Chapter 13

Permanent Waving

Key Terms

Alkaline waves
Alkanolamines
Aminomethylpropanol and monoethanolamine
Ammonium thioglycolate
Croquignole perm
Cysteine
Disulfide bonds
Endothermic waves
Exothermic waves
Glyceryl monothioglycolate
Hydrogen bonds
Modern acid waves
Neutralizers
No ammonia waves
Peptide bonds (or end bonds)
Reduction
Salt bonds
Side bonds
Spiral perm
Thioglycolic acid
Thiol compounds
True acid waves

Learning Objectives

After completing this chapter, you should be able to:

- Relate hair structure to permanent wave chemistry.
- Understand the theory of chemical bonds in hair.
- Describe the action of reducing agents and neutralizers.
- Define hair shape and how it is changed.
- List the different types of waving systems.
- Recognize and avoid typical permanent wave problems.

Probably the greatest tribute to hair's fantastic properties is that it withstands so much abuse. Hair gets brushed, blown, washed, weaved, waved, combed, colored, and curled. But hair can be destroyed!

Permanent waving is an important, practical, and profitable salon service. If done properly, permanents produce beautiful results. If done incorrectly, they may spell disaster.

A detailed step-by-step, guide to proper permanent wave application and neutralization techniques can be found in *Milady's Standard Textbook of Cosmetology*. This chapter will focus on the theory behind the scientific structure of hair and the effects of permanent waving.

You may hear several excuses for why perms fail. Remember, success comes from skill, understanding, and knowledge. Permanent waving involves a scientific process. If you learn the science of permanent waving you will not have failures and won't need excuses.

HAIR STRUCTURE

Permanent waving involves chemical and physical changes within the structure of the hair. Understanding the structure of the hair is essential to understanding permanent waving.

Cuticle

The *cuticle* layer is the tough outer layer that protects the hair from damage. Although a strong cuticle is responsible for resistant hair, the cuticle is not directly involved in permanent waving. The bonds involved in permanent waving are all located within the cortex. The cuticle only interferes with permanent waving because it resists penetration of the permanent waving solution. Alkaline permanent waving solutions soften and swell the hair, which raise the cuticle and permit the solution to penetrate to its target within the cortex.

Cortex

The cortex gives the hair its strength, flexibility, elasticity, and shape. Countless millions of amino acid chains called polypeptides make up the cortex.

Several polypeptide chains cross-link with **disulfide bonds** creating tiny, threadlike fibers that twist around each other to make larger bundles called *micro fibrils*. Dozens of micro fibril, in turn, twist to create larger *macro fibrils*. Finally, macro fibrils intertwine to form fibrils.

The design is much like the high-strength cables used to support suspension bridges. The polypeptide chains found in keratine are both physically and chemically bound together. Millions of these keratinized cells securely bond together to form the cortex. They are covered with a protective cuticle shield, thus creating hair, a super-strength structure with amazing physical characteristics and chemical resistance.

CHEMICAL BONDS

The polypeptide chains are connected by end bonds and cross-linked by side bonds, which form the fibers and structure of hair. These chemical bonds hold the hair in its natural shape and are responsible for the incredible strength and elasticity of human hair.

Peptide Bonds (End Bonds)

Proteins are made of long chains of amino acids linked together, end to end, like pop beads. The chemical bonds that link amino acids together are called **peptide (PEP-tyd) bonds** or **end bonds**. Long chains of amino acids, linked by peptide bonds, are called polypeptides. Proteins are long, coiled, complex polypeptides made of many different amino acids.

Although different amino acids have different structures, all amino acids have an amino end and an acid end. The amino end contains an amine group ($-NH_2$), which is alkaline, like ammonia (NH_3). The acid end contains a carboxylic acid (COOH), which is acidic. Peptide bonds join the amino end of one amino acid with the acid end of another amino acid to form a polypeptide chain.

Polypeptides, the smallest individual strands in keratin, are polymers of amino acids. When two or more amino acids chemically join, they are called *peptides*. Polypeptides are long chains of peptides. Polypeptide chains may contain over 8,000 amino acids. These bonds are the major, binding force for all protein structures, including hair.

Peptide bonds are the strongest chemical bonds in the hair, but if even a few are broken, the hair becomes weak and damaged. If more peptide bonds are broken and remain broken, the hair will completely break off. Luckily, under normal circumstances, peptide bonds are not involved in the chemical action of salon services.

Side Bonds

The cortex is made of millions of polypeptide chains, which are cross-linked by three different types of **side bonds**: disulfide bonds, salt bonds, and hydrogen bonds. Altering these side bonds is what makes wet sets, thermal styling, permanent waving, and chemical hair relaxing possible.

Hair is an insoluble, *complex protein*. Cross-linking a coiled, simple protein (polypeptide) creates complex proteins. This is like placing tiny bridges between the coils of a spring. The bridges make the spring stronger and more rigid.

Disulfide Bonds (Side Bonds)

Disulfide side bonds are formed between two **cysteine** (SIS-tuh-een) amino acids, located on neighboring polypeptide chains. A **disulfide bond** joins two sulfur atoms, one from each of the two neighboring cysteine amino acids. A disulfide side bond joins a cysteine sulfur atom on one polypeptide chain with a second cysteine sulfur atom on a neighboring polypeptide chain. Disulfide bonds are weaker than peptide bonds but much stronger than hydrogen or salt bonds.

