Inside Hair: A Closer Look at Color and Shape

For the past decade women and men alike have had chemical treatments preformed on their hair. Consumers spend millions of dollars on hair care products such as dyes, relaxers, perms, and conditioners. These products are used to alter the chemical bonds that are responsible for the color and shape of hair. The chemistry of processes such as dyes, perms, relaxers and conditioners will be explained by reviewing the chemical composition of hair.

The Chemical Makeup of Hair

A human head of hair consists of approximately 100,000 hair fibers ("Hair"). Each hair fiber grows from a hair follicle, a small, sac-like hole in your scalp. The living tissue in hair grows from the hair follicle. Dead cells make up the shaft, the hair people see. There are two parts to the hair shaft, the cuticle and the cortex. The cuticle is the outer layer that protects the hair from damage. If a person cuts their finger, their skin will heal because it is made of living tissue. Hair on the other hand is made of dead cells. Once hair is damaged it is hard to repair. The cortex is made of proteins that are coiled like a telephone wire. Keratin and melanin are the proteins that make up the cortex. Keratin is the same protein found in skin and fingernails. Melanin is the pigment that colors hair and is found in the cortex. A person's natural hair color depends on the ratio of eumelanin and phaeomelanin (Helmenstine). Eumelanin is responsible for dark shades while phaeomelanin is responsible for lighter shades.

Bonds Within Hair

Bonds are located within the keratin proteins. One type of intermolecular attraction, the hydrogen bond, allows the hair to be stretched and returned back to its original shape ("Damaged Hair"). This bond allows us to change the shape of the hair temporarily with water. Hydrogen bonds are the easiest to break down and repair. In fact, they account for the hairs strength and elasticity. Another type of bond, the salt bond, is an ionic bond formed by transferring electrons from a basic amino acid chain to an acidic amino acid chain ("Damaged Hair"). Not only do these two amino acid chains have opposite pH values they have opposite charges. The negative basic chain and the positive acidic chain attract each other resulting in yet another bond that accounts for hairs strength and elasticity. A third type of bond found in hair is the cystine bond. This bond is

found perpendicular to the hair, holding the hair fibers together making it tough (“Damaged Hair”). The last type of bond found in hair is the sugar bond which is also found perpendicular to the hair, giving it additional strength. As a result of sugar bonding, moisture is formed.

Do or Dye

All hair color products contain both a developer, typically hydrogen peroxide, and an alkalizing ingredient (“Hair Coloring”). Together, the hair color and the alkalizing ingredient combine with the developer to create an alkaline or basic peroxide environment. The peroxide enters the cortex and breaks down the melanin replacing it with new color. The cortex can be related to shingles or tiles on a roof. When hair dye is placed on the hair strands, it is absorbed into the shingles (See Figure 1). The size of the color molecules determines how they are absorbed into the hair strand. There are five types of hair dye including temporary, semi-permanent, demi-permanent, permanent, and bleach (“Hair Coloring”). Each of the five types of hair dye has different size color molecules that stay in the hair strand for different lengths of time.

Figure 1: The picture on the left is a hair strand and the picture on the right is a tile roof. The hair dye molecules slip between the cuticle cells as they would in the gaps between the tiles.

Temporary Hair Color

The pigments in temporary hair dye are so large that they can not get in to the hair cortex. These pigments are acidic. Acid dyes have low affinity to hair meaning they are not attracted to the hair. They only coat the shaft rather than being absorbed inside so they can be washed out with one shampoo.

Semi-Permanent Hair Color

When semi-permanent hair color is applied to hair, very small color molecules enter the cuticle and continue into the cortex (Helmenstine). Since the molecules are so small, they end up washing out after several shampoos. This form of hair color does not contain ammonia or peroxide, therefore it will not harm the natural color of your hair.

Demi-Permanent Hair Color

When demi-permanent hair color molecules enter the cortex they pair up to form larger color molecules. The larger the size of the molecule the longer it takes to wash out. Similar to semi-permanent hair color, demi-permanent hair color doesn't contain ammonia so it won't lighten the hairs natural pigment. Demi-permanent hair color however does contain peroxide which enhances and blends hair color.

