which is applied with a wand applicator. The formula is very much like a mascara but with a different color and flavor.

Consumer lip problems

Consumers use lip products for many of the same reasons they use other cosmetic color products. They want to change the color of their lips and they want to enhance lips so they look larger (or smaller). Lip products are also used to help moisturize lips that feel dry and chapped.

The primary problems with the products that exist today are that they come off too easily and the colors do not last long enough. As a cosmetic formulator it will be your challenge to improve these shortcomings of current formulas.

To solve the problem of lip color dissatisfaction lipsticks are designed to cover the natural color and show a new color. This is done through the use of pigments. To solve the problem of lipstick not lasting long enough or getting rubbed off, formulators have developed transfer resistant formulas that adhere better to the skin after application.

Lipstick technology

Much of the technology used to create lip products has already been discussed in this chapter and in the previous chapter on raw materials. However, we will go into more details about a couple aspects of lipstick technology.

Lipsticks are made up of three main components.

- Pigments
- Solidifying Agents
- Oils

Pigments have already been covered so we won't discuss this further except to say that it is helpful to know that the pallet of colors available for lip products are even less than the facial area. Only colorants allowed for external use can be used in lip products.

Lipstick characteristics

When formulating a lipstick there are a number of factors you have to consider. It can be difficult to optimize your formulas because some of the characteristics directly conflict with each other. An ideal lipstick formula should have the following:

- Doesn't melt, sweat, drip
- Applies easily - feels nice
- Remains solid in the package
- Withstand purse forces - Which is where they are usually kept
- Suspend pigments evenly - to get a consistent color
- Stick to lips - so it is long lasting
- Won't bleed on lips - so the color continues to look good

The main feature of lipsticks after the color is the solidifying system. Solidifying agents are added to impart structure and rigidity to the formula. You can think of them like they are the frame of the structure. The two main types of solidifying agents include fats and waxes.

Lip product ingredients

Fats

Fats are found naturally and are typically composed of triesters of glycerin. If you look at the glycerin molecule, you'll see it is made up of three carbon atoms, each with an OH group and an H group attached. In fats, the OH groups are replaced with long fatty acids in the range of C8 to C18. The types of fats that are useful for making lip products are Cocoa butter, solidified vegetable oils, castor oil, coconut oil and palm kernel oil. It is also possible to create synthetic triglycerides that are easier to work with because they have a better odor and taste profile. Synthetic triglycerides include Glyceryl Tristearate and Glyceryl Tripalmitate.

Waxes

As a quick reminder, waxes are solid hydrocarbons derived from a variety of sources including animal, vegetable, mineral and synthetic. For creating lipsticks, typically a blend of various types of waxes are used. We'll revisit the most common ones used for lip products which include Beeswax, Carnauba wax and Candelilla wax.

Beeswax is produced by bees as the name implies. It is a blend of hydrocarbons that has a mild taste and can provide good rigidity. However, it typically is too hard to make a good lip product on its own so it is often blended with other waxes.

Candelilla and Carnauba wax are the most frequently used waxes for lipsticks. They have a great taste profile, good rigidity and excellent melting point range. They also satisfy marketer's desire for an all-natural ingredient.

A few synthetic waxes are used in lipstick production including materials like Ozokerite, Ceresin, and paraffin wax.

Oils

Unlike waxes, oils are liquid hydrocarbon materials. They cannot be used to create the product solid structure but they can be used to disperse pigments and fillers, stabilize lipsticks against separation, reduce melting point, enhance the slip properties during application, provide cushion and emollience during use. Oils make lipsticks feel better to apply.

The primary oil used in lipsticks is castor oil. It is composed primarily of glyceryl ricinoleate and is highly resistant to rancidity. Rancidity is the process by which a fatty oil is broken down by oxidation, and is a problem for many types of oils. When this happens, it makes the product taste and smell bad. Other oils that are used include Palm kernel oil, coconut oil and to a limited extent mineral oil. The reason mineral oil isn't used more frequently is because it is not as compatible with the pigments in lipsticks.

Other lipstick additives

In addition to waxes, pigments, and oils other ingredients are useful in a lipstick formula to improve the aesthetic characteristics and to stabilize the formula. These are the same kind of ingredients found in other cosmetic formulas such as antioxidants, sunscreens, flavors, fragrances and preservatives. Polymeric film formers can be added to make the product remain longer on the lips. It can also help resist wear.

Lip product formulas

We've discussed the basic lipstick ingredients and below we present a general formula. The solidifying agents make up anywhere from 10-15% of the whole formula. The oil phase makes up about 50-70% of the formula. The pigment makes up only 0.5 – 5% of the total. Then there are fillers and special additives (marketing ingredients) that make up the remaining percentages.

Figure 26: Lip product formula

Ingredient	% in batch
Solidifying Agents	10-15%
Oils	50 – 70%
Colorants	0.5 – 5%
Fillers	1 – 3%
Special additives	0.1 – 3%

Matte formula lipstick

The below formula is a matte lipstick. This product provides good color coverage but it is not shiny or glossy. The basic structure of the formula is a result of a blend of waxes including Carnauba, Candelilla, Ozokerite, and Microcrystalline wax. To create the proper melting point and improve the ease of spreadability Isostearyl stearoyl stearate and castor oil are used. These ingredients make up the highest portion of the formula. The pigment makes up just around 5% of the formula and uses two red colors and a blue to get the proper shade. Parabens are used as the preservatives.

Figure 27: Matte Lipstick

Formula Name			Batch size	
Matte lipstick formulation		Red color	500 grams	
	Purpose	**Ingredient**	**%**	**Amt. In Batch**
1	Solidifier	Carnuaba wax	1.800	9.00
2	Solidifier	Candelilla wax	7.000	35.00
3	Solidifier	Ozokerite	2.000	10.00
4	Solidifier	Microcrystalline wax	2.500	12.50
5	Diluent oil	Isostearyl stearoyl stearate	15.000	75.00
6	Diluent oil	Castor oil	8.600	43.00
7	Diluent oil	Trisostearyl trilineolate	1.000	5.00
8	Pigment dispersion	Isononyl isononanoate	10.000	50.00
9	Pigment dispersion	Octyldodecanol	7.000	35.00
10	Emolllient	Hydroxylated lanolin	1.000	5.00
11	Preservative	Methylparaben	0.200	1.00
12	Preservative	Propylparaben	0.100	0.50
13	Colorant	Red #7	3.800	19.00
14	Colorant	Red #6	2.400	12.00
15	Colorant	Blue #1	0.600	3.00
16	Diluent oil	Castol oil	31.000	155.00
17	Filler	Silica	1.000	5.00
18	Filler	Nylon-12	5.000	25.00
		TOTAL	100.00	500.00

Procedure:

1. Mix items #1-12 and heat to 80-85C
2. Mix for 15-20 minutes
3. Separately, grind colors, fillers and castor oil
4. Add color paste to rest of batch and mix for 20 minutes
5. When shade is correct pour into molds and allow to cool
6. Place mold into container

The formula is made by mixing the waxes and oils together while heating them to above the melting point (80C). The pigments are ground with the solid fillers then mixed with castor oil to make a consistent paste. This is then added to the oil phase and the whole thing is mixed. The liquid product is poured into molds and allowed to cool in the familiar bullet shape. The solid can then be put into packaging for finishing.

To get the matte look this formula has a relatively lower level of castor oil and no silicones. It also has a higher level of fillers than a glossy formula.

Glossy lipstick formula

A glossy formula uses a slightly higher level of wax but uses the same basic blend as the matte formula. To get the glossy look you'll use a higher level of castor oil and a less fillers which tend to reduce shine. The caprylic / capric triglyceride is a lighter oil which lessens the tack that might come from the extra castor oil. For increased shine Mica can also be used as a filler / shine enhancer in the formula. The formula is produced in the same manner as the matte lipstick formula.

Frost/shimmer lipstick formula

A frost/shimmer formula has a high level of pearlescent pigments and also a high level of castor oil and other oils to create more shine. You could include paraffin wax in addition to candelilla and carnauba wax. A number of different oils may be incorporated to disperse the colorants better and provide slip upon application. The pigments used are a blend of organic and inorganic compounds. Additionally, bismuth oxychloride is included for an extra shimmery appearance.

The procedure for making this lipstick formula is the same as the previous.

Transfer resistant lipstick

A transfer resistant formula is made up of 40 – 50% volatile cyclomethicone. The solid phase makes up 30% of the formula so it will feel harder when applied. This is necessary to accommodate the high level of cyclomethicone. The extra wax will also make the formula adhere to the lips better. To offset the drag of the extra solidifiers, lighter esters are incorporated into the formula. With a high level of mica, methicone, and bismuth oxychloride the formula will tend to be shinier.

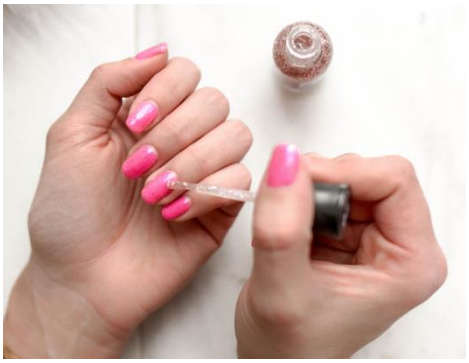
It's important to note that long-lasting formulas can dry out due to evaporation of the cyclomethicone so the package must be sealed to prevent this from happening.

You might be wondering why all lipsticks aren't made like this since it addresses one of the most significant problems of lipsticks. Unfortunately, it solves one problem (wear) but can possibly cause another – this formula can be drying due to the high level of solvent.

Natural Lipstick

The previous formulas all contain petroleum derived ingredients and thus wouldn't qualify by most natural standards. Natural formulas typically use vegetable derived carnauba wax, beeswax and shea butter to give it some bulk. High levels of castor oil and jojoba oil can improve the feel upon application. The colorants all come from inorganic pigments such as iron oxides. For the most part natural marketers are satisfied using colorants that are mined rather than organic ones that are synthetically produced. The downside to this is that there is a very limited pallet of colors available.

Nail Products



There are a wide variety of products for nails. The most common is nail polish but there are also finishing products like top coats, ridge fillers, nail fixers, and nail strengtheners. Nail polish removal products are available in order to remove enamel. And to treat the nail and cuticle area, there are cuticle oils and creams along with cuticle removers.

Consumer nail problems

There are numerous reasons people use nail products beyond the standard desire to change the color of their nails. Nails can naturally look unattractive so a polish improves the look. But nails can also be cracked, brittle, split, broken, have dry cuticles, or otherwise feel bad.

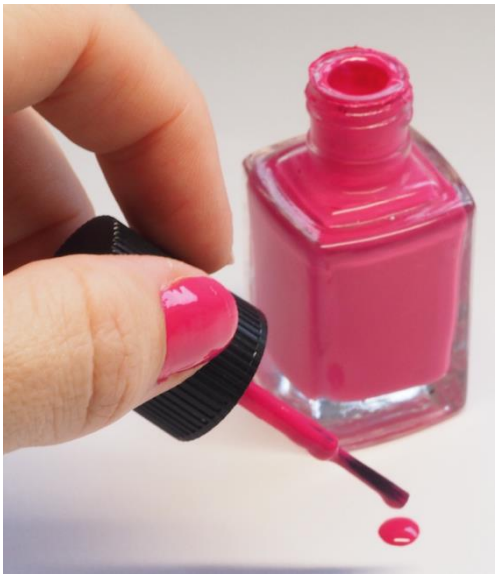
These problems can be caused due to a number of reasons but genetics, aging, skin diseases, lack of nutrition, and typical environmental exposures can all be factors.

Nail treatment technologies

While we can't completely solve the problems consumers have with nails there are a number of technologies that can help. To improve nail appearance, there are colorants and pigments plus film formers to keep colors on the nail and make them apply evenly. To improve the condition of nails, fillers can be applied in addition to cross-linking polymers that help to strengthen nails. To address the problem of poorly conditioned cuticles there are alkaline materials that can help in removal and conditioning ingredients that help reduce dryness.

Nail product ingredients

Nail products use many of the same ingredients that we've discussed thus far such as pigments, aesthetic additives, solvents and more. In this section we will cover just the topics that we haven't already gone into more detail already.



Film formers

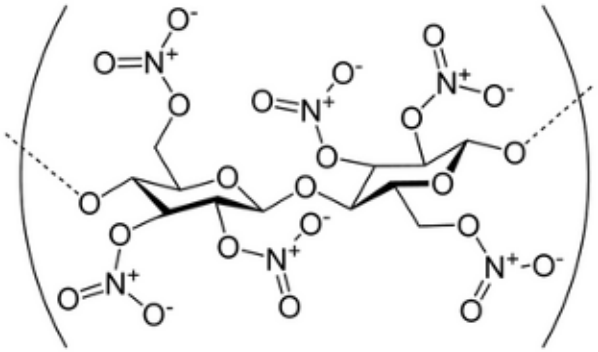
While pigments give nail polish its reason for being, film formers are crucial to the functioning of the product. They help spread the pigment in a thin, consistent layer and help it resist removal.

For a film former to work it needs to be non-sticky on the surface when dry, it needs to be flexible on the nail, and it should be glossy to enhance the color.

Early examples of film formers included styrax benzoin gum, shellac and certain waxes. These were all replaced when superior polymers were discovered and used.

Nitrocellulose

By far the most important film former used in nail products is nitrocellulose. This compound is an ester created by the reaction of cellulose with nitric acid. It is typically derived from wood or cotton. The reason it is so widely used is because it gives the best results. It dries quickly, is water resistant, is transparent, and provides a nice hard coating.



Nitrocellulose

Of course, the one significant downside is that it is an explosive ingredient and can be dangerous to work with. This is why there are so few companies that actually produce nail polish.

There are different grades of nitrocellulose that are allowable in cosmetics and the regulations differ around the world. Most regulations allow nitrocellulose grades with a maximum nitrogen

content of between 12.2 and 12.6%. The higher the nitrogen content of the polymer, the more dangerous.

Plasticizers

While a nitrocellulose film is hard and flexible, it can also be brittle. To solve this problem and make it even more flexible on the nail plasticizers are used.

To be effective a plasticizer has to be non-toxic, stay in the film, and it can't migrate throughout the product. In this way the overall film will be consistent throughout.

In the early days of nail polish formulation, ingredients like castor oil and camphor were used. These have since been replaced by superior synthetic ingredients.

The most effective nail polish plasticizers include Phthalates like dibutyl phthalate, Adipates like Dioctyl Adipate, Benzoates such as Sucrose benzoate and Citrates like Acetyl triethyl citrate. You have no doubt heard some of the bad press surrounding phthalates and the concern about safety. These concerns have largely been resolved but a number of nail product marketers still tout the fact that they are “phthalate free” as a product benefit.

Resins

To further enhance the film, resins are incorporated into formulas. Resins can speed drying time, improve gloss, and increase the adhesion of the film to the nail. Some natural resins that have been used include Shellac and Dammar. More commonly synthetic resins are used.

Perhaps the most effective is TSFR – Toluene-sulfonamide-formaldehyde resin - but the association with formaldehyde has significantly reduced its use. Other resins used are acrylic polymers, vinyl esters and polyesters.

Solvents

Unlike many cosmetics, nail products are primarily anhydrous and water is rarely used as a solvent. The solvents used are designed to be easily spread and dry quickly. They also need to provide an adequate viscosity which will be thin enough to spread but thick enough not to slide off the nail surface. The solvent also needs to evaporate quickly so the film can set up.

Since these compounds are volatile organic compounds the levels that can be used are regulated by some environmental regulatory agencies. The primary solvents used for nail formulations are alcohol, ketones, and esters like methyl acetate.

Nail product technology

Since there is such a wide range of nail products, there is also a wide range of ingredients used. Here is a list of the type of nail product and the ingredient or technology used:

- Cuticle Remover - Alkaline materials are used to help break the molecular bonds in the cuticle making it easier to remove.
- Cuticle softener - Quaternized compounds are used to help soften and moisturize the cuticle.
- Nail bleach - To make nails appear less yellow and more white chlorine bleaching agent are used.
- Nail Cream - To soften brittle nails a variety of humectants are applied.
- Nail Strengthener - Using a formaldehyde donor ingredient can help cross-link the nail proteins and strengthen them.
- Nail White - To whiten nails such as when someone gets a French manicure, titanium dioxide is the primary pigment.
- Nail menders - To repair nails acrylic polymers are used.
- Polish removers - To remove the nail polish film a solvent like acetone is the most effective technology.