Disulfide bonds are strong, covalent side bonds that are not broken by heat or water. Although fewer disulfide bonds exist than hydrogen or salt bonds, disulfide bonds are much stronger and account for about one-third of the hair's overall strength. As we will soon see, the chemical and physical changes in disulfide bonds make permanent waving and chemical hair relaxing possible.

Almost all the cystine in hair is found in the cortex and cuticle layers. The extremely hard cuticle contains the highest percentage of cystine.

Salt Bonds (Side Bonds)

Salt bonds are relatively weak ionic side bonds. You should remember from Chapter 9 that ionic bonds are the result of an attraction between opposite electrical charges. Within the structure of the hair, a salt bond occurs when the negative charge of an amino acid on one polypeptide chain is attracted to the positive charge of an amino acid on a neighboring polypeptide chain. Salt bonds are much weaker and less resistant than disulfide bonds. Salt bonds are weakened by water and easily broken by alkaline solutions. Salt bonds are far weaker than disulfide bonds, but there are so many more salt bonds, they account for about one-third of the hair's total strength. Salt bonds are affected greatly by changes in pH level. At high pH levels, an amino acid may alter its charge from positive to negative. Then there are two negatively charged amino acids side by side. The negatively charged amino acids will repel each other and push apart. This is why hair swells and the cuticle lifts when alkaline solutions are applied.

Hydrogen Bonds (Side Bonds)

Hydrogen bonds are a special type of ionic bond. Within the structure of hair, a hydrogen side bond occurs when a hydrogen atom, from the acid portion of an amino acid on one polypeptide chain, is attracted to an oxygen atom, in the acid portion of an amino acid on a neighboring polypeptide chain. Although individual hydrogen bonds are weak, there are so many of them in the hair that they account for about one-third of the hair's total strength.

Hydrogen bonds are weaker and less resistant than all other bonds in the hair. Hydrogen bonds are easily broken, simply by wetting the hair with water, and are reformed when the hair is dried.

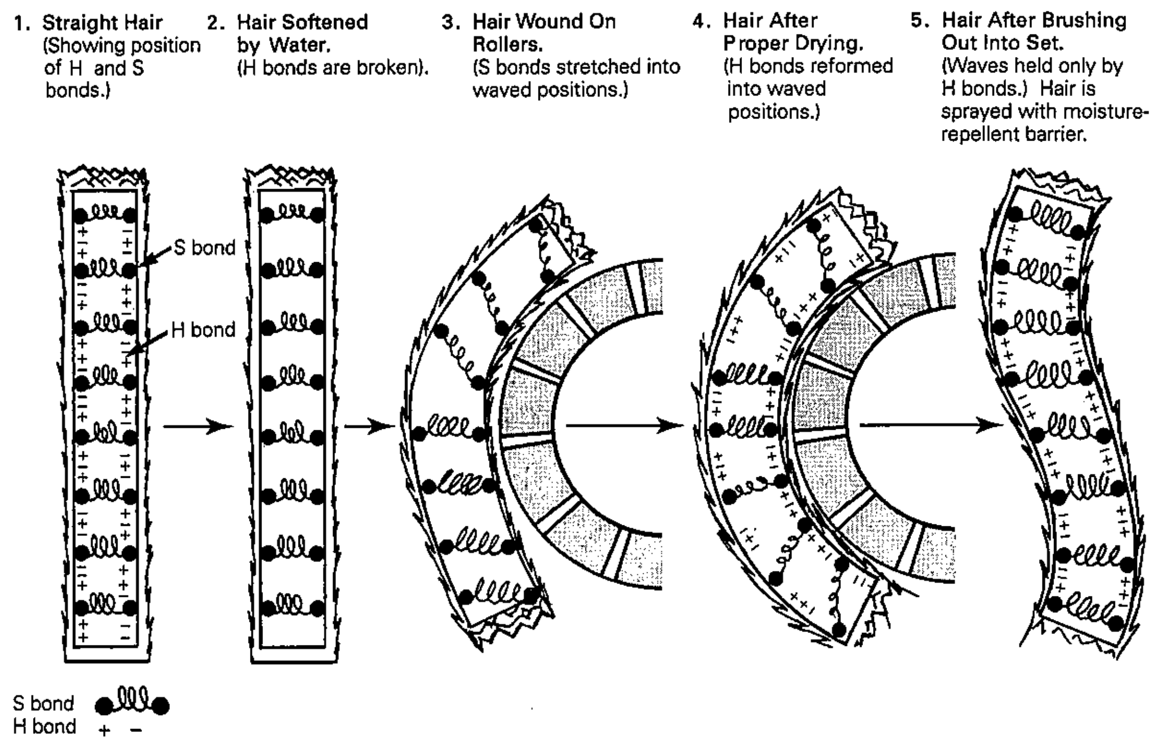

Figure 13–1 *Changes in hair cortex during wet setting.*

When hair absorbs water, the shaft swells. This happens because water interferes with the hydrogen bonds between amino acids. The amino acids form hydrogen bonds with the water instead of with each other. When the hydrogen bonds between the amino acids break, the polypeptide chains push apart, causing the hair shaft to swell. A wet set is an example of a physical change that results from breaking and reforming the hydrogen bonds within the hair. Wetting the hair breaks the hydrogen bonds and permits the hair to be stretched and wrapped on rollers. Drying the hair removes the water and reforms the hydrogen bonds in their new shape. These changes are only temporary. As soon as the hair is wet or exposed to high humidity, it will revert to its original shape (Fig. 13–1).

Thermal styling with hair dryers, curling irons, and pressing combs also break hydrogen bonds within the hair, just like a wet set. These styles involve a physical change and the results are only temporary. The hair will revert to its original shape as soon as it is wet.

