



***How do we use chemistry to enhance our physical appearances on a daily basis?
How would you react?***

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This curriculum unit is recommended for:
Chemistry, Physical Science, grades 10-12

Keywords: science, cosmetic chemistry, diversity

Teaching Standards: See [Appendix 1](#) for teaching standards addressed in this unit.

Synopsis: Science should be accessible for all students, but some students are deterred due to perceiving themselves as incapable of doing science or not seeing science as important. To help a wider range of students see how chemistry impacts their lives, students will look into how chemistry is used in a cosmetic manner. Topics will cover a range of North Carolina chemistry standards. Each topic can easily fit into these standards to enhance the chemistry units. These activities can be used to differentiate based on interest (to engage students that are not typically interested in chemistry) or to give students a real-world application of chemistry. Topics will include: hair products, chemical skin peels, hair removal, skin lightening, and more. The purpose of this curriculum unit is to help students see how chemicals plays an active role in day-to-day beauty routines.

I plan to teach this unit during the coming year to 90 students in standard and honors chemistry classes.

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Introduction

I enjoy teaching chemistry because of the abundant opportunities to capture student interest with demonstrations. Students sometimes come into the class a little too enthusiastically asking when we will “blow stuff up.” Students are sometimes disappointed when they learn that explosion will not be the main topic of the class and I eventually have the question of “when will I use this information in life outside of class?” I always smile at such an innocent and naive question and begin listing examples of relevant topics for each unit ready for that question. Chemistry is used in the daily lives of every person. Specifically, chemistry is used to help enhance the appearance of people.

From what I’ve observed, how we describe or discuss science is sometimes skewed to more of a perspective that traditionally interests males. For example, physics work so well using sports analogies and they kind of go hand-in-hand. Science can be viewed through many different lenses to accommodate the interest of different groups of students. What I plan to do with this curriculum unit is to help unravel some of the mysteries of how chemistry is used cosmetically. The purpose isn’t to focus on actual cosmetics (i.e. powders and films applied to the skin), but how chemistry is used to “enhance” the appearance.

Additionally, with this curriculum unit, there is the opportunity to discuss some cultural differences. Taking that topic as a starting point, there are many different paths that can be chosen, but we will be looking at topics that highlight the diversity that represented by CMS (see table 1). This brings an excellent opportunity to make students feel more represented in science, because they can “see” themselves as a part of the learning experience.

Table 1: Charlotte-Mecklenburg Schools and William A. Hough 2016-17 School Diversity Report

	2016-2017 Diversity data (%) CMS	2016-2017 Diversity data (%) Hough
American Indian	0.4	0.3
Asian/Pacific Islander	6.4	2.8
Hispanic	23.0	11.0
Black	39.0	9.3
White	28.6	73.8
Two or more races	2.5	2.8

Class Demographics

I teach at William A. Hough High School. There are approximately 2700 students. The ethnic demographics of the school is shown in table 1. Hough currently has standard, honors, and advanced placement levels of chemistry. The school day is 90 minute block schedule. The goal of this curriculum unit is to bridge the gap between chemistry and cosmetics. There will

be connections regarding the following topics: Bohr model and light, nomenclature, intermolecular forces, concentration, and acids/bases.

Learning objectives for this Bohr model and Light include:

1. Students can look into the wavelength of the laser and the energy of the wave.
2. Students can look into how the dark hair is “excited” with the energy.
3. Students will look into why only a limited skin tone range can be used with this process.
4. How can this light energy hurt you?

Overarching idea: this process relates to chemical interactions in the body due to the energy/light being absorbed (and damaging) in the hair follicle.

Learning objectives for intermolecular forces include:

1. Students will look at the process making hair curly or straight.
2. How can we change what our genetics dictates (in terms of hair properties)?
3. After we break the main intermolecular forces, what happens?
4. Why do chemical processes last longer than physical (heat)?

Overarching idea: Hair properties are dictated by intermolecular forces, we can temporarily change these properties, but this can lead to damaging the hair.

Learning objectives for concentration include:

1. Why does it matter how much of a component we have?
 - a. Won't a higher concentration mean that we have a better product?
2. What are the unintended results of a high concentration
 - a. hard to distribute evenly, too much of an effect

Overarching idea: Skin products have a certain amount of an active chemical to provide the desired result. If the concentration is too high, this might cause negative effects. This will also minimize the manufacturer's profit.