Nail product formulas

As a reminder of the ingredients, you'll find in these formulas, here is a list of the most common. Resins - Sucrose acetate isobutyrate, Toluenesulfonamide-epoxy resin or Toluenesulfonamide-formaldehyde

- Film former – usually nitrocellulose
- Plasticizers – Camphor or Dibutyl Phthalate
- Solvents - Ethyl acetate, Butyl acetate, Isopropyl alcohol
- Pigment suspending agent - Stearalkonium hectocite

Base coat

The base coat is meant to be put on the nail first prior to applying nail polish. It is designed to prepare the nail surface to make the nail polish easier to apply. It has about 70% of solvents which include Butyl Acetate, Ethyl Acetate, Toluene, and Isopropyl Alcohol. The nitrocellulose film makes up about 4% of the formula (by activity). This formula also has a resin and a plasticizer making up 7 and 9% of the formula respectively. Stearalkonium hectocite is included to increase the viscosity of the formula and make it easier to apply.

The primary difference between this formula and a nail polish is that it doesn't contain a pigment. It's meant to leave a clear hard layer which you cover with a nail polish.

Nail polish

Below is a formula for a red nail polish. This is essentially the same formula as the base coat but pigments such as titanium dioxide, red number 7 and red number 34 are included. Notice the low level of pigment required as compared to the color powders and lipstick products we've previously discussed. Nail polish requires a lot less pigment to be effective.

Figure 28: Nail Polish

Formula Name — **Batch size**

Red nail polish — Red color — 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Solvent	Butyl acetate	27.000	135.00
2	Solvent	Ethyl acetate	23.200	116.00
3	Solvent	Toluene	12.000	60.00
4	Film former	Nitrocellulose (30% active IPA)	13.000	65.00
5	Resin	Tosylamide/formaldeyde resin	9.000	45.00
6	Plasticizer	Dibutyl Phthalate	7.000	35.00
7	Solvent	Ispropyl Alcohol	5.000	25.00
8	Thickener	Stearalkonium Hectorite	1.500	7.50
9	Plasticizer	Camphor	0.950	4.75
10	Antioxidant	Benzophenone-1	0.150	0.75
11	Color	Titanium dioxide	0.500	2.50
12	Color	Red # 7 (Ca Lake)	0.500	2.50
13	Color	Red #34 (ca Lake)	0.200	1.00
		TOTAL	100.00	500.00

Procedure:

1. Combine items #1-#3 in container
2. Dissolve items #4 and #5
3. Separately blend colors (#11-#13) in item #6 in a grinder mill
4. Add blend to main batch. Mix remaining ingredients.

While making this product the pigments are ground together and then mixed with the plasticizer before incorporating them into the formulation. This ensures an even distribution of the colorants.

Top coat

A top coat formula is an added layer which brings out the shine of the polish, speeds drying and makes the color last longer. Top coats usually feature an antioxidant to protect the color (benzophenone-1). Rather than use a formaldehyde resin, an acrylic polymer is used. This is

because the acrylic polymer binds better to the formaldehyde resin surface than it does to the nail.

Again, a top coat is very similar to a nail polish except it doesn't contain a pigment.

Nail polish remover

This is a simple solution formula which combines Water, Acetone and color and fragrance. The fragrance is used to cover the strong odor of acetone. The yellow coloring is used to offset the red color that is often used in nail polishes. Red is particularly adhesive to nails.

When the product is applied to the nitrocellulose film the acetone breaks the bonds holding the film together and allows for it to be easily wiped away with a cotton ball.

Nail Hardeners

Often consumers are concerned with having brittle nails so they use nail hardeners. In truth, a nail hardener is very much like a base coat in that it has a nitrocellulose film, solvents, and it lacks a pigment. To get the nail hardening effect a cross linker like formalin is used at a low level. This ingredient bonds with the nail protein and creates links between the keratin sheets which can make the nail harder. The nitrocellulose film helps to keep the reactive ingredients in place.

Cuticle remover

Finally, we have a cuticle remover. This is a very simple solution formula designed to soften the cuticle to make it easier to remove. The main ingredients are a humectant like glycerin and an alkaline material (trisodium phosphate). The alkaline breaks down the bonds between the cuticle proteins while the humectant moisturizes and softens. A device like a nail clipper or file is then used to remove the cuticle.

Figure 29: Cuticle Remover

Formula Name **Batch size**

Cuticle remover 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Solvent	Water	80.000	400.00
2	Humectant	Glycerin	12.000	60.00
3	Alkaline	Trisodium Phospate	8.000	40.00
		TOTAL	100.00	500.00

Procedure:

1. Combine ingredients in order while mixing until clear

Specialty facial products

Since we didn't get a chance to cover these products in the last chapter, we'll include two facial products that were specifically asked for by students – facial masks and chemical peels.

Facial masks

Facial masks have been used as cosmetic products since at least the time of the ancient Egyptians. They are valued for both the benefits they appear to provide and the experience of using them. Modern facial masks are used around the world and it is approximated to be a worldwide industry of about $6 billion in yearly sales. The top markets are Japan, France, and the US.

Facial masks are products that are meant to be applied to the face, left on for a specific amount of time, and rinsed away. Disposable sheet masks have also grown in popularity and are simply removed from the skin without the need for rinsing. Masks are designed to clean, moisturize, exfoliate and to provide a pleasant experience. On some level people buy and use these products just for the unique experience.

There are five types of facial masks which are classified by the base material. These include:

- Clay
- Wax
- Rubber
- Vinyl
- Hydrocolloid

To formulate a proper facial mask, you have to keep in mind some typical properties which consumers expect.

The formula should be a smooth paste or gel that does not have any particles that can feel harsh on the skin. This can be a challenge when formulating with natural materials. You have to ensure that your supply of base material is free from particulate matter.

The formula also has to avoid having an excessively earthy odor which can sometimes happen with clay materials. For this reason, formulators often add a fragrance to the facial mask.

A good facial mask also adheres to the skin surface but needs to be easily removed when the time comes. To ensure easier removal without irritation a nonionic surfactant will typically be

added to a mask. These surfactants are mild but can help break up the mask when rinse water is used.

Since facial masks are meant to create an experience often ingredients are included to provide a tightening sensation or a cooling effect. Alcohol is a good option to have a cooling and tightening effect without drying out the skin.

Finally, facial masks should include some type of moisturizing ingredient like a humectant to ensure that there is some skin moisturization happening.

Facial mask formats

There are five types of mask base ingredients. These include clay, wax, vinyl, rubber, and colloids. Clay masks are the most popular and work well for people who have normal, oily or acne prone skin. They can absorb the excess oil, act as astringents, and help remove dead skin cells. Typical clays include China clay, colloidal kaolin, smectite and bentonite.

Wax masks are more typically found at spas and salons and are made from paraffin wax and microcrystalline wax. These will have a more tightening effect than clay masks and also will be better at removing dead skin cells.

To create a peelable mask, vinyl masks are typically used. They are based on polyvinyl alcohol and create a continuous film on the skin surface when allowed to dry. This can then be pulled off (or peeled) after a certain amount of time. They work well for AHA masks because they can aid in the penetration of the ingredient.

Rubber masks using latex can be made but are not as popular as some people are allergic to the ingredient.

In addition to the base ingredients, other materials are added to enhance the performance of masks. These include humectants, moisturizers, emollients, exfoliants, and anti-acne compounds. Fragrances are also included to offset a potentially unpleasant odor.

Below is an example of a typical Clay mask. The formula is a thick paste designed to be applied to the face and let dry. It is based on bentonite clay with titanium dioxide included to make it

opaque. For a cooling effect alcohol is used. The polysorbate is included to both help solubilize the fragrance and to aid in removal of the product.

Figure 30: Clay Facial Mask

Formula Name **Batch size**

Clay mask 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Diluent	Water	65.300	326.50
2	Thickener	Hydroxypropyl Methylcellulose	1.000	5.00
3	Active	Bentonite Clay	17.000	85.00
4	Colorant	Titanium Dioxide	5.000	25.00
5	Special Effect	SD Alchohol	10.000	50.00
6	Solubilizer	Polysorbate 20	1.000	5.00
7	Preservative	Methylparaben	0.100	0.50
8	Preservative	Propylparaben	0.100	0.50
9	Fragrance	Fragrance (parfum)	0.500	2.50
		TOTAL	100.00	500.00

Procedure:

1. Mix item #2 into #1.
2. Heat to 80C and add item #3. Mix thoroughly for 30 minutes. Allow to hydrate overnight.
3. Add items #4-#9. Mix until homogenous.

Since clay takes a long time to absorb water this formula requires a significant amount of soaking time of the clay. More humectants or natural materials can be added to the formula as desired.

Acid peels

Acid peels are a special type of mask in that they include a high level of acid and are meant to treat skin. Dermatologists use acid peels because they can have an impressive effect. Acid peels help to remove skin imperfections, small wrinkles, and can leave a shiny glow.

An acid peel is a product that actually removes the top layer of skin. The acid is applied to skin via a mask type formula and left on the skin for a set amount of time depending on the acid concentration. The acid penetrates skin and breaks the bonds which hold cells in the epidermis together. This allows whole layers of skin to be easily removed by washing it with water or peeling it off. Immediately after treatment the skin will look red and may continue to peel for days afterwards.

These masks remove the outer skin layer prompting more skin cell production in the dermis. These newer cells will naturally make the skin look smoother and “dewier”.

The most common acids used in acid peels are alpha hydroxy acids. Glycolic acid is the most common however Citric acid and Lactic acid can also have a beneficial effect.

Below is a typical AHA chemical peel. It is based on a water and PVA mixture. A couple of surfactants are included to aid in removal. Humectants are also used to help moisturize the skin and give more flexibility to the film created by the PVA. Alcohol is also used to get a cooling effect during use.

Figure 31: Acid Facial Mask

Formula Name **Batch size**

AHA Chemical Peel 500 grams

	Purpose	Ingredient	%	Amt. In Batch
1	Solvent	Water	48.450	242.25
2	Adjustment agent	Disodium EDTA	0.050	0.25
3	Thickener	Polyvinyl Alcohol	7.500	37.50
4	Emulsifier	Ceteareth-20	0.500	2.50
5	Solubilizer	Polysorbate 20	0.500	2.50
6	Humectant	Butylene glycol	2.000	10.00
7	Humectant	Glycerin	2.000	10.00
8	Moisturizer	PEG-8 Dimethicone	1.500	7.50
9	Active	Glycolic Acid (70%)	10.000	50.00
10	Solvent	Water	15.000	75.00
11	Neutralizing agent	TEA	2.000	10.00
12	Preservative	Glycerin	0.500	2.50
13	Solvent	SD Alcohol	10.000	50.00
		TOTAL	100.00	500.00

Procedure:

1. Add items #1 and #2. Mix until dissovled. Heat to 85C.
2. Add item #3 and mix for 30 minutes. Begin cooling.
3. At 75C add items #4 and #5.
4. At 60C add items #6-#9.
5. Premix items #9 - #11. Add to batch when temp is 40C.
6. At 35C add items #12 and #13.

The formula is made by mixing the PVA in hot water and maintaining it there for 30 minutes. The temperature is then steadily cooled and things like the emulsifiers, moisturizing ingredients, active acid, fragrance and preservatives are added. The end formula will be a viscous paste/cream which can be applied to skin during use. It is left on the skin for a set amount of time then can be peeled off. This particular formula uses a 10% glycolic acid solution and will be relatively strong. You can vary the level of acid based on the skin sensitivities of the person using the product.

Chapter 8

COSMETIC PRODUCT PROTOTYPING & PRODUCTION

Cosmetic Product Prototyping and Production

We are now going to go through some practical lab tips to show you how cosmetic chemists identify new formulations and create new prototypes to test. You'll also get a number of pointers about scaling up your batches from lab sized to production sized batches. We'll also cover how to save batches when they don't meet the specifications on the first try out.

We'll be covering three main topics which will further expand your formulating skills and also help you turn your prototypes into large scale formulations. The topics include:

- Prototyping
- Formula Scale up
- Packaging

In each section we will go over a variety of practical tips that nearly every formulator will find useful at some point in their career. Some of them will not be applicable to all jobs as large companies often have whole departments dedicated to things like packaging selection. However, you never know where you will end up in your formulation career and it is helpful to know as much about the product development process as you can.

Development – Creating the Product

If you work for a company, before you even begin creating formulas your marketing department has done work to develop a product concept that appeals to consumers. Ideally, they will put together a Product Information Sheet which describes everything about the product.

The product information sheet is an important guide for formulation work. It outlines the key product benefits that need to be delivered from the formula. It also gives you guidance on the performance characteristics, the aesthetic properties and a number of other important characteristics you need to achieve with your prototypes.

Even if you are working as a solo entrepreneur, you should collect a variety of information to give your formulation efforts direction.

Creating a product information sheet

Some of the crucial pieces of information in the product information sheet include:

- Type of product
- Comparable standards (benchmark)
- Aesthetic
- Performance targets
- Total formula cost
- Claims
- Packaging
- Key raw materials

The type of product should be obvious but when filling out a product information sheet, you'll need to list it. That way everyone is on the same page as to what you are developing. This will also give you a good idea of the type of starting formulas you will begin with.

Another important factor is identifying a benchmark product or comparable standard. We will discuss this in more detail, but you should realize that there rarely such a thing as a completely new product. There is almost always something on the market that is somewhat similar to the new product idea. It doesn't have to be exactly the same, in fact it shouldn't be, however, you should be able to identify something that is close. This gives you some characteristics to target when making your prototypes.

The next thing you should list are product aesthetics. This includes product color, the fragrance, the thickness or rheology, the opacity, the pH, the feel, the overall appearance and any other characteristics that are indicative of your final formula. Listing aesthetics makes sure all parties are on board as to what the final product will look like. You do not want to surprise your product development partners by creating a product that looks drastically different than they had first imagined.

Performance targets are a list of characteristics that your prototype must achieve to decide whether it is a success or not. These can be performance in lab tests like foam tests, skin moisturization tests, combing tests, or others. It can also be a performance target for how well it does in human panel testing, salon testing, or even consumer home use testing. You should list exactly the minimum scores that are expected in specific tests.

One of the key details you need the formula cost. You should understand the expected profit margin and how much money the formulation will cost to produce. You don’t want to be surprised at the end of your process when you have a formula that meets all the aesthetic and performance hurdles only to cost two or three times as much as anyone expected. Before you start your project, **get a definitive product cost**.

Product claims are another factor to list on your product information sheet. These are statements that your or your company will want to make about your product in advertising or

on the bottle. If you haven't thought of these claims before you start formulating you may have to go back and modify things to meet the product expectations.

Related to product claims are a list of featured raw materials. If you have some formulation requirements like the addition of a feature ingredient or the avoidance of other ingredients (like formaldehyde preservatives), you will want to list them on this sheet. This helps give you some guidelines as to what ingredients you can choose or have access to. Having it listed prior to doing any formulation work will make your prototyping more efficient.

Finally, you should also have a good description of the type of packaging that is going to be used in the creation of this project. Often the packaging material can interact with cosmetic raw materials and lead to an unstable or strange smelling formula – or the formula might be too thick for the packaging. I remember once testing a conditioner formula that was in a square bottle. The formula was so thick I wasn't able to get it out of the packaging. If the developer would have picked the packaging before developing the product, this would not have been a problem

Benchmarking

There are virtually no completely new products so you are going to want to start off with a competitive product that will serve as the benchmark for your project. The objective of benchmarking is to find a commercial product that approximates the characteristics of your final product.

The way that you do this is you list the characteristics of your desired formula, look for market leaders who would be your competitor who has many of those characteristics already, get samples and start making prototypes that match the key characteristics.

There are a number of factors to consider when picking a benchmark product. These include:

- Performance characteristics – how it performs in your tests
- Product Aesthetics – what the product looks and smells like
- Patents – benchmarks that have patents are easier to emulate
- Consumer reaction – benchmarks that are loved by consumers are good choices
- Manufacturing ability – you need to pick a benchmark that your company could make
- Market leader – you should always benchmark against a market leader

Since you should always benchmark yourself against a market leader, it is helpful for you to find out who that is. In fact, whenever you are developing a product, you should know who the

market leader is in your specific category. The market leader changes based on where you are located in the world and who your target niche is but you can use some online sources to find the appropriate data. If you work for a company they will often have subscriptions to services like IRI (Information Resources Incorporated) or Mintel which publish paid reports on exactly which brands and SKU (stock keeping unit) sell the most in your region.

If you don't have a budget for this information, you can find some market data by using search engines like Google or Bing. You can also find market data in industry magazines like GCI, Happi, or Cosmetics & Toiletries. Beauty blogs or Women's magazine websites are another good source for finding out what is the market leading product in your particular market. In reality, the market leader is often something produced by large companies like P&G, Unilever or L'Oréal. It is always wise to compare yourself to these brands.