PERMANENT WAVING

Permanent waving is a two-step process involving a physical and a chemical change. The first part of any perm is the physical change caused by wrapping the hair on the rods. The second part involves the chemical changes caused by the perm solution and the neutralizer.

The Perm Wrap

In permanent waving, the size and type of curl is determined by the size of the rods and the type of wrapping method. Permanent waving solution, by itself, does not cause the hair to curl any more than water causes a wet set to curl. Permanent waving solution simply softens the hair, allowing it to conform to the shape in which it was wrapped. As long as a perm is processed correctly, what you wrap is what you get.

The first step in any permanent is wrapping it in the desired shape. If you have ever set someone's hair on perm rods and let it dry, you have completed the physical part of a permanent. Aside from any differences in wrapping, the major difference between a wet set and a permanent wave is in the types of side bonds that are broken. In a perm wrap, just as in a wet set, wetting the hair with water breaks the hydrogen bonds and permits the hair to be wrapped in the desired shape. A perm wrap is essentially a wet set on perm rods instead of rollers (Fig. 13–2).

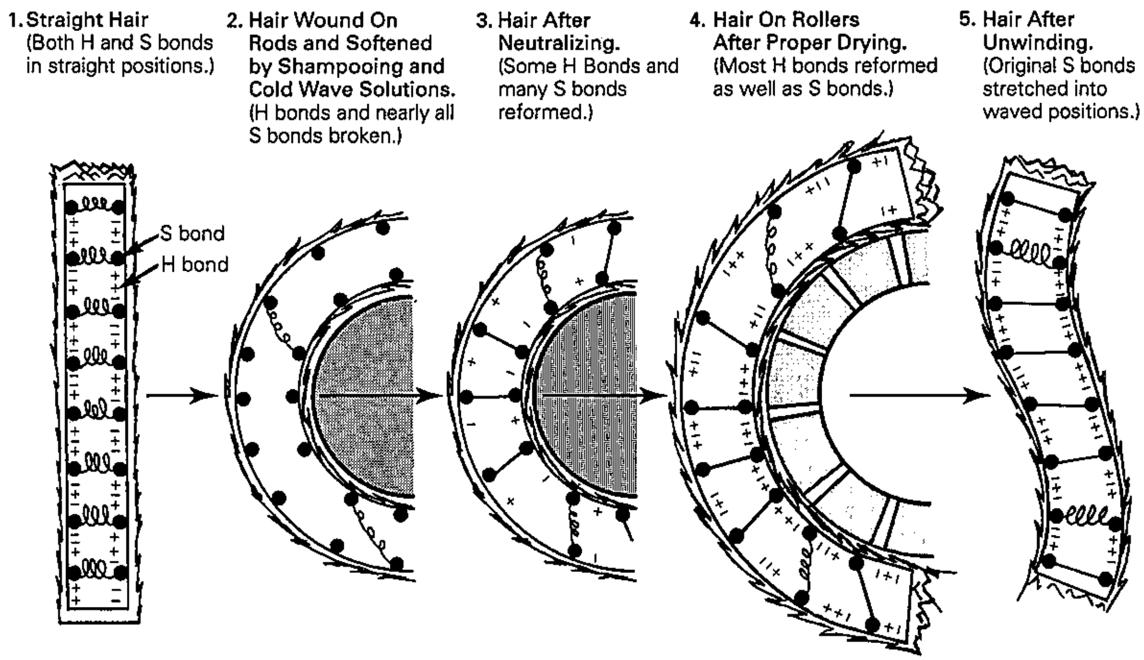

Figure 13–2 *Changes in hair cortex during permanent waving.*

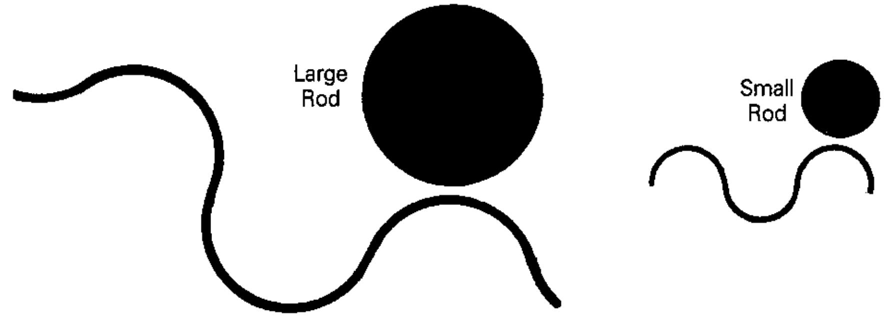

Figure 13-3 *The size of the rod determines the size of the curl. A small rod gives a tight curl and a large rod gives a loose curl.*

All other things being equal, the size of the perm rod determines the size of the curl. Small rods produce small curls and large rods produce large curls (Fig. 13–3). Wrapping the hair on small rods increases the tension, which increases the amount of curl. Although tension produces the curl, too much tension, especially in one spot, can mark or break the hair. Keep the hair wet while wrapping, and always wrap with uniform, even tension.