Permanent Hair Color

Permanent hair color involves a process called double bonding. Double bonding first removes the original hair color and then deposits the new color. Before being able to permanently dye hair, the cuticle must be opened up. This is ammonia's job because it is alkali. Ammonia is also used as a catalyst to speed up the chemical reaction once mixed with peroxide or the developer. Peroxide breaks down the chemical bonds in hair by releasing oxygen, decolorizing the melanin. Once decolorized, new hair color attaches to the cortex (see Figure 2). Conditioner is then applied to close up the cortex and seal in the new color. The molecules found in permanent hair dye are so large they can't be washed out, that is why a person has to wait for the hair to grow out before their hair returns to its original color.

Figure 2:
The picture on the top shows the mixture applied to hair to permanently dye it. The picture on the bottom shows how the peroxide in that mixture bonds to the molecules in the hair shaft once the cuticle is opened up.

Bleaching

Bleaching involves double processing or bonding similar to permanent hair dye. Hydrogen peroxide is the chemical used most often as a lightening agent. The hydrogen peroxide in bleach softens and expands the cuticle cells while the bleach oxidizes, or breaks down the melanin molecules by the use of oxygen. Melanin still exists in the hair; however, once oxidized it becomes colorless. The natural color of keratin is yellow, so the bleached hair tends to have a

yellow hue. Bleach reacts better with the eumelanin pigment than the phaeomelanin pigment so some gold color might be left over after lightening.

Reshaping the Hair

It is not uncommon to hear people with curly hair complaining about how they want straight hair or vice versa. Nowadays, this hair transformation is just a chemical treatment away. Reshaping hair, whether temporarily or permanently reacts with the hydrogen bonds found within the hair. Hydrogen bonds are one of the weakest bonds in the hair. These bonds are formed when an unattached hydrogen atom from one protein attaches to an unattached oxygen atom from another protein. When your hair gets wet, the oxygen and hydrogen found in the water molecules join the protein bonds resulting in a weaker bond, one that is easily manipulated. Wet hair can be scrunched into curls or blown dry straight, which remakes strong hydrogen bonds that hold the desired shape. But once water is added again, hair will return back to its natural shape.

Figure 3: The hair pictured is wrapped around curlers. within a matter of time the disulfide bonds will take the shape of the curler.

Perms and Relaxers

During a perm, ammonium thioglycolate breaks down both the hydrogen and disulfide bonds. Disulfide bonds give hair elasticity. Strands of hair are then wrapped around curlers (see Figure 3) and hydrogen peroxide rebuilds the disulfide bonds, giving them a permanent curl. Relaxers use calcium hydroxide to break the hydrogen and disulfide bonds. Unlike perms relaxers don't reform the disulfide bonds which leave the hair straight.

Figure 4: Conditioner is processing on this head of hair. Leaving conditioner on hair for a few minutes allows the waxy layer to form completely, repairing the damaged cuticle.

Treating Damage

The chemicals found in color, perms and relaxers can cause severe damage to the hair. It is important that after hair is treated with chemicals it is properly conditioned. Conditioners protect the cuticle cells by placing a waxy coating on the hair (see Figure 4). Conditioners also lock color into the cortex. When cuticle cells get tangled together,

hair shafts become damaged (see Figure 5). Once damaged, the only way to restore the hair is to cut off the damaged ends or to let the hair grow completely back out. Small tasks such as taking vitamins and brushing the hair contribute to keeping hair healthy. Reducing the performance of chemical processed on hair is the best way to prevent further damage.

Figure 5: This picture illustrates hair damaged by a relaxer. The ends of the strands are frayed.

To summarize, numerous products can be applied to one's hair to alter its chemical makeup. Such products include color which come in five forms, temporary, semi-permanent, demi-permanent, permanent and bleach. Relaxers and perms, as well as dyes can cause damage to hair. While most of the mentioned hair processes negatively affect hair, conditioner helps to keep hair healthy. The chemistry of each of these processes has been analyzed thus explaining how one can change their hair color and shape.

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