Once you've identified your product benchmark (and you can have more than one) you need to collect data on the product and outline the various characteristics that you will try to match. Some of the key information that you need will include LOI (list of ingredients), the claims, the type of packaging, and you'll also want to get a sample of the product. Use the product to get a sense of how it performs.

Finding starting formulas

After you have identified your benchmark and created your product information sheet, you'll need to find starting formulations.

It's pretty rare that a chemist knows exactly the type of ingredients they need to make their first formula. What usually happens is that you find a starting formula from which you begin your development work. There are a number of places that you can get starting formulations including:

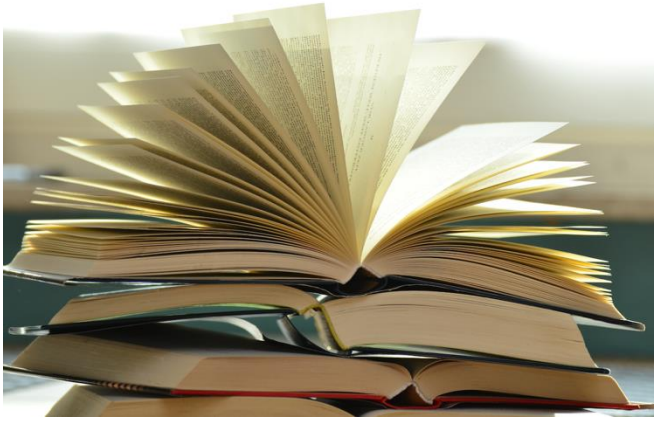
- Chemical suppliers
- Trade journals
- Patents
- Books
- Ingredient lists – LOIs

Chemical suppliers produce formularies which give you starting formulas for a number of different types of products. This is an excellent source to start because the formulas are usually put together by a cosmetic chemist who either works for the company or is hired by them on a consultant standpoint. The one problem with these formulations is that they are not optimized for performance. Instead, they usually maximize the amount of ingredients that are sold by the

supplier. Remember the reason they put the work into creating these formulas is to sell you the maximum amount of their own raw materials.

Trade journals are another source of starting formulas. Again, these are usually compilations of formulations from different suppliers so they are a lot like the ones you'll find from suppliers. However, you'll have more options of different chemicals to use so you get a wider variety of formulation.

There are a number of excellent books that list cosmetic starting formulas. One of my favorite series is the Bennet's Chemical Formulary series. This has been produced since 1936 and has formulations for all sorts of different products. Not only do they have cosmetic formulas but they also have formulations for other consumer products like household cleaning products, invisible ink, automotive products, paint & coasting, laundry detergent, etc. It's really interesting to see the differences and similarities between the formulations. Below are more excellent reference books:



- Beginning Cosmetic Chemistry 3rd Edition
- Chemistry and Manufacture of Cosmetics: Science 4th edition
- Harry's Cosmeticology 8th Edition
- Handbook of Cosmetic Science and Technology, Third Edition
- A Short Textbook of Cosmetology
- Surfactants in Personal Care Products and Decorative Cosmetics, 3rd Edition
- Chemical and Physical Behavior of Human Hair

Another source for finding starting formulas is to look at competitive product LOIs. You can your knowledge of raw materials and the knowledge of product ingredient listing rules to come up with a good starting formula.

In addition to these sources, you can also find starting formulas from patents. Patents are a great source for finding information about cosmetic products including formulations and ideas for claims and performance testing. They can also provide ideas of how to get around the patent so you are not illegally infringing.

To get this information from a patent it is helpful to understand the various sections of a patent. But first you need to be able to find patents to review. Fortunately, Google makes finding patents from around the world easy. Just go to Google Patents and do your search of a key word. There are other sources for patents online but Google does the best job of indexing them.

The Title lists what the patent is about. When you do a search if the keyword is listed in the title, it will be shown and can help you decide whether the patent is applicable. The Abstract gives a brief summary of everything that is in the patent. Usually, you can decide whether to read the patent further just by reviewing the title and abstract. If after reading you don't think you will get the information you want, don't bother reading further.

If you want to get a good idea of the historical development of the product which the patent discusses, then the Background section is a great place to start. You will see listed here much of the work that came before this patent and how it is relevant to someone skilled in the art. This area also gives you some great leads on other patents that you might want to review.

The summary / description gives you some more information about the background development of the specific patent in question. This isn't critical information but if you are interested in learning more this section is worth reading...eventually.

The most relevant section of the patent is the Claims section. Here is where the authors list exactly what they are claiming to have patented. They will include crucial raw material identification and the percentages used. Additionally, in this section is where you will find

example formulas. If you are looking for starting formulas here is where you look. These formulas do not have to be exactly what is being sold on the market but they are pretty close.

The example section is also where you will find an explanation of the support testing that was done for the patent. You'll find in the cosmetic industry there are not a lot of published procedures and tests. Most companies end up reinventing the wheel whenever they want to support some new claim. But you can get a good idea of how to run certain support tests in this example section. It is incredibly valuable.

It's important that if you are going to market a product that started from a patent example that you do not infringe. If you work at a large corporation, they will have a legal department that can help you avoid infringing but if you are a small company or individual there are a couple of things you can do to avoid infringing. These will not guarantee it but they will keep you under the radar and make getting sued a low probability event. As an entrepreneur that's usually the best you can hope for.

To avoid patent infringement, it's pretty simple. Don't use exactly the same ingredients mentioned in the claims section. If the basis of the patent is 3 ingredients you can use 2 of the same ingredients, you just can't use all 3. For cosmetic formulation patents there are typically 3 or more ingredients that make up the patent.

Even if you do use all the same ingredients the other option you have is to just use them at percentages that are outside the stated patent range. Patents always list a range of % use so as long as your formulation is outside that range of use you are not infringing.

Note that companies are generally required to police their own patents. If you are a small company, it is unlikely that you will be contacted by a patent holder unless your formula uses exactly the same ingredients. To be safe just don't use exactly the same ingredients as some big corporation in your formulas that are based on a patent.

Just a final word about starting formulas. Make sure you are working within the constraints of your project. There are three things in particular for which you should be aware. These include the cost of the starting formula (don't start with something that is too expensive for your project), the manufacturability of the formula (your company has to be able to make it outside of the lab) and the regulatory implications.

Prototyping

In chapter 2, we covered some aspects of creating prototypes including finding starting formulas and benchmarking. Now we are going to introduce some new ideas that will be helpful during your prototyping efforts.

Prototyping Goals

A common reason for prototyping is to create the best performing product. Every formulator should have an idea of the type of formula they want to produce and should strive to create it during any project. However, to achieve a prototype that is world class in performance you have to make a number of prototypes, conduct testing, make adjustments and repeat...a lot of times.

In 2005, I was working on a new shampoo formulation which resulted in more than 500 prototypes. It was a huge amount of work. But the end result was a formulation that performed better in home use tests than our chosen benchmark. The formula is still on the market today nearly 20 years later.

While making excellent performing formulas is a laudable goal it is only one of the reasons for prototyping. Much of your time as a cosmetic formulator will be spent trying to reduce the cost of formulas that your company currently produces. This process of cost optimization won't necessarily result in a superior performing product however, it should result in something that performs well enough. Sometimes it doesn't make sense to deliver the consumer a BMW when a Toyota will perform the job just as well.

For new formulators another goal of formulating is to learn how to work with specific raw materials and what their function is in a formula. We'll introduce the idea of a knockout experiment and show you how it can be used to see what effect an ingredient has on the performance of a product.

Another prototyping project you will no doubt face is to come up with a second source for one of your raw materials or even find a replacement. It frequently happens that suppliers either discontinue a raw material or raise their prices. To maintain the maximum level of control over your formulation it always makes sense to have a secondary source of any raw material. It also makes sense to learn how to find a replacement ingredient if the particular raw material isn't readily available any longer. This also can become an issue if there are regulatory problems with any of the ingredients you are using.

Sometimes formulas will experience stability problems where they may separate, change color, or change odor over time. This can happen for a number of unknown reasons but you have to be ready to fix them when they do. Therefore, many prototyping projects will be focused on solving quality control problems.

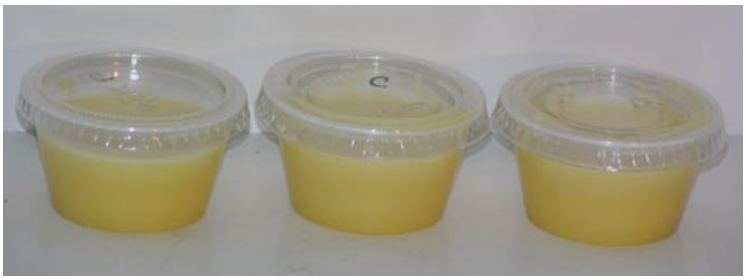
A number of companies employ a “fast follower” strategy in which they do not create innovative products themselves but they look to see which company is leading the industry and they quickly copy the formulation or marketing position while typically offering the product at a lower cost. You see this all the time with value shampoo brands like Suave or VO5 or private label brands. The private label companies will often make their products look nearly identical to the popular name brand.

Finally, you may have a prototyping project that requires you to make a truly innovative new product. This is pretty rare in the cosmetic industry as consumers reject most things that are a significant departure from what they are used to. If you are lucky enough to get to work on a project like this, it is helpful to learn tricks that can speed up the process.

To be an excellent formulator you have to develop some experience with both the raw materials and the formulation itself. We'll review three techniques that will be extremely helpful in your future work as a formulator. This includes:

- Knockout experiments,
- ingredient adjustment experiments
- Identifying raw material equivalents

Knockout Experiments



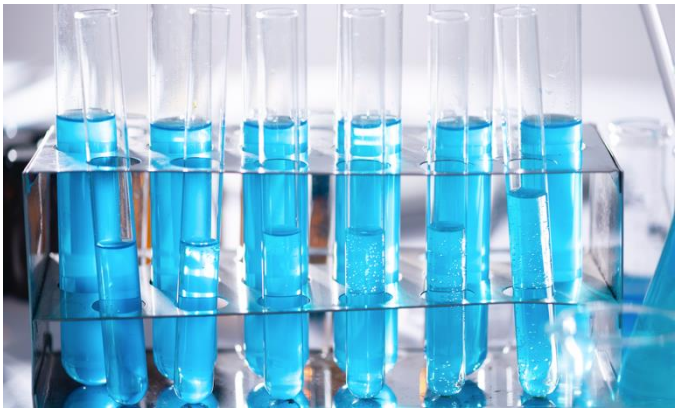
One of the most useful experiments you can learn and perform in your formulating career is the knockout experiment. We'll begin with this one because the information you can learn from this type of study will be helpful with innovation, cost savings, batch adjustments, troubleshooting and new raw material sourcing.

The term “knockout experiment” is taken from the field of genetic engineering. In this field, scientists create organisms in which they remove or “knock out” a specific gene. Then they see what effects the removal of a certain gene has on the organism. For example, geneticists may find a gene that codes for a certain protein in mice but are unsure what the protein does. They conduct a knockout experiment where they create a new mouse by splicing out that specific gene and then determine what effect it has on the new mouse. This type of experiment has led to much of our knowledge about biochemistry and the effects of genes and proteins.

In the cosmetic chemist version of a knockout experiment, you take a known formula and “knockout” a specific raw material. You then see what effect the absence of that raw material

has on the final product. It's a simple, yet powerful study that can quickly get you familiar with any formula.

What will a cosmetic knockout experiment teach you?



When you start your cosmetic formulating job, you will often work on projects with a formula that your company had previously developed. I remember the first formula I ever made (a shampoo) was originally developed by the person whose notebook I inherited. My boss asked me to make samples to give to our Marketing group for evaluation. I didn't know why any of the raw materials were used, what they did, why the specific amounts were used or even how hard they were to work with.

As a new formulator you will undoubtedly be in the same position. When you are given a new formula (or find one on the Internet) you will only have a rough idea as to what the ingredients are doing and why they are included at the levels stated. Even if you've been around for a long time, it's impossible to know the effect of raw materials in any formula you haven't personally made (or observed being made).

Benefits of a knockout experiment

Knockout experiments can rapidly tell you exactly which ingredients have the most effect, which ones can be removed and which ones interact. When you're done making the formulas, you can learn what raw materials have the most impact on the final specifications and the product performance. You may also get clues as to which ingredients you may be able to substitute without much concern. The amount of information you can learn from a single knockout study makes it well worth doing on every new formula on which you are asked to work.

How to conduct a cosmetic knockout experiment

Running a knockout experiment is fairly easy. All you have to do is take your initial formula and make a series of batches in which you remove one ingredient. The formula mass you remove is replaced with the formula's main solvent. If it's a water-based formula, you simply add water to replace the missing mass. If it's an anhydrous formula you might replace the missing volume with Mineral Oil or Petrolatum. In color cosmetics the replacement is typically one of the fillers like Talc.

After you make the batches, you then evaluate the effect of removing an ingredient on a variety of things such as specification tests, product stability, formulation performance. When

you've completed the study, you'll have a good idea of what ingredients are crucial to the formula performance and which aren't.

Knockout Experiment example

Figure 32 is an example of a batch sheet for conducting a knockout experiment on a bubble bath formula. As you can see, each subsequent formula has a line where the value of one ingredient is supposed to be.

Figure 32: Bubble Bath Knockout Experiment

Formula Name: **Bubble Bath**

	Ingredient	%	Control Amount	Test A	Test B	Test C	Test D	Test E	Test F	Test G	Test H	Test I	Test J
1	Water	64.50	322.50	324.50	337.5	323.00	387.50	397.5	325.00	332.50	325.00	325.00	325.00
2	Polyquaternium 10	0.40	2.00	-	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
3	Glycerin	3.00	15.00	15.00	-	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
4	Tetrasodium EDTA	0.10	0.50	0.50	0.50	-	0.50	0.50	0.50	0.50	0.50	0.50	0.50
5	Ammonium Lauryl Sulfate (28%)	13.00	65.00	65.00	65.00	65.00	-	65.00	65.00	65.00	65.00	65.00	65.00
6	Ammonium Laureth Sulfate (25%)	15.00	75.00	75.00	75.00	75.00	75.00	-	75.00	75.00	75.00	75.00	75.00
7	PEG 5 Cocamide	0.50	2.50	2.50	2.50	2.50	2.50	2.50	-	2.50	2.50	2.50	2.50
8	Cocamidopropyl Betaine	2.00	10.00	10.00	10.00	10.00	10.00	10.00	10	-	10	10	10.00
9	Citric Acid	0.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	-	2.50	2.50
10	DMDM Hydantoin	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	-	2.50
11	Fragrance (Parfum)	0.80	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	-
	TOTAL	100.000											

In this formula there are 11 unique ingredients which means you will need to make 11 different batches. The first batch is the control batch which should be made first. This ensures that you are able to successfully make the formula.

Ideally, you will control as many variables as possible such as raw materials, temperature, mixing speed, mixing time, mixing equipment, batching equipment, etc.

For a knockout experiment like this it's useful to make 500 gm batches. In some cases, a smaller batch size may be adequate but if you can do it make 500gm your minimum.

In conducting this experiment, the first batch you make is the control where you just make the full formula. In the next batch you make, rather than using Polyquaternium 10, you leave it out and instead replace the lost mass with water. Therefore, batch A will be completely missing Polyquat 10 and will likely behave significantly different than the control. Don't worry about how the batch ends up. You will not be making any adjustments and you shouldn't try to guess

what effect the change will have. When you finish the batch put it in an appropriate container (or leave it in the beaker) and make the next batch.

In batch B the Glycerin is removed and replaced with water but the Polyquaternium 10 is included. This will give us an idea of the effect of removing that ingredient.

This same procedure is continued through the rest of the experiment. Batch C removes the Tetrasodium EDTA, Batch D removes the ALS, ALES is removed in the next batch and so on.

When you are completed making the batches you will have 11 different formulas. The next step would be to see how those formulas differ from the control.

You would conduct appropriate lab tests to see how the removal of a certain ingredient affects performance. For foaming products, conduct foam tests. For skin lotions, do a moisturizing test. Perhaps most important is to try the product out on yourself. Try to experience the product like a consumer. This will give you excellent clues about how important any raw material is to the overall effect of the formula.

Simplifying the knockout experiment

While it is best to make a new formula for each ingredient in the formula, this can become impractical and unproductive if there are dozens and dozens of different raw materials. In these cases, you may be able to minimize the number of batches you make by ignoring ingredients not expected to significantly impact the end performance. These include:

1. **Dyes** – For most hair or skincare products the dye will be used at a small level and will have an obvious effect on color only. It is highly unlikely that the presence of a water-soluble dye in these formulations will have any significant effect on characteristics like foam, moisturization, viscosity or pH. For color cosmetics this will not be true and there is a tiny chance for some effect but in the vast majority of cases the presence or absence of dye will not matter.