Croquignole Perm Wrap

In a **croquignole (KROH-ken-ohl) perm** wrap, the hair is wrapped from the ends to the scalp in overlapping, concentric layers (Figs. 13–4 and 13–5). Because the hair is wrapped at an angle perpendicular to the length of the rod, each new layer of hair is wrapped on top of the previous layer, as the rod is wrapped toward the scalp. Since the effective size of the rod increases with each new overlapping

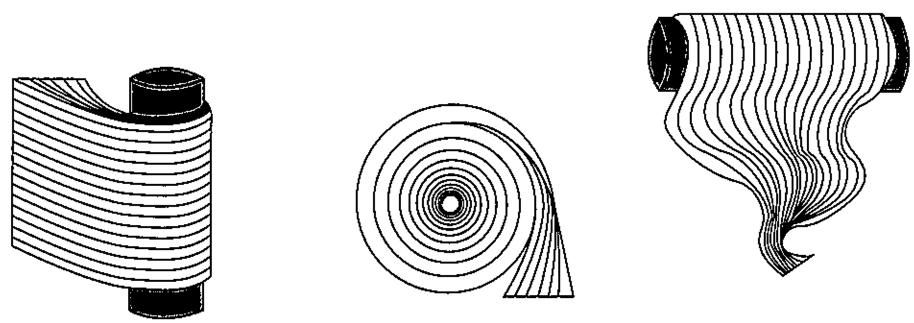

Figure 13-4 *In a croquignole perm, each layer of hair is wrapped on top of the preceding layer, which makes the effective size of the rod larger as the hair gets closer to the scalp. The resulting curl is larger at the scalp and tighter at the ends.*

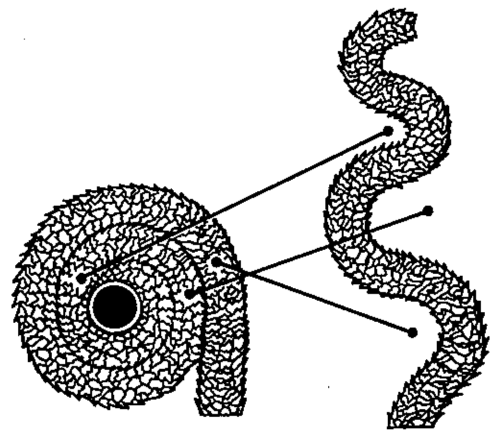

Figure 13-5 *Hair croquignole wound on a rod, giving a larger curl on the top layer.*

layer, this wrapping method produces a tighter curl at the ends and a larger curl at the scalp. Longer, thicker hair increases this effect.

Spiral Perm Wrap

Most **spiral perms** are wrapped from the ends to the scalp, although depending on the rods used, some may be wrapped from the scalp to the ends. The difference should not affect the finished curl. In a spiral perm wrap, the hair is wrapped at an angle other than perpendicular to the length of the rod. The angle at which the hair is wrapped causes the hair to spiral along the length of the rod, like the grip on a tennis racquet (Figs. 13–6 and 13–7).

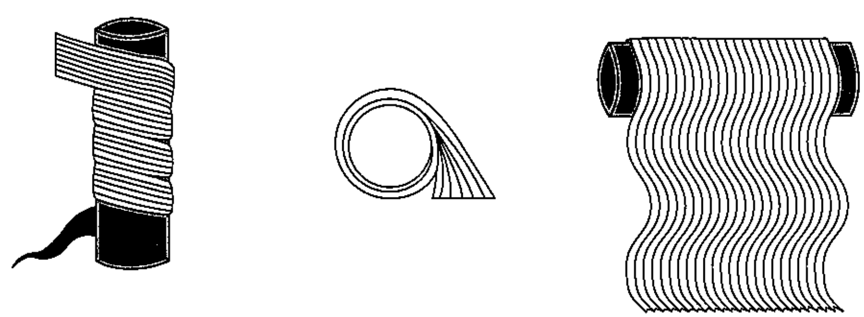

Figure 13-6 *In a spiral perm, each layer of hair is wrapped against the rod, which makes the effective size of the rod the same throughout the length of the hair strand. The resulting curl is the same size from the scalp to the ends.*

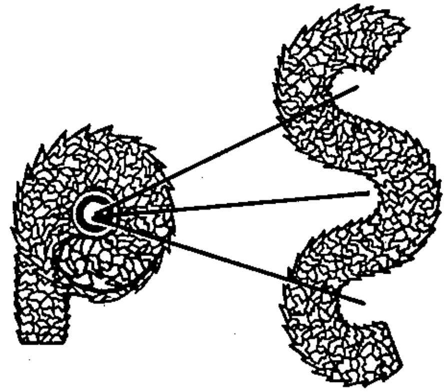

Figure 13-7 *Hair spiral wound on small rod, giving tight, even wave.*

In a spiral perm wrap, each layer of hair partially overlaps the preceding layer. As long as the angle remains constant, any overlapping will be uniform along the length of the rod and the entire strand of hair. Since the effective size of the rod remains constant along the entire strand of hair, this wrapping method produces a uniform curl from the scalp to the ends. Longer, thicker hair will benefit most from this type of perm wrap.

THE CHEMISTRY OF PERMANENT WAVING

Permanent wave solutions cause the hair to undergo a chemical change. Strong, alkaline substances cause disulfide bonds to break. Alkaline solutions also make ionic bonds repel each other, instead of attract. This will make the hair shaft swell and lift the cuticle.

Alkaline reducing agents have a high pH. These highly alkaline solutions open the cuticle and allow penetration into the cortex. At a pH level of 9, the hair shaft can swell up to twice its normal diameter.

Alkaline permanent waving solution softens and swells the hair, which raises the cuticle and permits the solution to penetrate to its target within the cortex (Figs. 13–8 through 13–11). Once in the cortex, permanent waving solution breaks the disulfide bonds by a chemical reaction called **reduction**. You should remember from Chapter 9 that a reduction reaction involves either the addition of hydrogen or the removal of oxygen. The reduction reaction in permanent waving is due to the addition of hydrogen.