Background Information

The U.S. Food and Drug Administration (FDA) defines a cosmetic as “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.”⁷ The FDA defines a drug as “articles intended for use in the diagnosis, cure, mitigation, treatment, or prevention of disease” and “articles (other than food) intended to affect the structure or any function of the body of man or other animals,” but you can have a hybrid of these two definitions, which is sometimes called a cosmeceuticals. A cosmeceutical is not recognized by law and is used informally to describe a substance or process that can fall into both a cosmetic or drug category.⁷ While I describe how chemistry is used cosmetically, I am describing how chemistry can be used to enhance the appearance and promote attractiveness. Standards of beauty vary by culture, but I intend to bring a diversity component into this curriculum unit by discussing a cosmetic use of chemistry for different groups of people.

Bohr model and Light described with laser hair removal

Evidence of hair removal has been found to date the practice back to 30,000 B.C.⁹ This has been

performed for a number of reasons (religious, aesthetics, punishment, etc.).⁸ But there have also been many different manners in which hair is removed. Laser hair removing devices work by targeting the melanin protein, which is largely responsible for skin and hair color. A laser hair removal device works by using light waves [ruby (694 nm), alexandrite (755 nm), diode (810 nm), and Nd:YAG (1064 nm)] to add energy to the melanin protein to “excite” the molecule. Different wavelengths of lasers are used to target ranges of hair color ($c = \lambda\nu$). If enough energy is added to the molecule, the hair follicle is damaged and limits the ability for hair to regrow. To accomplish this process, significant amount of energy are required and a cooling step is typically performed topically to avoid excessive heating. Modern hair removing lasers have a treatment area of 0.5 inches or more in diameter, to increase the efficiency of the procedure. This current method limits availability based on skin tone. The ideal candidate is a person with light (white or low amount of melanin) skin and dark hair. This creates the largest contrast (between hair and skin) and the energy will be absorbed into the hair as opposed to the skin. People with darker skin tones can damage their skin if they try to use a device that uses this process (many machines come with a safety feature that forces the user to unlock it by placing your hand onto a sensor that determines if you are a good candidate for the machine).⁵ Multiple treatments are necessary due to the growth cycles of hair.

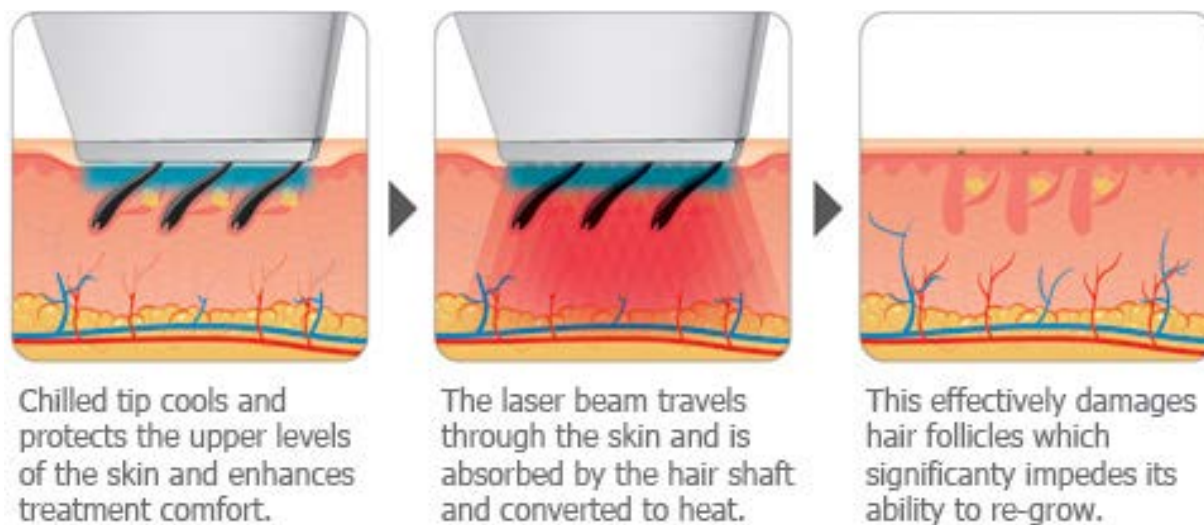


Figure 1: Laser hair removal process¹⁶

Teaching Strategies and Classroom Activities

Students are familiar with the structure of an atom. As a warm-up, students will be given Wint-O-Green Life Savers (cannot be sugar free) and a mirror (or they can use their phone). If students cannot bite hard candy, pliers or a mallet will be available. Students will bite the candy in the dark and should observe blue light being emitted. Students will be asked to describe what they think is occurring.