2. **Marketing ingredients** – Remember in chapter 3 where we discussed the different types of cosmetic ingredients? Well, the ingredients used in a formula for marketing reasons alone typically will not have an effect on any final characteristics. In fact, they are not supposed to have an effect except a marketing one. You can skip the knockout versions which include these ingredients.

3. **Preservatives** – It's unlikely that the preservative will have a significant effect on the end characteristics of the formula so if you want to skip doing a knockout batch that removes the preservative, that's a reasonable shortcut. Although it might be interesting for you to make this batch just to convince yourself of the need for a good preservative. Note Tetrasodium EDTA is another ingredient that you might be able to skip when doing a knockout experiment.

If you don’t know which ingredients are superfluous, you might ask one of your more experienced peers or post the question to our forum or send me an email. You want to err on the side of caution as it can be problematic to make any assumptions about a formula. There could be ingredients you expect not to have any effect that do.

Knockout Experiment – Case Study - Shampoo

Next, let's take a look at a real knockout experiment that I conducted in the past. In this case we will run a knockout experiment on a shampoo formula. When the batches were finished, they were evaluated for how well they matched specification (pH and viscosity) and for performance (foam). I could have done other performance characteristics but this will be suitable for our purposes.

Here is a shampoo formula made up of eight unique ingredients. I simplified the knockout experiment by keeping the preservative constant. I didn't think this would have much impact on the characteristics I was examining and it would save me some time.

Figure 33: Shampoo Knockout Experiment Case Study

	Formula Name		Batch size						
	Basic Clear Cleansing Shampoo		500	grams					
	INGREDIENT	%	Control	A	B	C	D	E	F
1	Water	38.800	194.00	394.00	244.00	209.00	219.00	204.00	199.00
2	Sodium Laureth Sulfate	40.000	200.00	-	200.00	200.00	200.00	200.00	200.00
3	Sodium Lauroylmethyltaurate	10.000	50.00	50.00	-	50.00	50.00	50.00	50.00
4	Cocamide DEA	3.000	15.00	15.00	15.00	-	15.00	15.00	15.00
5	Glycerin	5.000	25.00	25.00	25.00	25.00	-	25.00	25.00
6	Sodium Chloride	2.000	10.00	10.00	10.00	10.00	10.00	-	10.00
7	Fragrance	1.000	5.00	5.00	5.00	5.00	5.00	5.00	-
8	DMDM Hydantoin	0.200	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	Water	0.000	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL	100.000	500.00	500.00	500.00	500.00	500.00	500.00	500.00

This experiment required 7 batches to be made - the control and all the test formulas.

Evaluating your cosmetic knockout formulas

Each batch was tested for pH, viscosity and foaming performance. The pH was measured using a standard pH meter and the viscosity was measured with a Brookfield viscometer (LVT spindle 12 RPM). And here are the results.

The control formula had a pH of 5.5, a viscosity of 9000 and a foam rating of 8. The foam rating was a subjective rating on a scale from 0 – 10 with 0 being no foam and 10 being a lubricious, creamy foam. It was the average score of responses from a 10-person panel. This is a subjective score which wouldn't be useful for substantiating a claim but good enough for give us formulation direction. The key to this kind of testing is that it needs to be blinded which means the panelists couldn't know what was the composition of the samples.

The test samples had varying values when the characteristics were measured. The sample which lacked Sodium Lauryl Sulfate had a pH of 6.0, a viscosity of 4000 and a foam rating of 3. So, what does this mean?

In this formula Sodium Lauryl Sulfate helps to reduce the pH a bit because the pH is higher when the ingredient is absent. Similarly, the SLS also contributes to the viscosity because without it the viscosity is lower. And clearly the SLS contributes to foam because without it you get a lot less foam. This last fact is not surprising because SLS is the primary surfactant.

We can compare that to the next batch which was made without Sodium Lauroylmethyltaurate, the secondary detergent. The absence of this ingredient results in a slightly higher pH value 5.7, a lowered viscosity 6000 and a significantly lowered foam score. So we know that this ingredient reduces the pH, increases viscosity and provides good foam scores.

Next look at Sodium Chloride. In this formula, a knockout of salt had no impact on the pH of the final formula. It also had no noticeable impact on the foam of the formula. But it had a huge impact on the viscosity. In fact, without salt the formula barely had a viscosity higher than water. Clearly, salt is a viscosity adjuster. This is well known and expected.

The secondary surfactant Cocamide DEA has an effect on pH, viscosity and foam. Without this ingredient the pH is lower (4.8) the viscosity is lower (2000) and the foam score is lowered (5). It turns out this ingredient is an important one.

Glycerin on the other hand has no significant impact on the scores. pH is slightly lower but this is within experimental error. Viscosity and foam are unaffected. It seems that we could remove glycerin and it wouldn't have any noticeable effect at all. This is good to know if we are ever in a situation where we are trying to reduce the cost of the formula.

The last ingredient to discuss is fragrance. An absence of fragrance has no impact on pH but it does affect viscosity (12000) and foam (10). Here the presence of fragrance causes a reduction in viscosity and a reduction in foam performance. Since it is an oil, this is not surprising.

To summarize what we learned from this knockout experiment:

pH

SLS and SLMS reduce the pH while Cocamide DEA, increases the viscosity. None of the other ingredients have a significant impact on pH.

Viscosity

Fragrance reduces the viscosity while the SLS, SLMS, Cocamide DEA, and Salt increases the viscosity. Glycerin has no impact on this characteristic.

Foam

SLS, SLMS, and Cocamide DEA all positively impact foam. That is presence of them increases foam. Fragrance on the other hand reduces foam. Glycerin and salt have no impact on the foam.

Using Knockout results

One of the most useful ways to use data from a knockout experiment is to help you adjust batches. In this particular case you will be measuring specification values of pH and viscosity. Since you know the impact that certain ingredients have on these characteristics you can make small adjustments using these ingredients.

For example, if the pH is off you can add SLS or SLMS to reduce the value if it is too high or add Cocamide DEA to increase the pH if it is too low. Realistically this formula should have an acid and base included so we can adjust using those.

If the viscosity is too high you could add a little more fragrance to reduce it. If it is too low you can try any of the surfactants or even salt.

And if the foam performance is off you can adjust it by adding more SLS, SLMS or Cocamide DEA.

Knockout experiment limitations

While the knockout experiment is helpful there are still a few shortcomings of which you should be aware.

First, if you have a lengthy formula, it could require you to make many batches which might be time restrictive. We've discussed some ways to cut down on the number of batches made but it can still take a lot of time.

Second, you may miss some synergistic effects between ingredients. Sometimes ingredients work together to create effects that by themselves do not happen. For example, if you do a knockout experiment on a Carbomer containing formula you will get a thin product result if you don't neutralize the polymer. Or maybe you have a couple of conditioning ingredients in a formula which together are more conditioning than any single ingredient alone. Knockout experiments can't predict these interactions.

Third, leaving some ingredients out can lead to unrealistic results which don't provide you much new data. There is not a lot of value in making a body wash that does not contain the primary surfactant because it will clean and foam much less. There is not much you can learn from that formula.

It’s worth noting that more complicated versions of this knockout experiment can be conducted using DOE (design of experiment) software. These experiments can give you much more information especially about ingredient interactions and levels. Unfortunately, they also require many more batches to be made. During my formulation career I learned how to execute a DOE protocol on a formulation but the amount of work required was not worth it for the usefulness of the data developed.

The knockout experiment is not a perfect way to learn all you can about a formula. There are important synergistic effects it will miss. That’s why DOE is often superior. However, you can’t beat knockout experiments for speed and ease and you’ll definitely learn about raw materials quickly. To become a great formulation chemist, you have to make a lot of batches and try many different ingredients. The knockout experiment helps get you there faster.

Evaluating new raw materials

One of the most common things you will do when developing new prototypes is to evaluate new ingredients. A supplier might meet with you about their new offering, you might find out about it at a trade show or online, or you might read about the new ingredient in a trade journal. New raw materials are one of the key ways that innovative new formulations get created.

When you get a new raw material, you might wonder what is the best way to evaluate how well it works and whether it is worth using. Here are a few tips to consider when evaluating a new raw material.

First think about your objective for evaluating this new raw material.

- Is it going to help you solve a formulation stability or performance problem?
- Is it going to help you improve your current formulas? Will it help create a whole new formulation?
- Are you trying to use it for a cost savings reasons?

Answering these questions will dictate how you should go about evaluating the new material.

In most cases you will be looking at a new raw material to determine whether it provides some improvement to your formula. The reality is that suppliers often don't know what new raw materials can do. They frequently create new raw materials because one of their chemists figured out a new way to create something new. They leave it up to customers to determine whether or not there is any useful application.

How much to use?

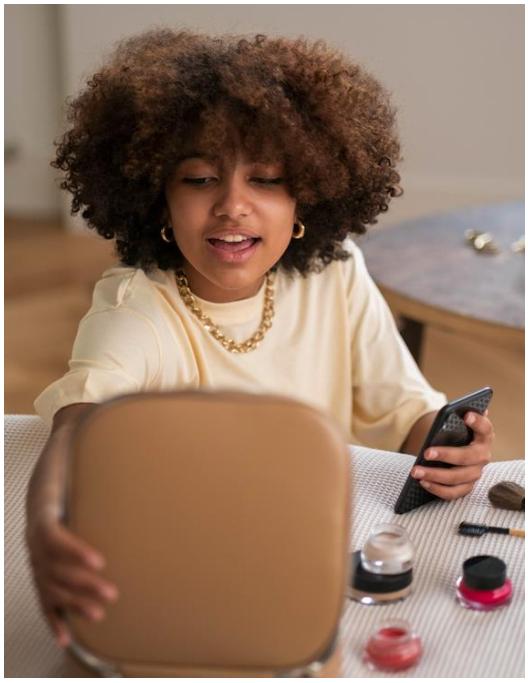
There are a few questions you'll have right away about a new raw material, but the first one should be about how much of the ingredient you should use. Suppliers always have a suggested use level so in your initial testing you should use that much of the ingredient.

Always start with the maximum suggested level of the new raw material

This gives you the best chance of determining whether the new raw material has any noticeable effect at all. Realistically, most raw materials are not noticeably different. Surfactants can create a different amount of foam or have a different effect on viscosity but most people can't pick up on subtle differences. A seasoned formulator might be able to however you have to remember that you are creating products for consumers and they aren't nearly as good as noticing differences as you will be.

If you don’t notice any added benefit to using an ingredient at its maximum suggested use level, it probably isn't worth using.

How do you test it?



When you create a prototype with a new raw material the main objective is to find out whether or not it has improved your formula. To determine this, you are going to need a couple of things. First, you'll need to have a formula to which you compare it. This is what we call the base formula. Second, you'll need to have some standard tests which you run for comparison.

The base formula can be a current formula or an in-house formula that provides standard performance. When evaluating a new raw material, add it to your base formula and compare the resulting prototype to the base formula.

What you test it for will depend on the specific formula but for cleansing products you might compare foam, for moisturizing products you would compare moisturizing performance. It really depends on what product you're testing.

Of course, all your testing should be done on a blinded basis so you (or your panelists) do not know which formula contains the new ingredient. There is a natural bias for us to see differences that may or may not be there. The only way to know if you've really made an improvement to a formula is to conduct a blind study.

In addition to comparing the new raw material to the control prototype, you should also compare it to whatever the best technology is for that particular attribute. When I was developing a new shampoo prototype, I compared the new raw materials to the base formula but if there was a noticeable difference, I also compared it to the best technology on the market. Based on our testing the Pantene shampoo formula performed the best in both lab foam tests and consumer use tests. This was almost always our benchmark product which we tried to beat. You should find the benchmark product in your market and compare any new technology to it when you've refined your prototypes well enough.

Prototype base formulas

Most manufacturers have standard formulas for whatever market you sell products in. I worked for a moderately sized personal care company and we had standard formulas for shampoo, conditioner, skin lotion, gel, and a variety of styling products. To make the different SKUs for

each product line we would modify the color, fragrance and maybe the surfactant levels depending on the particular product. Typically, when we launched a new product, we would take the base formula which contained no color or fragrance and send it to fragrance houses for them to create a new fragrance.

It makes sense to have a set of base formulas in your own formulating playbook. They are particularly helpful in testing new raw materials. They can speed up prototype creation since you merely have to take the finished base formula and just mix in the new raw material to see if it is compatible. This isn't always simple to do as sometimes you have to heat up the raw material or it may not be compatible, but often you can just mix it in at the suggested use level and test the formula to see if there is any effect.

Base formulas can also speed up your evaluation of raw materials because you will have something to compare it to and you'll know how well that base formula performs on the various tests you have used to characterize your formula. For example, if you have a base formula for a body wash, you'll have foam data and know how well it performs. When you try the same base formula with a new raw material, you'll be able to tell whether it makes an improvement. This has the added benefit of giving you consistent data that can be compared across different raw materials.

Some formulation types work better as base formulations than other. Solutions and gels make excellent base formulas. They are liquids in which you can simply add new liquid raw materials at the suggested percent level. If the ingredient is a solid you can also heat up the solution above the melting point of the new ingredient and incorporate it. Solid formulations also are good for making bases but they always need to be heated to incorporate new raw materials.

It's not as useful to make an emulsion base formula. This is because when you add a new raw material to an emulsion at room temperature you do not know if it gets properly incorporated into the emulsion particles. You could heat up the base emulsion formula above the melting point and attempt to recreate the emulsion upon cooling but this could increase stability problems. For the most part when you are evaluating new raw materials in emulsions you have to make the complete formula from scratch. Although I should note that if you are just screening materials there is still some value in just adding the new raw material directly to the emulsion. You just can't completely rely on the results.

Speeding up prototyping

When you work with certain raw materials you will find that it takes a long time to get them to go into solution. This is especially true of powders like Carbomer, Cellulosics, or other thickening powders. In these cases, it can be extremely helpful to create a stock solution of the powder in water to save you a lot of time. That way instead of having to add the powder and wait for it to hydrate every time, you can simply use the ingredient which is already in solution.

This advice also works for powdered ingredients that may be easy to incorporate into water but are used at such low levels that it is difficult to measure them accurately. This is true of things like dyes, acids, and salt. If you do not have a scale that can measure 0.001 g then you definitely need to make dye solutions. Typically, a 1% dye solution is suggested. For salt or acids, you can make 10% solutions.

The concentration of the solution that you make will depend on the ingredient but a 1% solution works well for dyes and Carbomer. This works because those ingredients are rarely used at a level of 1% or higher. For an ingredient like an acid or salt it makes more sense to create a higher percentage solution because formulas sometimes call for a higher percentage of these ingredients. It does you no good to have a 1% salt solution for a formula that requires 2% salt.

Whenever you create an aqueous solution of a material you need to use a preservative to ensure that it doesn't become contaminated. Adding something like DMDM Hydantoin or Methylisothiazolinone is always a good idea.

Adjusting ingredient levels during prototyping

During the prototyping process you will typically have to adjust the levels of ingredients to try and make improvements. It's unrealistic to think that your first attempt at a formula will result in the best formula possible. To quickly and efficiently adjust ingredient levels it makes sense to follow a few guidelines rather than just guessing at levels.

First you need to create a prototype then test it using a standard test appropriate for that formula. For cleansing products, a foam test is appropriate. For lotions a moisturizing test on your own hands or a small panel test might be appropriate. For color products it makes sense to test the color as spread on skin.

Once you have quantified the way the prototype works you need to identify the ingredients that impact the characteristic you want to change. This is where the knockout experiment is

useful. If you remember back on that experiment the surfactants all had an impact on foam. If you wanted to increase the foam score it makes sense to increase the level of the surfactants. To optimize an ingredient in a formula the first step you can take is to double the level of that ingredient in the next prototype. Remember to only change one ingredient so you know exactly the effect on your formulation.

After doubling the amount of the ingredient, you can see if it had any impact on the characteristic you were trying to change. If it didn't then you can go back to the original level and try adjusting another ingredient. If it does have an impact, your next step could either be to increase the level or cut back on the level. In this way you can steadily find the proper level of an ingredient.

Cost Savings

In your career as a formulator, you will undoubtedly have the following experience. After months of prototyping and testing you create the most inspired, most incredible cosmetic formulation of your career. You present it to your marketing group and they absolutely LOVE IT! The project starts to move forward and everything is going great, but then they make a simple request.

"We love it, but can you make it less expensive?"