A disulfide bond joins two sulfur atoms. A disulfide bond joins a sulfur atom on one polypeptide chain, with a second sulfur atom on a neighboring polypeptide chain. Permanent waving solution breaks a disulfide bond by adding a "free" hydrogen atom to each of the sulfur atoms in the disulfide bond. The sulfur atoms

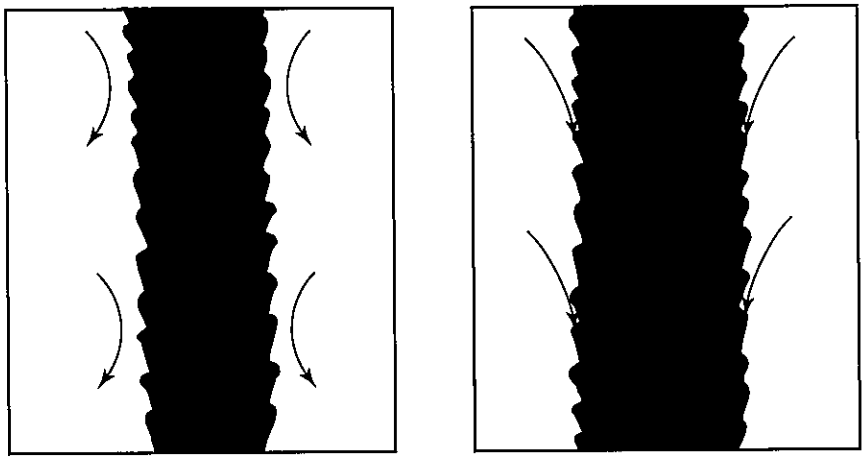

Figure 13-8 *Action of wetting agents on hair-waving solutions. Solution with wetting agent, right, allows penetration while solution without, left, does not.*

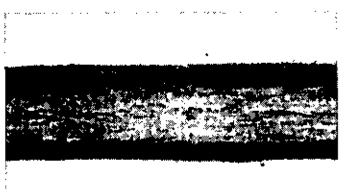

Figure 13-9 *Hair in ammonium thioglycolate solution (pH 9.4) for 5 minutes. Slight swelling of imbrications.*

Figure 13-10 *The same hair in ammonium thioglycolate (pH 12.5) for 5 minutes; severe swelling of cortex.*

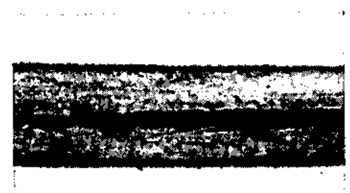

Figure 13-11 *The same hair in neutral waving solution (pH 7.5) for 5 minutes.*

attach to the free hydrogen atoms, from the permanent waving solution, and break their attachment to each other (Fig. 13–12). Once the disulfide bond is broken, the polypeptide chains are able to slip into their new curled shape.

The reducing agents used in permanent waving solutions are **thiol (THY-ohl) compounds**. They are also called mercaptans and are commonly referred to simply as *thio* (THY-oh). **Thioglycolic** (thy-oh-GLY-kohl-ic) **acid** ($HSCH_2COOH$) is the most common. Thioglycolic acid provides the free hydrogen ions (H^+) that cause the reduction reaction in permanent waving solutions and break the disulfide bonds.

The strength of the permanent waving solution is determined by the concentration of thioglycolic acid. Stronger perms have a higher concentration of

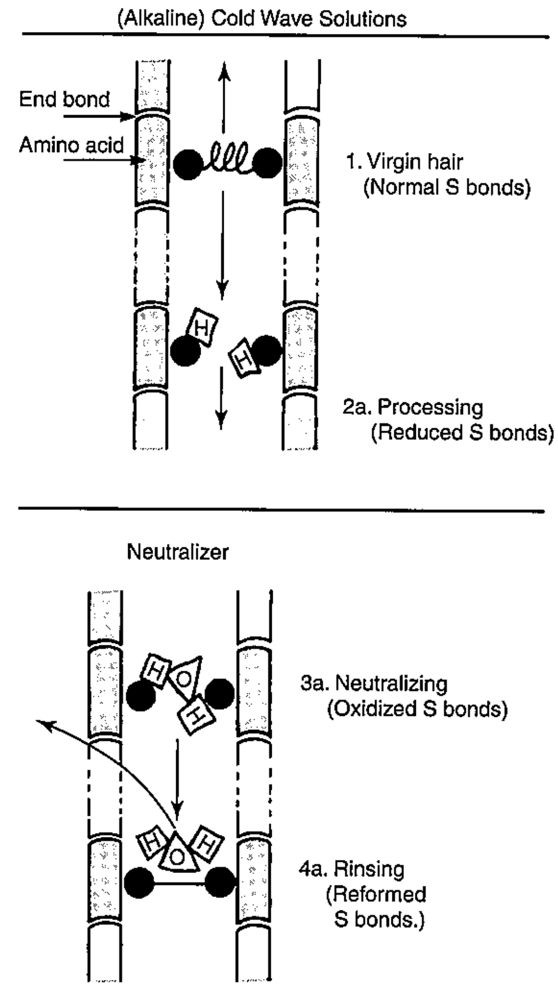

Figure 13-12 *Chemistry of cold waving.*

thioglycolic acid and a greater number of free hydrogen atoms. When more free hydrogen atoms are available, more disulfide bonds can be broken.