Students will be introduced to the Bohr model using a simulation (<http://science.sbccc.edu/physics/flash/siliconsolarcell/bohratom.swf>), which provides students with notes and visuals. Students will write notes and color code the energy transitions of the

electrons. Students will answer the following regarding the simulation:

1. Explain, in your own words, the Bohr model based on the simulation.
2. Why does the simulation use different colors when the electron is moving towards different energy levels.
3. What do the terms relaxation and excitation mean when discussing the Bohr model (draw a picture in addition to your answer)?
4. Refine your answer to the warm-up, why is the candy emitting blue light?
5. Using technology, what are some application of the idea of excitation and relaxation of electrons? Give approximately 10 minutes or whenever you notice students to be getting off task.

Note: this is an extremely broad question, but the students are still very new to chemistry

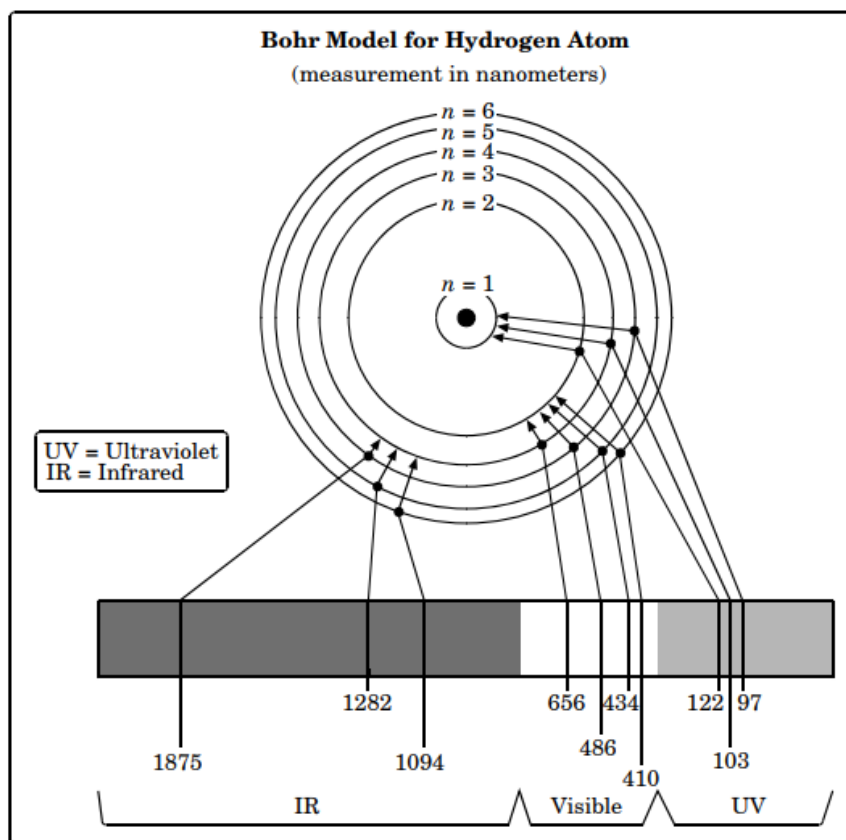


Figure 2: North Carolina Chemistry reference table Bohr model¹⁷

Students will be asked some problems regarding the Bohr model to ensure that all students have a basic understanding. These questions may resemble: If an electron goes from $n = X$ to $n = Y$, is the electron absorbing or emitting energy (if the electron is emitting energy, what wavelength of light being emitted).

To show an application of excitation of electrons, students will then watch a video by the YouTube science based channel Veritasium (https://www.youtube.com/watch?v=S20-1_XqVPM&t=301s). The six and a half minute video introduces the ideas of laser hair removal.

Students will answer the following questions regarding the video.