While your first inclination may be to answer "No" this is not always an option in the world of the cosmetic industry. But fret not, there are certain strategies you can follow to turn your excellent, expensive formula into an adequate, reasonably priced formula. Here are 5 tricks you can try:

Reduce the fragrance level

In most formulas, the fragrance is the most expensive ingredient. It's also often put in at a level that is higher than required. To get a quick cost savings, you can cut the fragrance level in half and see if a panel of users can tell a difference. You will be surprised how few people will notice even a 50% reduction. If people do notice a difference, try lowering it by only 10-20%. You probably have more fragrance than necessary and when you're looking for a quick cost savings, that's the first place you should start.

Reduce the level of Claims ingredients

Another source of a cost savings is the claims ingredients that you've put in your formula for the marketing story. These natural ingredients are frequently more expensive additions than standard ingredients so you can save money by reducing the levels. If you are using an extract at 0.5% or even more, you're probably wasting money. Verify it yourself by doing a knock-out experiment. On a blinded-basis, see if you can pick out the one that is missing the extract. If you can't, then you can reduce the level to almost nothing. For example, using a level of 0.01% of an extract in the formula is not unreasonable when you're looking to cut costs.

Eliminate unnecessary ingredients

Speaking of reducing ingredients, there may be some ingredients that are completely unnecessary. These represent a great cost savings not only in terms of formula cost but in terms of storage costs for additional raw materials. To figure out if an ingredient isn't necessary, you should do a knockout experiment and compare the formula with and without the ingredient. If you can't tell whether a missing raw material is in the formula or not, you don't need it.

Find less-expensive alternative ingredients

While you may love your specialty emulsifier or ultra-soft emollient, you may be able to replace them with a less-expensive but approximately equal alternative. It is surprising how few differences non-trained beauty product consumers notice. I once created a two-in-one shampoo formula and compared it to a basic shampoo formula that looked and smelled the same. 14 out of 15 panelists didn't notice any difference. To me, the differences were night and day. So, remember, just because you can tell a difference, your audience may not.

Dilute it

The last strategy to reducing the cost of a formula is to just add water. This only works for aqueous formulas, however, that is the majority of personal care products. When you add water, you reduce the overall concentration of all the other ingredients. This reduces the cost of the entire formula. Depending on the formula, you can add up to 5% more water and not notice any difference. This could be a significant cost reduction. A word of caution with this approach however, be sure not to decrease the level of preservative. Adding more water increases the chance of microbial contamination so you want to maintain a good level of preservation. (Note: For anhydrous formulas you can use mineral oil or propylene glycol as the less expensive diluent).

Cost saving and the cosmetic chemist

Reducing cost is all part of being a cosmetic chemist and if you can find hundreds of thousands of dollars in cost savings, you will be a company hero. When you first develop formulas, don't worry so much about optimizing them. When the product is successful, your business partners will no doubt ask you for a less expensive alternative. If you've already optimized it up front, it will be much more difficult to optimize it later.

Replacement ingredients

You may need to replace an ingredient in your formula with some other ingredient. There are a few reasons that this happens. First, raw material suppliers frequently discontinue ingredients. If they get rid of a material that you use in your formulation that can wreak havoc with your product. When a supplier company has that much power over your product you leave yourself open to some risky business situations. Incidentally, this is why it is a good idea to have a second supplier for any raw material you use. But when you don't have a second supplier, you'll have to find a replacement ingredient.

Photo by Amplitude Magazin on Unsplash

Another reason you may need to replace a raw material is for some cost savings. As we mentioned above, one important job of a cosmetic formulator is to reduce the cost of your formulas and one method is replacing expensive ingredients with less expensive alternatives.

Fixing stability issues is another reason you might replace one ingredient with another. If the raw material manufacturer makes some production method change in their raw material this could lead to stability problems in your own formula. Having a replacement may often be the only solution.

One final reason you might want to replace a raw material is that you are looking to improve the performance of your product. You can only get so far by optimizing the level of a raw material and often the only way to make a significant leap in performance is by completely replacing an ingredient.

Raw material substitutions

There is no specific technique for substituting one ingredient for another as all formulation are different, however there are some guidelines you can follow that can speed up your efforts. Remember ultimately you will have to figure this out through a method of trial an error. You'll find that much of cosmetic formulating involves trial and error.

Match raw material type – First, figure out the classification of the material you are trying to replace. Is it a surfactant, thickener, solvent, humectant, or any of the other types of ingredients discussed in the earlier chapter? You should try to be as specific as possible. If it is a surfactant, identify the charge (anionic, cationic, or nonionic). Also, take a look at the molecule itself. Figure out what the carbon backbone is composed of. If you remember the fatty acid distribution chart from the chapter on raw materials, you'll see that ingredients with source derived names often have the same fatty acid distribution of more purified ingredients.

For example, if your supplier of Sodium Cocoyl Sulfate was gone you could look at the molecule and realize that the majority of the raw material is the C12 fatty acid. C12 just happens to be Lauryl so you know that you could try to replace Sodium Cocoyl Sulfate with something like Sodium Lauryl Sulfate. In fact, they perform very much the same.

Match the activity level - Once you have found some candidate ingredients to replace yours, you are going to want to be sure to match the activity level of the ingredient. Remember some raw materials are sold at less than 100% activity levels so you'll need to adjust your formula so that your new raw material matches the activity level of your current raw material.

Replacement challenges

While some materials will be easy to replace others are a bit more difficult. The easiest ones to replace are things that do not have any significant impact on either the performance of the product or the feel of the product. These are the marketing ingredients like the extracts added to simply support the marketing story. Emollients are also relatively easy to replace because they all tend to have an oily feel that is easily reproduced. Other adjustment ingredients like salts, acids and bases are not difficult to replace either. You just need to be sure you are matching the pH and ionic strength of the raw materials. This requires some trial and error.

Surfactants are a bit more difficult to find replacements for because there are many options and many are quite similar. You need to have a good idea of the molecular structure and the structure of the potential replacements. For example, a C14 based raw material could be

replaced with either a C16 or a C12 raw material. Cetyl Alcohol and Stearyl Alcohol are often used as replacements for each other. But surfactants and emulsifiers are different and often two ingredients might seem like they would be compatible but when formulated they are not.

The hardest ingredients to replace are fragrances (since these are often trade secrets) and polymers. Polymers include thickeners like Carbopol which behave in a certain manner that isn't duplicated in other ingredients. Polymers are also difficult to replace because they vary by manufacturer and it's difficult to tell things like the monomer ratio from the ingredient name. However, when you are faced with replacing any of these types of ingredients it still makes sense to first find molecules that are similar in structure and then find ingredients that are similar in function.

Scale-up

Now we will cover the important aspects of scaling a formula up from a lab batch to a pilot plant to full scale production. For some, full scale production might mean going from a 500 mL beaker to a 5-gallon pail, for others it will be going from a 500 mL beaker to a 5,000-gallon tank. In either case, the same principles apply. An entire course could be done on scale-up of specific formulas but we will limit to information that is practical and can be more generally applicable. This will include the areas of Documentation, Process design, Equipment and Packaging.

Equipment washing

In all countries it is a requirement that when you formulate or produce cosmetics you need to work in a clean environment.

For lab equipment like beakers and mixer blades you need to clean them every time you use them. Not only does this help prevent microbial contamination, but it helps prevent formulation contamination. You don't want to produce a prototype that has an unknown level of contaminants.

Cleaning materials should be effective and not negatively impact the product you are making. You should also use the same cleaning procedure and ingredients to clean the equipment. This further ensures that the containers you start with are in the same condition each time.

Suitable cleaning solutions for lab equipment are standard detergents. A 10% SLS solution works well for most any cosmetic you might make. This can be cleaned at a sink using hot tap water. If it is suitable for cleaning dishes you would eat off of, it would be suitable for cleaning

containers to make cosmetics. If you are working with anhydrous solutions, you might find it easier to clean them with an alcohol solution. Alcohol solutions also have the added benefit of disinfecting the containers and surfaces. A standard alcohol solution for cleaning your equipment is a 70% solution of either ethanol or isopropyl alcohol. It's always a good idea to clean your countertops at the end of a day of formulating with chlorine bleach. A 10% solution of sodium hypochlorite works well.

When you are working in production or a pilot plant sized tank scrubbing the whole container is not necessary. One method of sanitation is to fill the container up with water (and detergent) and bring the temperature close to boiling. After mixing the hot solution for 10 to 15 minutes you can empty the container and rinse out any residual material.

Working with clean equipment is not only a good idea for consistent formulation, it is also a legal requirement. In the United States it is legal for the FDA to inspect your facilities to ensure you are complying with current good manufacturing procedures. Having a demonstrated disinfecting procedure will be important in passing this inspection.

Documentation - Regulations

Image credit: stock.adobe.com

Scale-up is a good time to review your own procedures to ensure that you are following the appropriate regulations in your country of operation. You may have heard that the cosmetic industry in the US is unregulated but this is false. The cosmetic industry is regulated by the FDA.

The FDA requires that you follow cGMP (current good manufacturing procedures).

When formulating in a lab even if you're not selling products, you still should follow GMP. When you are producing products for consumers, you absolutely have to follow these procedures. Additionally, you have to document what you're doing.

The EU has similar rules to the US but there are some variations. They follow the ISO 22716 standards which are described in detail in the document "Guidelines for Good Manufacturing Practice of Cosmetic Products (GMPC)." If you are producing products in the EU it is recommended that you get this pamphlet. It's worth mentioning that the third largest cosmetic market, Asia, follows the ASEAN Harmonized Cosmetic Regulatory Scheme. This is quite similar to the EU regulations but has some minor differences.

The common theme among these regulations as they pertain to both lab prototype development and larger scale production is that you must have standard procedures written down and documented proof that you are following them. Set up a system now if you are ever going to be a cosmetic manufacturer or formulation consultant.

Documentation - Specifications

The type of documentation you must keep is related to four areas of your cosmetic product production including:

- **Raw Materials**
- **Manufactured batches**
- **Finished products**
- **Distribution data**

When you receive raw materials from a supplier you should be given a certificate of analysis which includes specifications, results of specification tests, material identification and a lot number. The lot number is used to track the production information about the raw material. GMP requires you to keep copies of this information so that if there is a problem it can be used to track down what happened. There are no specific regulations on how to do record retention but it makes sense to digitize these documents and retain them.

You are also supposed to document the production of each batch of cosmetic product you create. This would include the batch sheet (formulation), the procedure, the amount of material added, the date and time of production, the lot number of the raw materials used, and the specification data you record when the batch is completed. This information will be particularly helpful when you are trying to troubleshoot batches.

You also should record and retain information about the final product. This would include filling information (when, where and how), quality control test results, and any sampling results you did during the filling process. Each batch should have a distinct lot number which would enable your company to track the origin of any product. Ideally, you'll be able to look at the lot number on a bottle of product and trace it back to the exact batch that it came from.

Finally, you are required to keep data about where your product is distributed. This record should include information about what lot number of product was sent to what customer and when. You should also have Material Safety Data Sheets (MSDS) for your finished product. These are required to be provided to any of your product distributors. If you distribute product online you are required to have an MSDS available for a consumer if they request one.

Cosmetic product production is much more paperwork intensive than lab formulation. If you want to operate a successful and legal cosmetic business you must follow good manufacturing practices and documentation. For large companies, there is likely standard operating procedures (SOP) already put in place by a team including your production, regulatory, and legal departments.

Process Design

When developing a manufacturing procedure for your lab formulas the real work begins in the lab with your prototypes. When creating prototypes take extensive notes about the order in which you add ingredients, the speed at which they went into solution, any types of changes that happened to the batch after adding an ingredient, etc. Keep track of temperatures, the amount of time it took to make the batch, and the mixing speeds. If there was an ingredient that prompted you to increase the mixing speed you should note that too. The more information you collect in the lab, the easier it will be to anticipate problems during scale-up.

In addition to keeping notes about the manufacturing process, you should also work out the specifications for your product in the lab. The exact specifications will depend mostly on the type of product you are producing however, all of your products should have a specification for the appearance and the odor. This is done by writing descriptions of what the final product is supposed to look and smell like.

For solutions, emulsions, and gels, it makes sense to have specifications for pH and viscosity. The pH range should be set based on the pH at which the product performs the best. Shampoos and body washes should be on the acid side with a pH range anywhere from 5.0 – 6.0. Hair conditioners should have a slightly lower pH because they function better at a pH range of 4.0 – 4.5. Skin lotions should be formulated at pH levels 6.0 – 7.0 to reduce chances of skin irritation. For powders and stick products the notion of pH doesn't make sense because there is no water to measure the H+ concentration.

It's unlikely that your formulas will always come out at the same pH level so you should set a pH range. A reasonable range is about a half unit. So, if your formula has a target pH of 5.5, the specification range would be roughly 5.3 – 5.7.

Viscosity specifications will depend on the desired thickness of your product. For liquid products like shampoos and body washes the viscosity can be in a range of 4000 – 15,000 cps.

Emulsions will have viscosity specifications of something like 15,000 – 30,000 or higher. It really depends on how thick you want the product. Gels have a high viscosity range also usually from 20,000 – 40,000 cps. When setting viscosity specifications, it's reasonable to set a range of plus or minus 20%. Therefore, a product with a target viscosity of 10,000 cps will have a range of 8000 – 12,000 cps. Ideally, the range will be tight enough that a consumer would not be able to tell the difference between the top and bottom of the specification.

Process Design – Scale-up

When ready to scale-up your batch, first outline a procedure based on the prototyping notes. This knowledge allows you to create an experimental procedure to use the first time you make the scaled-up batch. During the first production batch record your observations and compare them to what you observed in the lab. If there is an ingredient that takes too much time to incorporate consider changing the order of addition. Typically, you want to put ingredients that take a long time to hydrate in at the start of your batch. This means ingredients like thickeners and powdered polymers should be added first.

Understand that everyone's scale-up equipment will behave differently even if you have matching tanks and mixers. When you are scaling up there is no “right” way to do it as there are many options that can lead to a working finished product. However, you have to experiment with your own set-up to find the optimal settings and procedures that work best for your situation. One thing you should do is to expect an increase in mixing times. If it took you an hour to make a batch in the lab, it is likely to take two, three or even more hours in production.

Scale-up equipment

The equipment you use to make larger formulas will also depend on the type of formula you're producing. By far the most common mixer for personal care formulas will be center stir mixers. These are just much larger versions of the type of mixers you use in the lab. The size difference means you will not be able to get the same level of turnover in the large batch as you did in small batches. However, with an increase in mixer speed and a proper tank design you should be able to make any type of formulation you can make in a beaker in a large tank.

While center stir mixers are the most common your set-up should be tailored to the formulation type. For solution formulas a center stir mixer is almost always suitable. Also, when using them the liquid level should be high enough so the blade is completely submerged to prevent excessive air entrapment in the formula. For gels and emulsions, it is helpful to have side sweep blades that move along the outer edge of the batch and push any ingredients that stick to the side back into the batch. This will help make a more consistent product. If you are working with powders a ribbon blender is the best piece of equipment to use.

The tanks you use for scale-up should be stainless steel as they are the most corrosion resistant and easiest to create temperature controls. They are also non-reactive with most any ingredient you would use in a cosmetic formula. It is also possible to use a plastic 5-gallon

bucket to make batches but this is not advisable because you'll have no temperature control and plasticizers from the plastic can leach out into your formula and have unexpected results.

Scale-up filling equipment

When you work for a large corporation the filling equipment is automated. The finished batch is loaded into a stainless-steel tote which is hooked up to the filling lines. A carousel of filling heads is positioned on a conveyor belt and bottles are automatically filled as they pass under. But if you don't work for a company that has such equipment often the packaging is filled using hand fillers like the ones shown in the picture. These can be set to deliver an exact amount of product into the bottle. They can also be automated. I should mention that the technique of pouring your batch into a bottle also happens.

Scale-up tips – From lab to tank

While it is difficult to provide scale-up advice for your specific situation, there are some tips that I've learned over the years which can be helpful.

One of the best ways to speed up production and get a consistent result in your batches is to add ingredients in the proper order. You typically start with the ingredients that make up the largest volume, usually the solvent. To this you would add powdered materials that can take a long time to hydrate. For example, thickening polymers or clays. Other ingredients to add early are powders that dissolve quickly in the batch but do not have a significant impact on pH. Acids and bases are generally added at the end of the batch process to ensure you have the most control over pH. Temperature sensitive ingredients like fragrances, preservatives and some natural extracts should be added at the end during the cooling phase. It is also helpful to pre-weigh as much of your ingredients as you can. That way you can control the timing of when you add an ingredient. You'll also be alerted before making the batch if you've run out of an ingredient.