Since strong, thick, coarse hair contains more disulfide bonds than fine, thin hair, it needs a strong solution with a high concentration of thioglycolic acid. And since fine, weak, or chemically damaged hair contains fewer disulfide bonds than thick, coarse hair, it only needs a weak solution with a low concentration of thioglycolic acid. Strong permanent waving solutions contain higher concentrations of thioglycolic acid and are able to break more disulfide bonds. Weak permanent waving solutions contain lower concentrations of thioglycolic acid and break fewer disulfide bonds. A strong solution can break more disulfide bonds

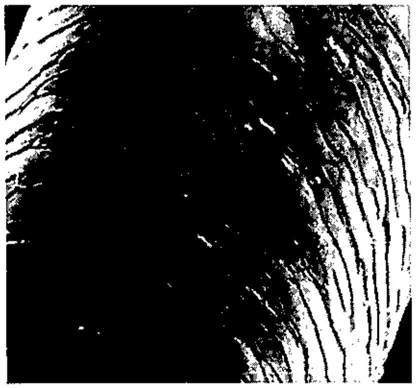

Figure 13-13 *Normal cuticle structure.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

Figure 13-14 *Resistant hair.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

Figure 13-15 *Tinted hair with high porosity.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

Figure 13-16 *Damaged cuticle with high porosity*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

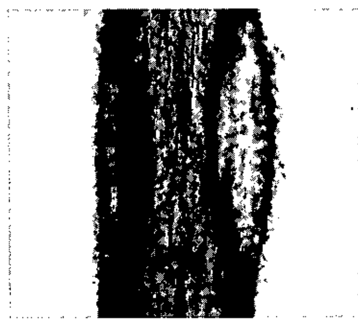

Figure 13-17 *Hair showing area of greater porosity. When cold waving, this would require preconditioning treatment to avoid this type of damage from thio.*

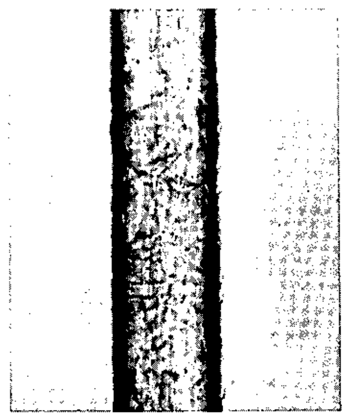

Figure 13-18 *Lightened hair after shampooing and rinsing*

than a weak solution. The strength of the perm solution should correspond to the strength of the hair.

Thioglycolic acid is an acid, and since acids don't penetrate into the cortex, it's necessary for the manufacturers to add an alkali. The addition of ammonia to thioglycolic acid makes a new chemical called **ammonium thioglycolate** (uh-MOH-nee-um thy-oh-**GLY**-kohl-ayt) ($HSCH_2COOHNH_4$). Ammonium thioglycolate is the reducing agent in most alkaline permanent waves.

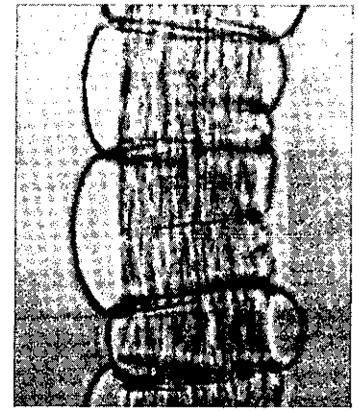

Figure 13-19 *Same hair after 5 minutes in ammonium thioglycolate (pH 9.4). Gross swelling of cuticle has detached scales from hair shaft.*

Figure 13-20 *After 8 minutes in "thio" cold-waving solution. Cortex has swelled excessively. Severe damage occurs when using alkaline-waving solutions on lightened hair.*

The degree of alkalinity (pH) contributes a second component to the overall strength of permanent waving solution. Hair with a strong, resistant cuticle layer needs the additional swelling and penetration provided by a more alkaline permanent waving solution. Fine hair or hair with a damaged cuticle layer is easily penetrated and would be damaged less by a permanent waving solution with a lower pH. The alkalinity of the perm solution should correspond to the strength and resistance of the cuticle layer.

TYPES OF PERMANENT WAVES

The Machine Wave

In 1905, Charles Nessler invented the first permanent waving machine. The hair was wrapped on metal rods that were heated by an electrical current from Nessler's machine. Twenty-six years later, other machines were developed that used pre-heated clamps that were placed over the wound curls. Although these methods worked, they damaged the hair and were dangerous for the client.

Alkaline Waves or Cold Waves

The first **alkaline waves** were developed in 1941 and relied on the same ammonium thioglycolate (ATG) that is still used in today's alkaline waves. Since alkaline waves could be given at room temperature without added heat, they also became known as cold waves. Most alkaline waves have a pH between 9.0 and 9.6. The terms *alkaline wave*, *cold wave*, and *thio* are interchangeable.

These high pH levels cause the hair shaft to swell, lifting the cuticle. Proper measuring and mixing of solution is very important. Hair will begin to dissolve above a pH value of 10. Serious errors can result from failure to follow the manufacturer's instructions. Never use any product until you read and understand the instructions.

True Acid Waves

The first **true acid waves** were introduced in the early '70s. True acid waves have a pH between 4.5 and 7.0 and use **glyceryl monothioglycolate** (GMTG) (GLIS-ur-yl mon-oh-thy-oh-GLY-koh-layt) as the primary reducing agent. Although a lower pH causes significantly less damage, acid waves process more slowly and do not produce as firm a curl as alkaline waves. Most true acid waves require the added heat of a hair dryer to accelerate processing (Fig. 13–21 and Appendix E).