1. How is laser hair removal related to the Bohr model (at this point, I am just wanting students to understand that the idea of absorbing and releasing energy is how the Bohr model is explained)?
2. What is the name of the primary molecule that is responsible for absorbing energy in hair?
3. What are the wavelength ranges of typical laser for hair removal? And why are these ranges used rather than other ranges (according to the video)?
4. Who is the ideal patient for laser hair removal and why are they idea?
5. Why are the laser pulses very short increments of time?

Safety Questions - not necessarily answered in the video, but important to note.

6. What is a potential risk of using today's laser hair removal methods with skin than has a large amount a melanin?
7. Why are goggles used in both the patient and the person administering the treatment?

Intermolecular forces described with hair properties

One of the most obvious choices for this project is the chemistry surrounding hair. People are naturally curious about things that are different and hair is an initial piece of information that we notice about somebody. Whether it be the color, texture, or shape, we are naturally curious about things that are different from what we have. Hair bias, both implicit and explicit does exist and can make minorities feel as though they have to change their hair to better fit into the dominate culture.¹⁰ One of the major reasons for diversity of hair are the intermolecular forces that are present. Intermolecular forces are chemical interactions that hold together different molecules. Intermolecular forces predominantly occur when there are covalent bonds. Covalent bonds are a type of bond that occur when the electronegativity “pull of electrons” is unequal between two elements, but not a complete transfer of the electron. One way to visualize this is to think of two people playing tug-of-war, but one person is slightly stronger than the other. See table 2 below for a summary.

Table 2: Summary of relevant types of bonding

Tug-of-war analogy	Type of bond
two sides are equally strong	non-polar covalent
one side is marginally stronger than the other	polar covalent
one side is greatly stronger than the other	ionic

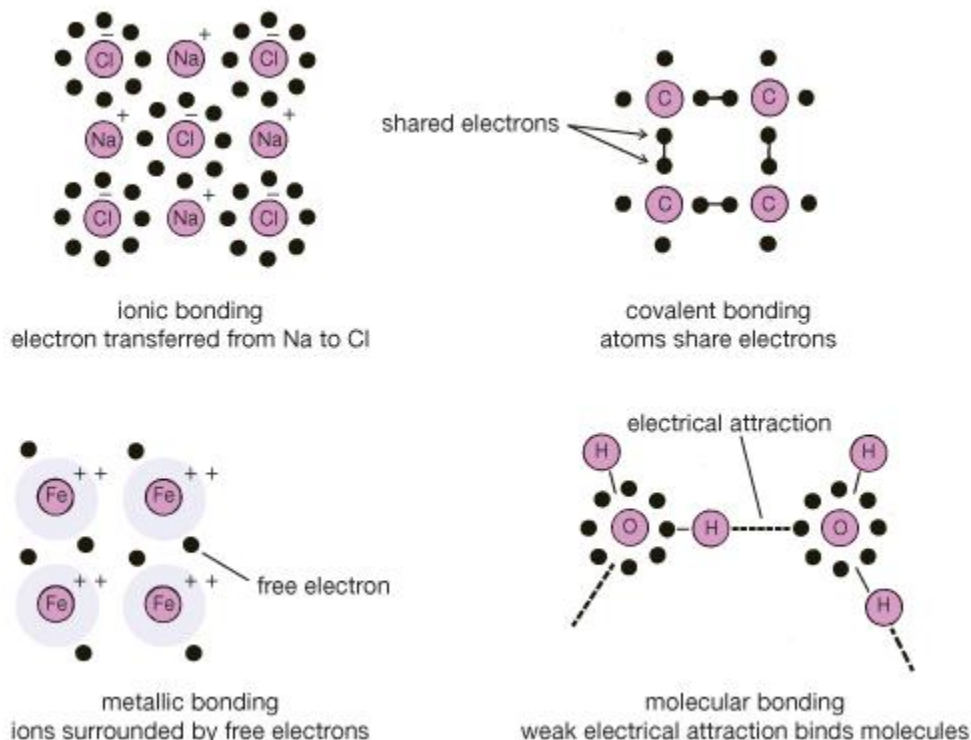


Figure 3: Visualizing types of bonding¹⁸

The curliness of hair is due to an intramolecular force known as disulfide bonds, which are covalent bonds. Straight hair has a lower percentage of disulfide bonds and very curly hair has a larger percentage of disulfide bonds. The amount of disulfide bonds we have naturally in our hair is determined by genetics.² Through chemistry, it is possible to change our hair's genetic predisposition in terms of properties. By subjecting our hair through different processes, we can break out the chemical interaction and reform them in various ways. This chemistry is why is it that when some white woman gets a "perm" her hair is curly, but when some black woman gets a "perm," this makes her hair straight?