A helpful tip is to add colors to your batch as early as you can. If you are working with a colored product, you should add the color as the first ingredient after the solvent. After the color has mixed do a color check to ensure it looks the way it is supposed to. It's not hard to weigh out the wrong amount of color. If you make a mistake on the first ingredient you can discard the whole batch and start over. If you add the color later and you make a mistake, you might have to discard the batch which will be much more costly.

Rapid cooling

When you are making emulsions one trick for speeding up the process is to hold back about 25% of the water at the start. After you have blended the oil and water phases and mixed them for an appropriate amount of time to form the emulsion, you can “flash cool” by adding the rest of the water (cold) to the batch. This will rapidly reduce the temperature resulting in less time to make the batch. However, you should test this in the lab before doing it in production to ensure there are no stability problems.

Adjustments

Your batches may not always turn out the way you anticipated. This is why you have a range for specifications. Ideally, the batch will fall right in the middle of the specification range for all the values. Realistically, this won't usually happen. If the batch falls outside the specification range you need a method for adjusting the batch to get it to the proper pH or viscosity level. Therefore, you should include both and acid and base in your formulations. You should also do a knockout experiment to see which ingredients have the most impact on your specification values. Prior to production you should have some idea of what to do if the batch ends up “out of spec”.

One final tip is that you should always observe the first production run of your formula if possible whether it is being produced by your production people or a contract manufacturer. This will ensure that the product is made the way you want it and will increase the chances that it stays within specifications. You need to be able to demonstrate that a batch can be made on a production scale before handing responsibility off to production.

Cosmetic Packaging

Even though your primary concern is with the chemical composition and performance of your formulation, **packaging plays a critical role in delivering formulations to the consumer in a convenient and useable manner**. It is important for chemists to understand the many types and functions of packaging available, the factors that influence what is used, and the effect of packaging on formulations.

The term packaging refers to the receptacle that holds the product. It is typically made up of a container that houses the bulk of the product and a closure that seals the container and controls dispensing. Cosmetic packaging is available in a wide variety of sizes, shapes, and materials.

Containers come in the form of bottles, jars, tubes, and cans. Bottles and jars are most common. They are formed from specially designed molds and can take on a number of sizes and shapes. The big companies have their own customized molds and create bottles that are specific to their brand. Smaller companies don't have the kind of money required to make a bottle mold (usually >$50,000 per mold) so they rely on stock bottles. Bottles can be made from various types of plastics and can be made rigid or squeezable, clear or opaque. You can get a wide range of stock bottles and containers from a place like ebottles.com. The containers are good quality but will look generic until they are labelled.

In addition to the container, the type of closure is an important choice. You can have passive dispensing closures like screw off caps or more active closures like snap tops or turret caps. Aerosols have their own unique closures as discussed previously. All of the materials in packaging have the chance of negatively interacting with your formulation so it is important to test to ensure the packaging is compatible. One simple method is just to cut up pieces of the package, submerge it in the formula, and track any changes to the formula over a few weeks.

Choosing packaging

There are five primary objectives for the packaging of a cosmetic product. The package must assure that the product remains clean and of uniform quality. The package should convey key information about the product (this is done via the label). The packaging must be attractive and appeal to potential customers. The packaging must be convenient for the consumer to use and handle. Finally, the packaging should be constructed so that it is suitable for display on store shelves where it is sold. These reasons are why you don't see more clever packaging designs. They have to look good but they also need to be functional and easy to ship and display.

When choosing a package there are a number of factors to consider:

- **Formula compatibility** – The composition of the container needs to be compatible with the formula.
- **Dispensing Properties** – The formula has to be able to be dispensed from the container. The type of closure you use could affect the final viscosity of your formula.
- **Cost** – Often the packaging can cost more than your entire formula. When choosing a package factor its cost in the final pricing of your product.
- **Aesthetic Considerations** – Of course, you want the packaging to help your product stand out on a store shelf so you have to keep this in mind. If you are only able to use stock packaging you can still make your product stand out by creating an impressive label.
- **Operational Factors** – Not all packaging can be filled on standard filling line so when choosing a package design, you have to know what your filling line system can handle.

Chapter 9

PRODUCT TESTING

Cosmetic Product Testing

This chapter is designed to introduce you to the key types of testing that are needed for creating and selling cosmetic products. We are going to cover the general types of testing you need to do and provide some suggestions about specific testing.

Whenever you create a cosmetic that is intended to be used by consumers these are the four basic types of testing you need to complete:

- Quality Control / Quality Assurance testing
- Stability testing
- Safety testing
- Claims testing

Quality Testing

There are two types of terms you will hear when referring to the subject of quality testing. This includes Quality Control (QC) or Quality Assurance (QA). In most cosmetic companies the job is done by the same scientists.

The difference between these two is related to what is tested. QC testing refers to tests you conduct on the incoming raw materials or the incoming packaging. QA testing refers to tests you conduct after your finished product is produced. This assures that the cosmetic you produce meets a minimum quality standard. You should have a list of all the required testing and values for all ingredients, packaging and finished products.

Quality testing for both incoming materials and outgoing products involves a number of tests which are both sensorial and analytical. Since cosmetics are products used by people it is often easier and more reliable to use humans to test sensorial aspects of the products. Analytical instrumentation is used to measure the physiochemical properties of materials and products.

The exact testing done on any material or finished product will depend on the type of material being tested. The most common type of testing done on both raw materials and finished products include:

- **Appearance**
- **Odor**
- **pH**
- **Viscosity**

A number of analytical tests such as IR, GC, Mass Spectrometer are also done to verify both the identity and quality of the raw materials.

All of the tests and standards that a material should achieve are recorded in a Specification Sheet. You should have a specification sheet for all incoming raw materials. When you receive a raw material there should be a Certificate of Analysis (CofA) which indicates what the supplier achieved when testing the raw material. However, you should not rely on the CofA alone as proof that the material is of suitable quality. Conduct your own tests on raw materials to ensure that the raw material is what you expected. Remember, the suppliers are not an unbiased source of information and have an incentive to sell raw materials that may not meet the proper specifications.

I'm reminded of a famous quote...

"Trust but Verify"

Specification Sheets

Your specification sheet should contain a variety of information which will quickly and easily allow you to determine whether the raw material or component is suitable for use. Here are some of the most important elements of a specification sheet:

Material Name – All raw materials should be identified by name. This should include both the INCI name and the trade name.

Material number – Each raw material should be identified by some number. We discussed this in a previous chapter but basically you should have a numbering system for any ingredient you use. Your company likely has a numbering system already but if you don't, you should create one.

Basic description – This is just a simple description of what the product looks like. For example, to describe Cocamidopropyl Betaine you would list an "amber colored liquid with a light waxy odor". Include both information about what the ingredient looks like and smells like. If you get a sample that is labeled as Betaine but is a blue liquid, you'll know that there is something amiss.

Required Tests –The required tests should include all of the tests that are listed on the CofA. If the supplier is going to be conducting those particular tests, you should also verify. This should also include any testing of factors that might affect consumer safety. For example, all materials should be free of any microbial contamination.

Critical tests are those that should be conducted by your lab on all raw materials that you receive. This would include things like pH, Viscosity, % Actives, appearance, odor, etc. However, you should also include on the specification sheet a list of secondary tests that you expect the supplier to run on any material they send you. These are tests that you won't necessarily run every time on the material but you can run them if you want. The supplier on the other hand should conduct these tests on everything they send you.

Standard Quality Tests

There are a number of quality control tests done on raw materials but the most common include pH, Viscosity, IR, HPLC, GC, and Mass Spectroscopy.

Before doing any instrumental testing, you should do standard ingredient identification tests. Be sure that the sample matches appearance and odor as listed on your specification sheet. Also, it is helpful to keep a standard sample for comparison to new samples.

pH - most labs have a pH meter and it is a quick and easy test to perform. It is also useful because the pH of a system is indicative of whether the chemical reactions used to make the material have gone to completion. Unreacted raw materials will often impact the pH of the entire system. The pH is also important because it can have an impact on how well the product performs. If your raw material pH is off, that could change the pH of your finished product which in turn could change the performance. It should be noted that pH is only applicable to water soluble raw materials. This value is not useful for ingredients that do not contain at least some level of water.

% Activity - Speaking of water, another factor that is tested with most ingredients is the water activity. This represents the amount of the material found in the ingredient sample. A number of liquid raw materials sold in the cosmetic industry are water solutions and the % activity is an indication of how much of the raw material is water and how much is the actual ingredient. For instance, Sodium Lauryl Sulfate is typically sold as a 28% solution. That means 72% is water and 28% is SLS.

When testing for % activity, you can simply do a mass measurement where you take a known amount of a sample, weigh it, then put it in an oven for some set amount of time and weigh it again. The amount of mass lost is assumed to be water. The remaining amount gives you the % activity. So, in the SLS example, take a 50g sample of the material, put it in an oven at a temperature higher than the boiling point of water (say 250F) for 30 minutes, then take the mass again. If it is 28% active, the sample should weigh approximately 14 g. (14/50 = 28%)

Viscosity - Measuring the viscosity can give you an indication of the consistency of the ingredient and also tell you whether or not the product is stable. When you get a raw material, it is sent to you after some amount of time sitting in the storage totes at the raw material supplier's manufacturing plant. If the raw material is not stable you might not be getting the ingredient you were looking to get.

Analytical tests – These are perhaps the most useful types of tests that can be done. Each raw material will have its own signature IR, HPLC, or Mass Spec reading. If you have a raw material and are wondering whether it is the ingredient you think it is, running a sample of it through an analytical instrument can often tell you what it is. The former tests (pH, Viscosity, % solids) can all be fooled but analytical tests are almost fool-proof. Of course, not everyone will have access to an IR or GC so while these instruments are great, you may not be able to use them.

There are many other tests that can be done such as:

- Melting Point
- Flash point
- Water solubility
- Organic solvent solubility
- Conductivity
- Refractive Index
- Freezing point
- Crystal size

The exact tests you conduct will depend on the material you're using. This should be worked out with your raw material supplier prior to ordering products.

Quality Assurance

While testing raw materials for quality helps with the quality of your final product, you are still required to test the final product to ensure quality. You will want to create a Certificate of

Analysis for your own product which is similar to the one you get from raw material suppliers. However, in a finished product there will be different tests that you run.

Standard tests – The tests you conduct on your finished product will depend on the type of product you are making but for most products you'll want to evaluate appearance, odor, pH and viscosity. The appearance and odor tests can be done by comparing the samples to a control. Your control sample can first be something you produce in the lab. You should change standard samples occasionally so later samples will come from production.

Performance tests – For finished products, you may also do performance tests to ensure the product works the way that you expect it to. This isn't something that will be done on every sample but should be done occasionally.

For cleansing products, it makes sense to conduct a standard foam test in the lab. For lotions, it you may want to do a moisturization test. For color cosmetics you'll need to do color matching or application tests. As a formulator, it will be up to you to determine what the standard performance tests will be and what scores need to achieved for your product to be a quality product.

You can make use of other tests like lab tests, controlled salon tests, trained panelists and even consumer tests which will be covered later in this chapter.

Stability Testing

There is a significant difference between being a formulator and a synthesis chemist. As a synthesis chemist you mix chemicals together and hope something happens. Ideally, you get a chemical reaction you expect. As a formulating chemist, you mix chemicals together and hope nothing happens. Cosmetics are mixtures of chemicals that mostly aren’t supposed to react with each other.

Unfortunately, they often do react (or otherwise change) so you need to test your formulas to see how long they will last. This is called Stability Testing and is something a cosmetic scientist spends a lot of time doing.

What is stability testing?

Cosmetic stability testing is run to determine whether your product will last on store shelves and on your consumers bathroom counter. Stability testing is an important predictive quality

test that you need to run in order to sell your products in the US. It is also useful to ensure that when people buy your product they won't be dissatisfied with an unpleasant odor, wrong color, or separated formula.

Stability testing can predict whether or how your product will change over time. It can determine any aesthetic changes and whether the product continues to work as it's supposed to. This testing can also tell you whether your preservative system will be adequate and if there are any packaging incompatibilities with your formula.

Requirements

Stability testing is a requirement for any product you sell but the details of how you conduct a stability test are not legislated and it is up to you or your company to create an adequate stability testing protocol. The protocol must be reasonable to people who work in the industry and efficient so you don't waste excessive samples. Above all, you must document the protocol, follow it, and record the results of your testing.

***Note** - this is significantly different than the requirements for drugs or over the counter drugs. For these products the FDA has a specific protocol that you are supposed to follow. The PCPC also has a suggested stability protocol which is the basis for the stability testing protocol that we are going to introduce here.*

When do you perform stability testing?

Since you'll be making hundreds or thousands of prototypes during your career, it won't be practical to run a stability test on all of them. Here is a short list of some of the most important times to conduct a stability test.

1. **New prototypes** — Whenever you make a new formula and are satisfied with the way it performs, you'll want to do a stability test. No need to test all prototypes, just the ones that perform the way you want.

2. **New raw materials** — Whenever you change the fragrance, color, or other raw material in a formula, you'll have to do a stability test to make sure there aren't unacceptable changes. Also, when you have a new raw material source (or supplier) you'll want to run a test.

3. **New manufacturing procedure** — Manufacturing is always trying to find faster ways to make formulas. This often means they change some order of addition or shorten mixing time. Whenever changes like these happen, it could affect your formula. Run a stability test to see if the change is acceptable.

4. **New packaging** — Cosmetic products change their look almost yearly so packaging is constantly being modified. Whenever you get a new package, you'll have to determine if the formula continues to be compatible. Stability testing helps ensure that it is.

5. **Scale-up** – Any time you are scaling up your formula you should run a stability test

6. **Ongoing QA** – Running a routine stability test on your production formulas once or twice a year is a good practice to ensure that you are not missing some hidden problem with your products. Lots of things can change without your knowledge and that can impact product stability.

7. **Regulations** – Sometimes governmental regulations require you to conduct new stability tests on your formulas.

General Stability Testing Requirements

There are three main considerations when conducting a stability test. This includes the formula and type of container or packaging that you'll test. Also, the storage conditions in which you place the samples and the timing intervals when you conduct readings.

Basics of a stability test

In practice, stability testing is simply an experiment in which you create a batch of your formula and put samples of it at different environmental conditions for a set period of time. These conditions vary in temperature and light levels and are meant to simulate what will happen to the product during its life cycle.

At select intervals you evaluate your samples for various physical, chemical and performance characteristics to see how they have changed. If the changes are minimal according to your company standards, then your formula is said to have "passed" stability testing. This means you can be confident that when the formula is shipped to stores and ultimately customers, it will still be as good as when it was first manufactured.

Other stability tests

Accelerated tests - During prototype evaluation instead of conducting a full stability test on the formula you can do an accelerated stability test in which you make just a couple samples to store at the various storage conditions. This accelerated stability test will give you a quick idea of whether a formula will be stable. It is particularly useful when you are evaluating a number of different fragrance options.

Freeze Thaw tests – These are tests that can quickly show you whether an emulsion is going to be stable or not. We'll go into these in more detail shortly.

Packaging Tests – Since the product is made up of both the formula and the package your stability testing should involve some compatibility tests. This can simply be cutting up pieces of the plastic used in your bottle, putting it in your formula in a jar, storing it at 50C and seeing whether the ingredients interact. If you're working with plastic bottles, you should also do a weight loss study to determine if the formula is evaporating through the package walls or the cap. This is done by weighing a number of bottles at the start of the test then weighing them after heat storage for a few weeks.

Stability testing details – making the batch

The first step in conducting a stability test is to calculate the amount of product that you need. This is going to depend on the number of samples the test requires and the size of your container. In general, you should always conduct a stability test in both a glass jar (because it is expected to be inert) and in the package in which sell the product. Our standard stability protocol required about 35 glass and package samples. The glass samples were 4-ounces (120 g) and the package samples were 8 oz (240 g). After doing a little multiplication, this meant the minimum batch size required was 11,880 g or about 12 Kilograms. It's always helpful to make about 30% extra because you will lose volume in the bottle filling process.

When you are doing a stability test it is sometimes advisable to have a control batch too. Typically, when you do stability testing, you'll be trying to determine if some formula change remains stable. The control batch is your standard formula which you know is stable and the test batch is your new prototype.

After making the batches, you need to take initial readings. For stability testing the initial readings will depend on the specific type of formula you are making but, in most cases, include:

- **pH**
- **Viscosity**
- **Color**
- **Appearance**
- **Odor**

Storage Conditions

There are two main factors you are testing while doing a stability test. This includes temperature and light exposure. Some standard temperatures to test include 50C, 45C, 37C, 25C (RT), and 4C.