Although acid waves don't swell the hair as much as alkaline waves, all permanent waves cause the hair to swell. Some swelling is essential to the chemical action of any permanent wave. Since alkaline solutions swell the hair, we expect alkaline waves to swell the hair. Since acidic solutions contract the hair, how can a true acid wave with a pH of less than 7.0 cause the hair to swell?

In Chapter 9, we learned that the average pH of hair is 5.0. So, although a pH of 7.0 is neutral on the pH scale, a pH of 5.0 is neutral for hair. Since every step in the pH scale represents a tenfold change in pH, a pH of 7.0 is one hundred times more alkaline than the pH of hair. Even pure water will damage the hair and cause it to swell.

Modern Acid Waves

In order to process at room temperature and produce a firmer curl, the strength and pH of acid waves has increased steadily over the years. Most of the acid waves

CHECKING POROSITY

More than ever, today's advanced products require special skills and training. Changing permanent waving techniques are good examples. Permanent wave success often depends on choosing the right product for a client's hair. The porosity of the hair is an important factor in this decision.

Simply described, porosity is the hair's ability to absorb liquids. Virgin hair cuticles form a tight, liquid-resistant barrier. This protective shield works much like a suit of armor.

Normal and resistant hair is not very porous. Both are resistant to chemicals and moisture, but to differing degrees. Once damaged by environmental, mechanical, or chemical factors, the cuticle no longer makes a tight shield. Damage to the cuticle makes it easier for liquids to penetrate. The greater the cuticle damage, the higher the porosity.

Evaluate the extent of damage and degree of porosity before each service. These observations help you make recommendations about salon services and home maintenance care.

Porosity is best evaluated on clean, dry hair. Check different parts of the head (i.e., the front hair line, behind the ear, and in the crown areas). Gently slide a single strand of hair between your fingers, from the tip towards the scalp. Normal to resistant hair feels smooth and silky. Roughness indicates a raised cuticle. The more damaged the hair, the rougher the texture. Using a few dozen strands, repeat the test several times.

As you gain practice, it becomes easy to recognize hair that is resistant, normal, damaged, or very damaged. Make a habit of feeling hair. You will quickly become an expert at determining other properties, such as density, texture, thickness, etc.

found in today's salons have a pH between 7.8 and 8.2, which means they aren't really acidic. **Modern acid waves** are not true acid waves but are actually *acid-balanced waves*. Because of their slightly higher pH, modern acid waves process at room temperature and do not require the added heat of a hair dryer. Modern acid waves also process quicker and produce firmer curls than true acid waves.

Glyceryl monothioglycolate (GMTG) is the primary reducing agent in all acid waves. All acids waves have three components: permanent waving solution, activator, and neutralizer. The activator tube contains GMTG and must be added to the permanent waving solution immediately prior to use. Although GMTG is the primary reducing agent, it is not usually the only reducing agent. The permanent waving solution in most modern acid-balanced waves usually also contains ammonium thioglycolate (ATG) (Fig. 13–21 and Appendix E).

Although the low pH of acid waves may seem ideal, repeated exposure to GMTG is known to cause allergic sensitivity in both hairstylists and clients.

The chances of irritant and allergic contact dermatitis are lessened if scalp and skin contact is limited.

Always wear gloves while using permanent waving lotions, especially low pH products. Watch clients closely for signs of allergy or irritation. If problems develop, suggest they see a dermatologist.

SELF-HEATING PERMS

Exothermic Waves

An exothermic chemical reaction releases heat to its surroundings. **Exothermic (ek-soh-THUR-mik) waves** involve an exothermic chemical reaction that releases heat and causes the permanent waving solution to become hot.

All exothermic waves have three components: permanent waving solution, activator, and neutralizer. The activator tube contains an oxidizing agent (usually hydrogen peroxide) that must be added to the permanent waving solution immediately prior to use (Fig. 13-21 and Appendix E). Mixing an oxidizer

TYPES OF PERMS

ACID WAVING LOTION	ALKALINE WAVING LOTION	EXOTHERMIC WAVING LOTION	NO AMMONIA LOW THIO WAVING LOTION
Ammonium Thioglycolate	Ammonium Thioglycolate	Ammonium Thioglycolate	Ethanolamine Thioglycolate
Ammonium Hydroxide	Ammonium Hydroxide	Ammonium Hydroxide	Mercaptamine
Diammonium Dithioglycolate	Diammonium Dithioglycolate	Ammonium Bicarbonate	Ethanolamine
DMDM Hydrantoin	Ammonium Bicarbonate	Dimethicone	Urea
Nonoxynol-15	Nonoxynol-15	Nonoxynol-15	Nonoxynol-15
Polyquaternium-10	Polyquaternium-28	Quaternium-75	Propylene Glycol
Sodium Borate	Glycerin	Silica	Glycerine
Fragrance	Fragrance	Fragrance	Fragrance
Water	Water	Water	Water
		EDTA	EDTA
ACTIVATOR		**ACTIVATOR**	
Glycerin		Hydrogen Peroxide	
Glyceryl Thioglycolate		Dicetyldimonium Chloride	
		Dimethicone	
		Phosphoric Acid	
		Silica	
		Water	
NEUTRALIZER	**NEUTRALIZER**	**NEUTRALIZER**	**NEUTRALIZER**
Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide
Dicetyldimonium Chloride	Dicetyldimonium Chloride	Sodium Phosphate	Dicetyldimonium Chloride
Dimethicone	Dimethicone	Polyquaternium-6	Dimethicone
Phosphoric Acid	Phosphoric Acid	Phosphoric Acid	Phosphoric Acid
Silica	Silica	Water	Silica
Water	Water		Water

Figure 13-21 *A list of common permanent waving ingredients, listed in order for easy comparison.*

with the permanent waving solution causes a rapid release of heat and an increase in the temperature. The increase in temperature increases the rate of the chemical reaction, which shortens the processing time. The rate of a chemical reaction doubles with an increase in temperature of 18°F/10°C.