Figure 4: Above is one example of White hair going from straight to curly via a perm¹⁹



Figure 5: Above is one example of Black hair going from curly to straight via a perm²⁰

Teaching Strategies and Classroom Activities

After students will have already been introduced to chemical bonding, molecular shapes, and intermolecular forces, students will have a warm up that asks them to “list ways to chemically

change their hair”. The prompt is left intentionally vague to get varied responses. Before answers are given, students will then have a second component to the warm-up, students will be asked to try and explain the processes they described in the first part of the warm-up. Within groups, students will compare their lists to refine their answers. After students have had an opportunity to talk with their group, we will summarize the class ideas in tabular form (something simple such as the table below will work. Students may predict that this has something to do with chemical bonding or chemical interactions (which is when this information will be presented).

Process	What are we changing about the hair?	What is the predicted chemistry behind this change?

Students will read the ChemMatters article “Natural, Braided, Bleached, Colored, Straight, and Curly Hair ... Thanks to Chemistry²¹” (this article can easily be found online for free. There is also a teaching guide that accompanies the reading with anticipation guides, project ideas, and additional resources, which can help extend this idea to differentiate for your classroom. Additional project ideas could involve students making an infographic explaining how they use chemistry to change the properties of their hair (infographic templates or websites are easy to find online and fairly user friendly). The class can vote for the “best” infographic and these can be printed and displayed in the classroom. This activity can be tailored to fit the time restraints of your classroom.

Concentration described with skin lightening creams

Skin lightening has been used by many Asian countries as part of their aesthetically pleasing standard of light skin.¹² Skin lightening can also be used to minimize freckles, scars, discoloration, age spots, etc..¹³ Skin lightening creams work by inhibiting or stopping the melanogenesis (melanin producing) process that gives skin its color.¹³