The underlying assumption in stability testing is that increasing storage temperature speeds up any aging reactions that will occur. There are some problems with this assumption but experience in the cosmetic industry has shown that the results are generally predictive. A handy rule of thumb is that a sample stored at 45C for 8 weeks is equivalent to one that is stored at room temperature for one year. This isn't an exact predictor, but is reasonable for the purposes of cosmetic products.

Different lighting conditions involve a fluorescent light box and a natural light box (to simulate sunlight).

The reason you test samples at different temperatures is because your product will experience different temperature conditions during transportation to stores, while stored in a warehouse, in stores, or even in the consumer's home. Similarly, different lighting exposures mimic conditions in both stores and at people's homes.

Sample evaluation schedule

After you put up your stability samples you need to test them at set intervals. In the cosmetic industry the standard sample checkpoints are 2 weeks, 4 weeks, and 8 weeks. At the 8-week interval you can make a decision about whether the formula is stable or not. However, it makes sense to continue the test with checkpoints at 12 weeks, 26 weeks, and 52 weeks. You don't necessarily have to keep all the samples going for the entire stability test but you should include the 4C (control), RT, and 37C. After one year of testing, you will know definitively whether or not your formula is stable.

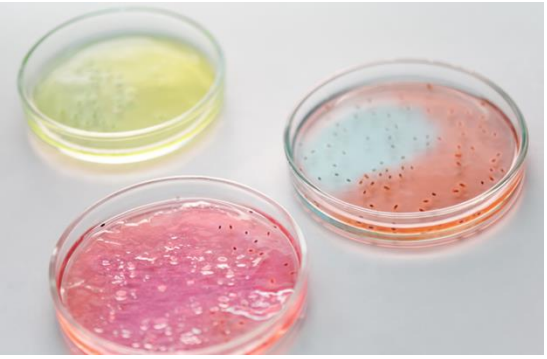
What to evaluate

On the date of the test checkpoints, collect the samples from each condition and take the appropriate readings. These are the same readings taken at the beginning of the stability test including factors such as pH, viscosity, odor evaluation, appearance, and color. For emulsion products it makes sense to use a microscope to observe whether there is any micro-level separation or if the particle size is getting larger. Larger emulsion particles are indicative of a stability problem.

Additional testing

There are other tests that you do at specific checkpoints. Weight loss samples are usually measured after 12 weeks of storage. You can also do performance testing, clinical testing, and consumer testing on formulas if you are making a significant enough change to an important product. Perhaps most important is to do a microbial challenge test to ensure that your preservative system remains effective over time.

Microbial testing



Microbial testing could be put under safety testing but it is so important that it deserves to be talked about separately. Whenever you create a new formula and are doing stability tests you need to ensure that the preservative system you are using is adequate for preventing dangerous microbial growth. There are two primary types of testing you need to do.

Contamination testing

You need to test for contamination on every batch of product you sell!

To determine whether you have initial contamination, bacteria and fungi counts, sometimes called Standard Plate Counts or Aerobic Plate Counts, are conducted. Bacteria and fungi counts done for research and development purposes don't take too long (about 5 days) and are relatively inexpensive (about $25-45 per sample, depending on the laboratory). This kind of work is better to farm out to a testing lab rather than do it yourself.

The test is simple, a sample product is mixed with a neutralizing agent to knock out preservative activity, if present, and then added to bacterial or fungal growth agar in a petri dish. After that, it is incubated at an appropriate temperature for 2-5 days and then bacterial or fungal colonies are counted.

The number of microbes is evaluated to determine whether they pose a consumer risk or not. Typically, a bacterial count of fewer than 10 per gram is ok since cosmetics are not required to be sterile to be safe. Your company will decide on what level of growth is acceptable but 10 per gram is standard in the industry.

Micro Challenge Testing — This is a test in which you purposely introduce microbes into your batches, then watch the samples over time to see whether your preservative system is good enough to kill off the microbes. If it's not, you need to improve your preservation system. The micro challenge test should be done on your initial stability test samples and on the RT and 45C, 8-week samples.

Microbial challenge tests consist of the following basic steps:

Step 1 – Evaluate the product for initial microbial contamination.

Step 2 - The sample is separated into 5 different containers and inoculated with different microbes at a high concentration. The initial microbe concentration is determined.

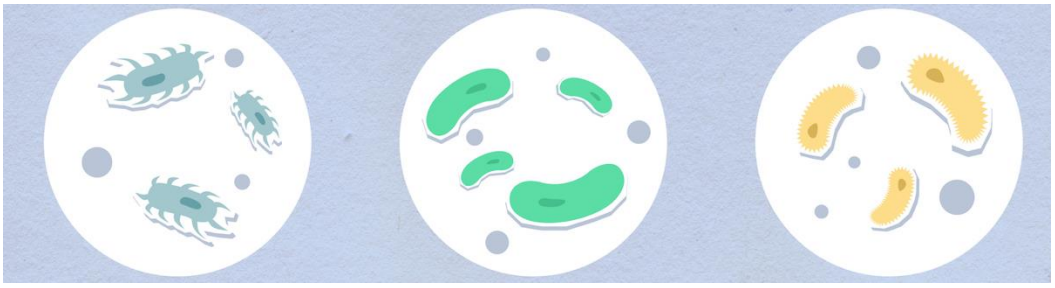
Step 3 - The samples are incubated at RT for about 7 days.

Step 4 - The microbes are then counted to see if there was a change. Ideally, they'll all be killed off.

Step 5 - The samples are then incubated further and evaluated ate 14, 21, and 28 days.

Typical microorganisms used for preservative challenge studies follow:

- Pseudomonas aeruginosa: Gram-negative, very hardy bacterium
- Escherichia coli: Gram-negative bacterium, similar to many pathogens
- Staphylococcus aureus: Gram-positive bacterium, opportunistic pathogen
- Candida albicans: Fungus (yeast), opportunistic pathogen
- Aspergillus niger: Fungus (mold), opportunistic pathogen



Freeze Thaw Testing

Freeze thaw testing is a type of stability test in which you freeze your formula, then thaw it out, and test to see what effect the process has on your product. To do a thorough freeze-thaw test you will repeat the cycle a few times.

Why do Freeze thaw testing?

Freeze thaw testing gives you information that regular stability testing can't. Namely, it will show you whether your formula will remain stable under varied conditions that it might experience during the shipping and storage phases of the product life cycle.

It's likely that your product will be shipped via trucks or rail cars. These vehicles are rarely equipped with temperature controls so it is likely that your product may freeze one day and be in hot temperatures another. It is crucial that your formula is able to withstand extreme, rapid temperature changes.

How to conduct a freeze-thaw test

While there is no "right" way to do a freeze-thaw test, the following method is standard in the industry and will give you the information you need.

Step 1 – Prepare samples. (3 test, 1 control)

Step 2 – Take initial readings.

Step 3 – Put test samples in the freezer for 24 hours

Step 4 – Remove samples and allow to thaw at room temperature

Step 5 - Put samples in 50C oven for 24 hours

Step 6 – Remove samples & allow to equilibrate at room temperature.

Step 7 – Take end of the cycle readings

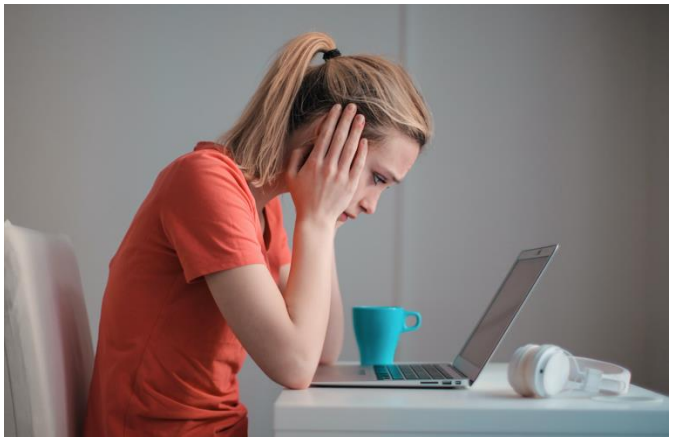
You should repeat this test through 3 cycles. If done correctly it can be completed in 3 weeks.

What to look for

While the specific tests will depend on the type of formula, generally you'll want to take readings for appearance, odor, viscosity and pH. Make particular note of whether there is any separating at the top or the bottom of samples. This is the most common form of instability.

You may also test the products for performance characteristics just to ensure that the formulas still work as expected.

Decisions – is it stable?



The main purpose of a stability test is to help you decide whether the product you are producing will be stable in the future or not. For that reason, you're going to have to look at the results from your tests and make a judgement as to whether it is or not.

Your stability goal is to create a cosmetic product that will remain basically unchanged for one year or more. For some products like sunscreens or anhydrous products this time might be up to three years. But shoot for one-year stability in most cases and you'll be fine.

An industry rule of thumb is that if your product is stable for 8 weeks at 45C then it will be stable for 1 year at room temperature. The results of your 8 week, 45C sample should weigh heavily in your decision about whether the product passes or not.

If you are doing a fragrance change, it is okay to make a decision about the formulation after only 4 weeks. However, remember you are taking a bigger risk when you shorten your testing decision making time. Your company may push you to make your decisions sooner than you necessarily want. 4 weeks would be the minimum amount of time that you should be comfortable making any stability decisions.

Ultimately, 12 weeks is the best time for making decisions about whether a product is stable or not. And it makes sense to keep the study going for 52 weeks on some of the samples just to verify your decision. For OTC products, it is a requirement to test the samples for 52 weeks.

Stability test simplified

Here is a basic format you can follow for conducting a cosmetic formula stability test.

Step 1 — Make your batch. Calculate how much to make based on the number of samples you'll be using for the test. It's a good idea to make 20-30% more than you think you'll need.

Step 2 — Fill your samples. Ideally, you'll have the correct packaging but don't count on it. When appropriate, fill glass jars with the product along with the finished package. In stability testing, you want to do both glass and packaging if possible. The number of samples depends on how much testing you're doing but at minimum you should have 2 samples for each storage condition.

Step 3 — Take initial readings. Once you have a sample filled test it for all the characteristics you're going to evaluate later. The exact tests depend on the product but minimally you'll want to record notes about the appearance, color and fragrance. You'll also want to take pH and viscosity readings. For aerosol products you will test spray patterns.

Step 4 — Put samples at different conditions. Stability testing requires different temperature and light conditions. Some standard temperatures include 50C, 45C, 37C, 25C (RT), and 4C. You'll also want to conduct a freeze/thaw stability test which involves cycling your product through 24 hours of freezing then 24 hours of thawing. Different lighting conditions involve a fluorescent light box and a natural light box (to simulate sunlight).

Step 5 — Evaluate the product. Samples should be evaluated at the following intervals. 2 weeks, 4 weeks, 8 weeks, 12 weeks, and 52 weeks. Only the RT, 37C and 4C samples will be evaluated after one year. The highest temperature samples and the light exposed samples only need to be evaluated for the first three test intervals. The evaluation tests should be the same ones you conducted when taking your initial readings.

Step 6 — Determine stability. After 8 weeks you can confidently decide whether your formula is stable or not. Nearly all products will exhibit some change so it will be up to you (and your boss) to decide whether the product passed or not.

Stability testing summary

Here are the key things to remember about stability testing:

1. It's a predictive test for how well your formula will last during use.

2. It is not an exact science and you have to use your own judgement whether things are stable or not.

3. The test evaluations depend on the type of product you are testing and why you are testing it.

4. You need to have a stability protocol written down and followed to be compliant with cosmetic manufacturing regulations.

Safety Testing

While there aren't always specific tests required to market cosmetics (at least in the US) there is an overriding rule. It is illegal to sell unsafe cosmetics. You just can't sell a product that is not safe. If you do, you open yourself up to litigation which could pretty much ruin any fledgling cosmetic manufacturer. This rule is true of all places in the world even though the specific regulations might vary. To understand the rules of your country you will have to investigate the local requirements. However, the testing we will review here will be applicable to any place in the world.

The amount of safety testing done depends on the type of product you are going to sell and how different the raw materials are. If you are making something that uses standard cosmetic raw materials, less testing would be needed than if you are using raw materials that are new to the cosmetic industry.

You want to ensure your products do not cause any adverse reaction to the end user.

Adverse reactions

There are only a few different types of adverse reactions that people experience from exposure to cosmetics. These include:

- **Irritant contact dermatitis** is the most common reaction to cosmetics and skincare products. It is characterized by erythema (skin reddening), desquamation (flaking), and mild itching or stinging. Any substance that damages the stratum corneum barrier can result in irritant contact dermatitis. Some of the more common ingredients that cause it include soaps, detergents, strong acids or bases, and solvents.
- **Allergic contact dermatitis** is a more server reaction and it is the result of exposure to an ingredient that causes an immune response in the person exposed. This reaction will vary from person to person as some people are allergic to ingredients while others aren't. One of the most universally irritating substances is the excretion from Poison ivy. Other ingredients that can cause allergic contact dermatitis are methacrylate, formaldehyde and nickel.
- **Contact urticaria** is a condition where the exposed develops redness and welts on the skin. Think hives. Some known hives inducing ingredients include alcohol, acetic acid, benzoic acid, and menthol. This doesn't happen to everyone but it can harm some people.
- **Phototoxic contact dermatitis** is a reaction to a material in the presence of light. They usually appear as a sunburn and may also result in hyperpigmentation (age spots) and skin flaking. Various ingredients have been shown to cause this condition including lactic acid, propylene glycol, benzoyl peroxide and even musk.

While it is not necessary to avoid all ingredients that might cause some of these problems, it is advisable to limit their use and find suitable replacements if available.

Safe product evaluation

The best way to ensure that you are creating products that are safe is to avoid ingredients that are known to be irritants and sensitizers. When you are formulating it is helpful to review the potential issues with ingredients you are using.

Another thing to consider is using fewer ingredients. The fewer ingredients you have, the less potential that someone will experience a negative reaction. This goes well with our minimalist formulation philosophy too. Fewer ingredients are generally better.

After you've finished formulating your prototype it's important to conduct stability testing to ensure your product remains safe. A product that has separated represents a bigger risk to consumers.

The next step in ensuring you produce safe cosmetics is to conduct in-vitro tests that predict eye / skin irritation potential. These are lab tests that involve cell cultures or tissues which can predict human skin reactions.

If the formula passes the in-vitro testing, in-vivo (animal testing) might be done next to evaluate the product for eye irritancy, skin irritation, or sensitization. The cosmetic industry tries to avoid this type of testing when possible but for some new ingredients it is not avoidable. You may have heard that animal testing is banned in the EU for cosmetics and it is. However, it is not banned from testing pharmaceutical ingredients and cosmetic companies are allowed to use safety data generated for ingredients no matter where it comes from so the ban can be circumvented if a company really wants to.

Finding replacements for animal testing is an area of intense research at the moment but for some information (like inhalation data) we just don't have any working substitutes.

After the lab testing is done, human patch tests and consumer tests can be done on the formula or raw material. If it passes that the company is required to monitor consumer reactions to cosmetics on the market. In the US the FDA has set up a system where consumers can report any adverse reactions to cosmetics. This database can help manufacturers decide whether to continue to produce a formula or not.

Formulation tips

Here are a few tips that will help ensure your formulations are have the best chance of being safe for consumer use.

- Avoid common allergens and irritants.
- Use high-quality raw materials. Just because you can get an ingredient for a lower price does not mean you should. It could have trace metal irritants contaminating it.
- Use antioxidants when applicable in your formulations to prevent known oxidation reactions that can cause irritation.
- Be wary of penetration enhancers as they can often cause more irritation reactions.
- Use less irritating surfactant blends in your cleansing formulas. Surfactants tend to be some of the most irritating ingredients so you have to use them at the lowest effective level you can and include ingredients that can mitigate irritation potential.
- Finally, preservatives can be irritating (because they are designed to kill cells) so try to use low sensitizing preservatives. One of the problems with newer preservatives on the market is that they may be more irritating than traditional preservatives.

External system tests

Here is a list of some of the more common external formulation tests.

- **Patch testing**
- **Controlled-Usage testing**
- **Sensitizers**
- **Photosensitivity**
- **Acnegenicity**
- **Eye irritation tests**

Photo by Amplitude Magazin on Unsplash

Patch testing on human volunteers can give you an idea of whether a formula or ingredient will be irritating or cause a problem. A controlled usage test can determine the concentration of an ingredient necessary to produce a negative reaction. Patch testing can also determine whether an ingredient will be a sensitizer and if you include light in the test, it can be used to determine photosensitivity. Tests are also done to determine comedogenicity of an ingredient. This is the tendency for an ingredient to cause acne. Many natural oils are known to be comedogenic.

Finally, there is the eye irritation test. This is the unpopular Draize test which involves tests on rabbits. It is thus far the best model for determining the eye irritation potential of a substance. I anticipate this will be replaced but at the moment it is still done on some formulations.

Internal system tests

Internal testing is done less frequently than external and is typically done on raw materials only but it is useful to know. The types of testing done include Oral and Percutaneous tests. In these tests the ingredients are either fed to an animal or injected under the skin. Inhalation tests are done for aerosol products and involve flooding the atmosphere of a cage with a known concentration of the ingredient and determining the effects on the subject. Then there are irritation tests on internal organs and systemic tests which determine things like whether a material is carcinogenic, mutagenic, or teratogenic (affects the fetus).

Typically, testing like this (if it is done at all) is farmed out to specialized testing houses. Not every formula will have to be tested for every possible problem but as a formulator you will have to be able to back up the fact that your products are safe as sold with data and testing that you know was conducted. In fact, in my 20+ years as a formulator I never had to do any animal testing. I tested products on myself a lot, but never on furry critters.

Performance / Claims testing

Performance tests are experiments let you determine and measure product functionality. They are useful for a variety of reasons including:

- **Prototype development** – lets you know how the product functions and whether formulation changes make it better.
- **Supporting advertising claims** –generates the data that prove the claims made about the product are true.
- **Developing patents** – when developing a product, you may stumble on something patentable and these are tests you would need to run to support the patent.

Before we move into a discussion about the specific tests it will be prudent to talk about what is meant by the term "claims". There are various types of claims including:

General efficacy claims – these are statements made about what your product does. For example, "shampoo cleans hair." These can be quantified claims like "makes hair 10x stronger".

Medical testing-based claims – "clinical tested" or "doctor approved" are medical based claims. These have to be verified by using a specific protocol and involve a doctor, usually a dermatologist.

Safety claims - statements telling the user that the product is safe to use and under what conditions. These may also take the form of warnings (ie aerosols).

Exotic materials - these are often made-up ingredients like "Regevium" or "Hydratien" which sound like they could be useful. They can also be herbal extracts from exotic plants like "contains Awaphui extract". The only requirement to support these is that the product actually has to contain what you claim it does.

Free-from claims – these claims were recently banned in the EU but you will still see them in the US. Essentially, the marketer claims what is NOT in their product like "paraben free" or "sulfate free". The implication of this claim is that if the product had those ingredients there would be something wrong with it. The reason these have been banned in the EU is because they make an erroneous implied claim. For example, there is no evidence that products containing parabens are actually dangerous or unsafe.

Undefined terms – there are some undefined terms that marketers use as claims. Terms like "hypoallergenic" or even "natural" have no legal meaning so anyone can put these words on their products. These would be considered "puffery" claims and do not require much support. Hypoallergenic might mean something to a consumer but there is no legal definition to use.

Types of performance / claims testing

The type of performance testing or claims testing that you need to do depends on the specific advertising claims and on the type of product. In the US, you are bound by the rules of the FTC which state that you cannot promote false advertising. This means if you say your product is going to clean hair, you have to demonstrate that it does. There are some industry standard tests but in many cases as a cosmetic chemist, you'll have to come up with your own reasonable test to demonstrate that what you say about a product is true.

It is not necessary to show the results of any of these tests to the government prior to launching your product. In the US, the industry is self-regulated. However, this does not mean you can skip testing because the FDA can inspect your facilities and levy huge fines on companies that do not have the proper paper work. Be sure to keep track of all your testing procedures and results of any product that you sell. If you are working to EU standards you have to have all this information collected in a dossier to be available to regulatory authorities. Check with the regulatory agency that governs your particular market to ensure compliance.

One thing to keep in mind is that "extraordinary claims require extraordinary proof." If you are going to claim that your body wash cleans the skin you won't need to do much testing to demonstrate that it is true. But, if you are going to make a claim like "this product will make your hair grow" you'll need to show a lot of clinical, controlled studies to prove that it really does.

The types of testing to support claims include lab efficacy tests using instruments, panel tests using trained evaluators, and consumer tests using untrained product users.

Performance evaluations

While there are a few industry standard tests, the cosmetic industry has traditionally been secretive and the protocols for testing is not widely shared. This has resulted in most companies developing their own methods tailored specifically to the equipment they have and the products they want to test. Generally, there are only a few types of tests you can do for any product type.

Cleansing products – Beyond viscosity and pH, the primary performance tests for cleansing products include foam tests and in-use performance. Foam tests vary but typically involve using a set amount of the product, mixed with water (and maybe artificial sebum). The sample is then blended for a set amount of time and the height of the foam is measured. You can also do

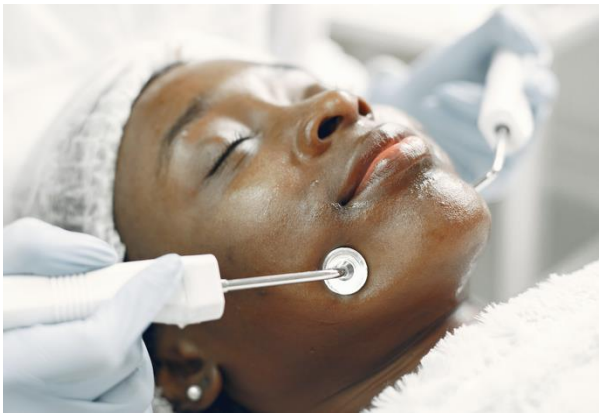
measurements on the foam by filling it up in a graduated cylinder and measuring the height of water formed at the bottom over time.

If you make other claims like moisturizing claims you can run standard moisturizing tests on the skin after using the product.

Moisturizer testing

There are a number of tests you can do to evaluate a skin lotion or any product that gets put on the skin. The easiest way is to use the product and develop a sense for the different aspects of the lotion. You can create a 10-point scale and score lotions for characteristics including:

- Greasiness – How slippery it feels
- Tackiness – How sticky it feels
- Spreadability – How easy it is to spread on the skin



- Absorption rate – How long it takes to feel like it is no longer on the skin surface
- After feel – How it feels after some amount of time
- Shine – A subjective measure of how shiny it makes skin

These are all subjective measurements and to train yourself or a panel of users you should have both a positive and negative control. The positive control would be your benchmark product or ingredient. It should score very high on the different categories. The negative control would depend on the characteristic but water or mineral oil would be a good choice for most things.

These quick and easy evaluations can be done by anyone and if they are done properly blinded, with the proper controls and enough panelists or samples, the data generated can be used to substantiate claims about your product. However, there are more formal ways to evaluate your products.

Skincare testing

A wide range of instruments have been developed for evaluating skincare products. The type of instrument used depends on the characteristic or claim you want to evaluate.

To measure skin moisturization you could use a Novameter or Corneometer. Both of these instruments measure the conductance of skin to give an indirect measurement of the amount of moisture. To measure the amount of water lost through the skin you can use an Evaporimeter or a Trans Epidermal Water Loss (TEWL) device. These instruments are

challenging to work with as you must control the temperature and humidity in the room and also develop a baseline score for your panelist on specific places on the skin.

To measure skin elasticity, you can use a torque meter or a device called the Twistometer. This is a circular disk which is placed on skin and twisted while measuring the amount of force required to move skin through a set number of degrees on a circle. It's interesting but difficult to use.

To measure skin color, you would use a Minolta Chromameter. This can give you a numerical value for the red, green and blue spectrum on a certain patch of skin. It would be useful for skin lightening products or color cosmetics.

For measuring wrinkles, you can do a silicone replica of the surface.

All of these devices are challenging to use and require lots of experience to get repeatable results. This is why most of this type of work is contracted out to companies that specialize in claims testing.

Perhaps the most valuable thing you can do as a formulator is get good at evaluating the products yourself using a subjective scale as previously discussed. This is pretty much true of all cosmetic product performance testing.

There are some clinical protocols which are used to substantiate moisturizing claims. One of the most widely used is the Kligman Regression Protocol. This involves getting 30 or more volunteers and washing their skin (usually the back of the leg) for 10 days with a harsh soap. One leg is treated with lotion and the other is left untreated. A dermatologist scores the skin based on a 5-point scale and this is repeated over the course of 14 days. They also take skin conductance measurements and test the skin using a desquam tape. Essentially, you stick a clear piece of tape on skin, rip it off, and quantify how many dried skin cells you removed. The more you remove the less moisturized the skin.

The treatment is then stopped and skin is evaluated for another week or so to see how well it returns to normal state. It's a bit complicated but when you see a company claim “Clinically Tested” this is the type of test that is done.

Color cosmetic testing

Many of the tests you can do for skin products you can do for color cosmetics since they are put on the skin. Most of the evaluations are going to be subjective studies with trained panelists or consumers. But you can use a chromameter to quantify colors. You can also use a corneometer to measure moisturization – it really depends on what claims you want to make.

Hair product testing

Hair products are a little easier to test because you can purchase tresses of real human hair to do your measurements. There are actually companies who collect and sell human hair specifically for this reason. The hair can be bought in all types of different conditions and types, natural brown, black, blonde, grey, bleached blonde, straight, curly and kinky.

The hairs are made into tresses as you can see in the picture and used for evaluations like:

- Ease of combing
- Detangling
- Shine
- Color
- Feel
- Curl retention
- Volume

These are mostly subjective studies which require you to get good at evaluating. It takes practice to become consistent enough for generating useful data. It's also helpful to get a group of trained panelists who can help quantify the performance of the products.

Hair devices

In addition to subjective measurements there are devices you can use to get a more precise measurement of performance. These include devices like the Diastron or Instron. These are robotic devices that can pull a comb through the hair while measuring the force required to do it. Less force is equivalent to easier combing and better detangling. There is also a tensile tester that pulls a single hair fiber and measures the force required to break it.

With these devices you can make claims about hair strength, manageability, and combing. These are the types of instruments used whenever you see numerical claims about how well a hair product works.

Another option for hair products is to evaluate them in a salon. At my previous company we had a salon with four stylists who would constantly test products for a variety of characteristics. These were typically half head tests and the people getting their hair tested got free salon services. Of course, they had to agree to let us test prototypes on their hair but saw it as a fair trade off. Salon studies could be suitable to support advertising claims if done in a controlled manner.

The benefit about these tests is you get real-world information. Products do not necessarily perform the same on a tress as they do on a full head of hair.

Performance evaluations

Something to stress is that the cosmetic industry does not have a lot of standardized tests to measure performance. It takes creativity to come up with reasonable studies that can support the claims you make about products. Remember to always have a test and a control sample when you are designing your studies.

However, you do not have to continually reinvent the wheel. A great source for finding test methods for products is to look at patents and see how they evaluated their products. You can use this information and adapt it to your own set-up. You can try Google Patents or USPTO (United States Patent and Trademark Office) for free searches.

Data collection

Now that we've talked about some of the different tests you could conduct, we will briefly cover how you collect data to support your claims.

There are three primary ways you can set up a test including:

- **Triangle testing**
- **Paired comparisons**
- **Panel testing**

Triangle testing

The objective of a triangle test is to determine if there are noticeable differences between samples. This could be different prototypes, tresses, or any situation where you have two different systems and you want to know if there is a difference. This testing works particularly well for odor and color evaluations.

To conduct a triangle test you create three samples from a test and control batch. Two of the samples are from one of the batches and one is from the other. This leaves you with three samples total. Next, you blind code the samples so they are not visually distinguishable. Of course, if you are doing a color evaluation this would not be done but if there is a different color and you want to evaluate some other characteristic like the odor, you'll need to make the samples look the same. For example, you might blind-fold your test subjects or use opaque packaging.

After coding your samples, give the three samples to a panelist and ask them to tell you which one is different. They are not allowed to say none are different, they have to choose one. Then you collect the results and tally them to determine whether there is a statistical significance in the choices.

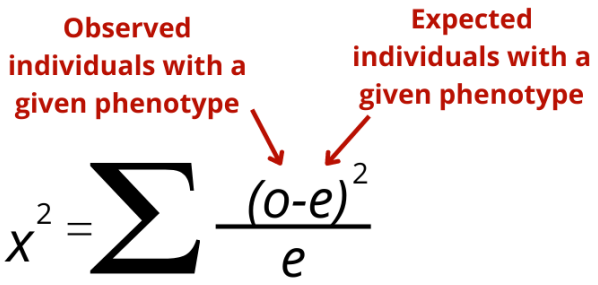
For example, if you had three samples and tested with 10 people and all 10 people picked the odd one out, you can be fairly certain that there is a significant difference. But for subtle differences it's not always so easy.

Suppose you test your samples with 30 panelists and 15 of them picked the odd one out while the other 15 picked the “wrong” sample. Is this significant enough for you to say that there is a difference?

To determine this, you need to use statistics. If you like statistics you can learn how to use a method called a Chi squared analysis.

Here is the equation and it has factors for the expected value, the values collected, the number of people who tested it, etc. After you run your results through this equation you compare it a Chi-squared distribution chart to find out where the significance value would be at a 95% confidence interval.

Figure 34: Chi-squared Calculation



The math can get a bit complicated but luckily the work has been done for you and it's much easier to use this chart which gives a perfectly fine approximation of the Chi-squared distribution.

Figure 35: Triangle Test Chart

Triangle Test Chart

Panelists	* Correct resp
6	5
7	5
8	6
9	6
10	7
11	7
12	8
13	8
14	9
15	9
16	9
17	10
18	10
19	11
20	11
21	12
22	12
23	12
24	13
25	13
26	14
27	14
28	15
29	15
30	15

* Demonstrates a difference to a 95% confidence level

This chart has only two columns. One is the number of panelists and the other is the number of panelists who would need to have identified the odd sample to have a statistical significance. In our example, we had 30 panelists and 15 of them picked the odd one out. According to this chart, that would be a significant result and there is most likely a noticeable difference between the samples.

However, if only 13 people noticed a difference, we wouldn't expect that there is a difference because it is not statistically significant.

Paired Comparisons

Sometimes a triangle test isn't the best choice. While it is good for finding differences a better option for quantifying differences is a paired comparison.

A paired comparison is a test where you have two samples and you ask a panelist to rate them on a scale for a specific characteristic. For example, you might give someone two different lotions and ask them to rate them for greasiness or tackiness. To get statistically significant or useful data, you'll need to set up a number of different paired comparisons and average the data.

To run a paired comparison, you first create a series of test samples. You blind code the samples and have a panel of people score the samples on some scale, usually 1 – 10 with 10 being the best. Or you could just ask them which one they prefer. You tally the results and determine if they are statistically significant.

Panelist / Consumer testing

Triangle testing and paired comparisons can be done by yourself or with a group of trained (or untrained) panelists. But these tests can only give you information about specific characteristics of a formula. In order to gauge if consumers like the product or not, you'll need to run consumer tests.

The method is pretty simple. You decide how many consumers to test (usually 100), create the questionnaire, create the samples and give them to consumers. After a couple weeks of using the product, the consumer will then fill out a questionnaire. You tally those results and determine statistical significance.

This type of testing is usually done by a market research group and they will run data models and statistical analysis to show differences between samples. Unfortunately, the types of things you test aren't really measurable. When you ask people why they like something it is incredibly difficult for them to articulate the reasons. Most of the time people don't know why they like or don't like something. For this reason, I think the most valuable information you can get from consumer tests is just answers to simple yes or no questions. "Do you like the product?" is a great question to ask while "What did you think of the foam?" is not very helpful.

Conclusion

That brings us to the end of an **Introduction to Cosmetic Formulating**. I hope you feel inspired to put your knowledge to the test. Whether you are just beginning to make your own products or are a seasoned professional, I hope you have found this ebook to be helpful and that you use the information to improve your skills and career. It doesn't have to end here.

The field of cosmetic chemistry is a tightly knit community and to fully reach your potential you need to connect and interact with as many other cosmetic chemists as you can. Joining a group like the Society of Cosmetic Chemist is a great way to get started.

But you can also join our online community in the following ways.

Participate in our cosmetic science forum
Connect with us on Twitter at @chemistscorner
Connect with us on Facebook
Connect with us on Instagram
Connect with me on LinkedIn

And, if you are looking to improve your skills even more in the area of formulating, raw materials or natural products consider one of our courses.

Practical Cosmetic Formulating
Natural Cosmetic Formulating
Cosmetic Raw Materials 101

Thanks again and Go Make a Difference!

Resources / References

- FDA cosmetic regulations - http://www.fda.gov/Cosmetics/default.htm
- EU Regulations - http://ec.europa.eu/consumers/sectors/cosmetics/regulatory-framework/index_en.htm
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