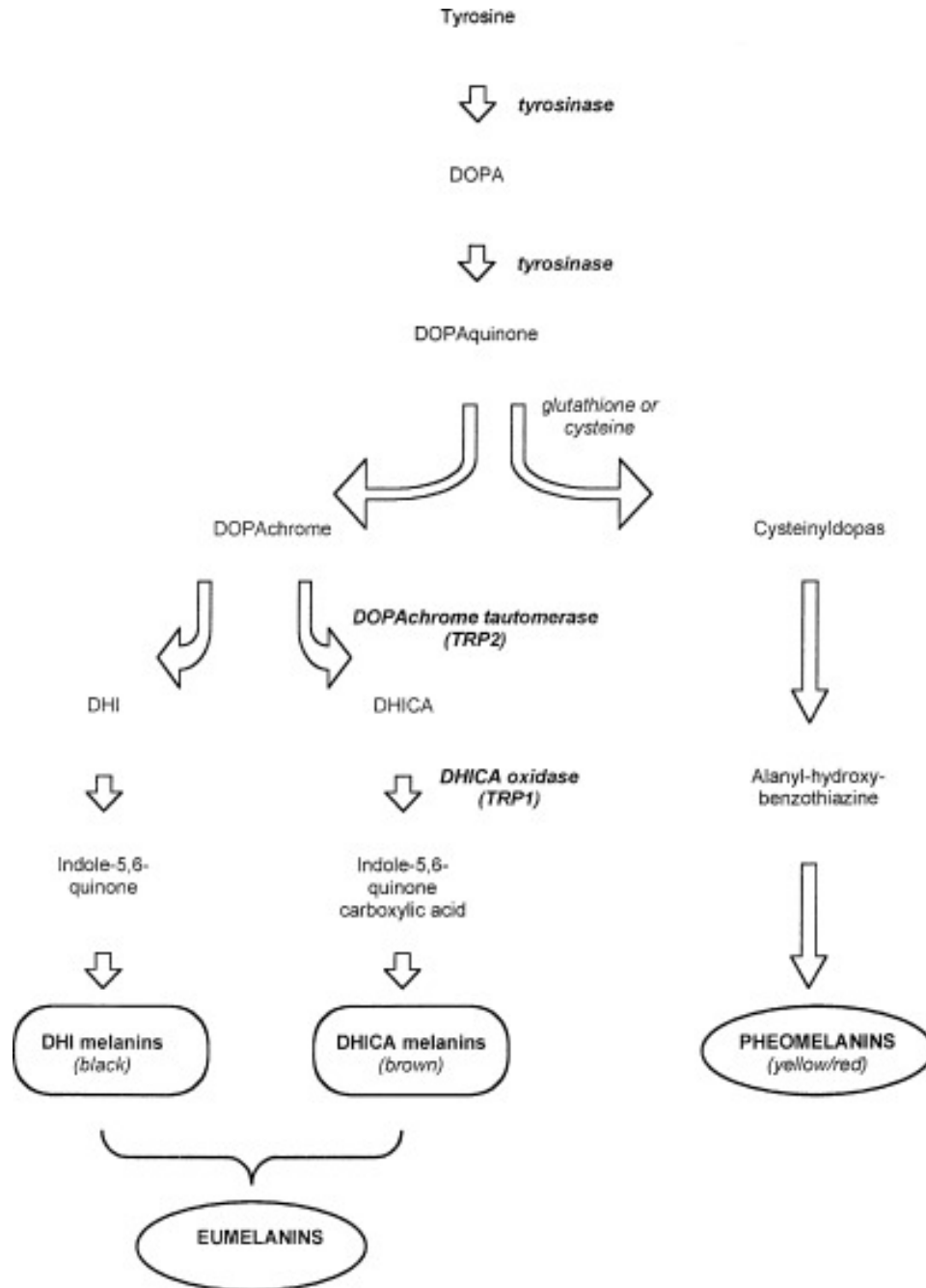


Figure 6: melanin producing pathway¹³

In this curriculum unit, we are not going to look into the process of skin lightening, but the importance of concentration when making a lightening cream (economics and desired outcomes of substance). Concentration is defined as the amount of a substance compared to the amount of another substance. The beauty industry wants to make money, which means they have to minimize the amount of chemicals put into their products. Predominantly, the main chemical used for skin lightening is hydroquinone and derivatives (compounds that have the hydroquinone structure somewhere embedded in the compound).¹⁴ Hydroquinone works by inhibiting the activity of certain enzymes (tyrosinase) that are needed to produce melanin.¹⁴ Figure 6 shows the pathway of melanin production. Hydroquinone has a similar structure to indole-5,6-quinone (see below). Both are cyclic (rings) with resonance structures and oxygen atoms attached to the ring.



Figure 7: the skeleton structure of hydroquinone (left) and indole-5,6-quinone (right)

The use of hydroquinone predates the FDA and has been “grandfathered in” without safety tests being performed for this chemical (since the chemical has been used for a long without major negative effects being attributed to this chemical). The maximum amount of hydroquinone allowed in over the counter sales is 2%, but 4% can be purchased with a prescription.¹⁴

Teaching Strategies and Classroom Activities

Students have been introduced to the idea and are familiar with formula of molarity. Students will have a homework assignment to determine what are the purpose of a class of molecules called “hydroquinones” and what are at least two positive and negative connotations of their use. You will need to have a disclaimer before this activity that everybody will remain respectful and attacks towards other people will not be tolerated. Students will have an opportunity to share their findings within their groups in order to ensure that every student has a quality answer. Each groups will be asked to share either one positive or negative connotation of the hydroquinone class of molecule. This can be a powerful subject, because the standard of beauty is very much skewed towards having light skin. Students may describe that negative uses could be: changing who you are to fit in with majority groups, or not feeling attractive in their skin color. There are positive uses for this product: minimizing scars or blemishes, but a level of respect must be maintained throughout this discussion. After students are satisfied that they have been heard in a respectful way, students can move on the to the next section of the activity.

Propose the following questions to the class: why does it matter how much of a component we have (won't a higher concentration mean that we have a better product), what are the unintended results of a high concentration? Allow students a few minutes to think about the question and discuss with their group before transitioning to technology. I would suggest limiting the use of technology for this activity to a maximum of 10 minutes.

Appendix 1: North Carolina Essential Standards

Chm.1.1.3

Explain the emission of electromagnetic radiation in spectral form in terms of the Bohr model.

Chm.1.2.3

Compare inter- and intra- particle forces.

Chm.3.2.3

Infer the quantitative nature of a solution (molarity, dilution, and titration with a 1:1 molar ratio).

Endnotes

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Notes

To be taken further (will be mentioned as ways to continue this idea, but will not be a part of the curriculum unit)

Equilibrium

Bright white teeth are another aesthetic standard. Strips, toothpaste, paints, and procedures have all been made to make our smiles more white and bright. Common drinks, foods, and habits will actually decrease the brilliant shine of our teeth. Sometimes people have to play a balancing game when they partake in whiteness decreasing activities by turning to strategies that can be implemented to increase the whiteness of teeth color.

Learning objectives for equilibrium include:

1. Why do teeth turn yellow?
2. What processes increase this rate?
3. What processes decrease this rate?

Overarching idea: The color of our teeth is the net product of many different factors. We can make our teeth more and less white by using different products. If you partake in a product that makes teeth less white, you will need to play a balancing game with a process that makes your teeth whiter.

Chemical reactions described with temporary lip plumping products

Full lips are a beauty standard (Kylie Jenner)

Bee stinging lip capsaicin or bee venom

How it relates to chemical interactions in the body:

Nomenclature described with hair products

The term “chemical” typically bring the misconception of being something harmful or negative. Students may “know” that chemical make up everything, but still have a lingering feeling that unpronounceable or foreign names should be avoided. Looking into product labels, we will look at these chemicals in terms of naming. This section brings an opportunity to look into how hair care products designed for various ethnic groups vary. We will use this information when we discuss hair properties in bonding.

Learning objectives for nomenclature include:

1. Students will identify chemicals used in hair products and determine that type of name (ionic, covalent, and metallic).
2. Students will compare the composition and amounts of chemicals between different ethnic hair care products.

Overarching idea: chemicals are not inherently bad, but there are differences in what kind of chemicals are needed to get hair to have desired properties.

virgin hair - unaltered human hair is hair that has not been chemically modified by treatment with bleaches, permanent waves, straighteners, or hair dyes

Learning objectives for acids/bases include:

1. What properties dictate why we use bases to dissolve hair?
2. What do acids do to the face that improve the appearance?
 - a. How does this work?
3. After a successful peel, how do you “remove” excess acid to prevent burning?
4. What are some of the dangers of acids and bases on the skin?

Overarching idea: Acids and bases are chemicals with unique properties. Concentration is a major component when discussing acids and bases. Acids and bases react with each other in a neutralization reaction.

Acids described with chemical peels

Facial peels typically utilize acids remove layers of skin to reveal an improved look. This can be to minimize blemishes or an anti-aging procedure. The time that the acid and concentration is carefully decided by a professional to minimize chances of injury. There are three main categories of chemical peels based on the penetrating power of the acid: superficial, medium and deep peels. There is some subjectivity on what qualifies a peel with a certain penetrating power.¹⁴

An acid used for a facial peel is typically known as a “weak acid.” A misconception about weak acids is that they are safer than “strong acids.” The term “weak acid” only provides information regarding the amount of dissociation (to what extent does the acidic H^+ ion exist in the solution, maybe a picture). Hydrofluoric acid (HF), for example, is a weak acid, but was used in the infamous scene on Breaking Bad. To dispose of a body in a bathtub, HF was used to dissolve the body, but also started breaking down the metal pipes that transport the HF from the bathtub. Alpha Hydroxy Acids (AHAs) are a groups of weak acids that occur naturally in fruits and have carboxylic acid acid portion (COOH).¹⁴ AHAs are commonly used in chemical peels and can be found in skin care products. The method of action for these skin peels is for the acid to penetrate the skin and weaken the proteins (glue) that binds the outer layers of skin. By removing the outer layers of skin, the new outer layer of skin typically has improved texture and reduce hyperpigmentation. After an acid chemical peel, the skin is typically washed and they a sodium bicarbonate (baking soda) solution is applied to the skin. This process is known as a neutralization reaction. Any remaining acid that is on the skin is removed with the basic sodium bicarbonate to produce salt and water. This prevents the acid from being applied to remain for an extended amount of time and possibly permanently damaging the skin.¹⁴

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