Endothermic Waves

An endothermic chemical reaction absorbs heat from its surroundings. **Endothermic** (end-oh-**THUR**-mik) **waves** require heat from a hair dryer and will not process properly at room temperature. Most true acid waves are endothermic and require the additional heat provided by a hair dryer. Remember that heat increases the rate of any chemical reaction.

No Ammonia Waves

Just like haircolor and hair lighteners, **no ammonia waves** use **alkanolamines** (al-kan-all-**AM**-eenz) (Chapter 11, Color and Hair Lightening) to replace ammonia and are gaining in popularity because of their low odor. These large, organic molecules contain carbon and are not as volatile as ammonia, so there is little odor associated with their use. **Aminomethylpropanol** (AMP) (uh-**MEE**-noh-meth-yl-pro-pan-all), and **monoethanolamine** (MEA) (mahn-oh-**ETH**-an-all-am-een) are examples of organic alkalis that are used in permanent waving solutions instead of ammonia (Fig. 13–21 and Appendix E).

Although ammonia has an offensive smell, it may actually be better suited to permanent waving and less damaging to the hair. Ammonia (NH_3) is a volatile, inorganic molecule that evaporates very quickly as a gas. As the ammonia evaporates, the pH drops. That means that the pH decreases during processing. An ammonia alkaline wave that starts out at a pH of 9.6 quickly drops to about 8.2 during processing. A high pH is not necessary once the cuticle is raised and the hair has been fully saturated. It's far less damaging if the remainder of the processing is at a lower pH.

Alkanolamines evaporate slowly, which is why they don't smell. The no ammonia waves remain at the same pH throughout the entire processing time. Although the no ammonia waves may start out at a lower pH, they will remain at the same pH throughout the entire processing time. Even though alkanolamines may not smell as strong as ammonia, they can be every bit as alkaline. Ammonia free does not mean free of damage.

PERMANENT WAVE PROCESSING

The strength of a permanent wave is due to the concentration of the reducing agent and the pH of the solution. The amount of processing is determined by the strength of the permanent waving solution. If weak permanent waving solution is used on coarse hair, there may not be enough hydrogen atoms to break the necessary number of disulfide bonds, no matter how long the solution processes. But the same weak solution may be perfect for fine hair with fewer disulfide bonds. On the other hand, a strong solution, which releases many hydrogen atoms, may be perfect for coarse hair, but extremely damaging to fine hair. The amount of processing is determined by the strength of the solution, not necessarily how long it processes.

Although baking a cake twice as long will cook it twice as much, processing a permanent wave twice as long, does not necessarily mean processing it twice as much. The rate at which a cake bakes is uniform over time because energy is added to the oven during baking. A cake baked for thirty minutes will cook twice as much as one baked for fifteen minutes.

Unlike baking a cake, the rate of most chemical reactions is not uniform and diminishes rapidly. In most chemical reactions, the amount of chemical activity is determined by the concentration of the reactants. The reactants only react once and are "used up" as they form products. So, as the concentration of reactants diminishes, so does the rate of the chemical reaction. In permanent waving, most of the processing takes place as soon as the solution penetrates the hair within the first five to ten minutes (Fig. 13–22). The additional time involved in processing allows the polypeptide chains to shift into their new configuration.

This means that if the hair is overprocessed, it probably happened within the first five to ten minutes and a weaker permanent waving solution should have been used. This also means that if the hair is not sufficiently processed within the first five to ten minutes, it probably never will be and a stronger solution, or a more thorough saturation of solution, may be needed.

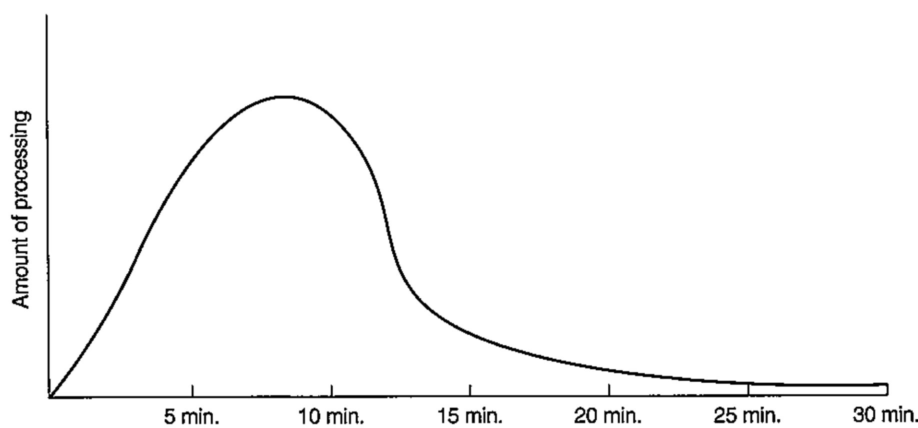

Figure 13–22 *The graph shows that the rate of most chemical reactions is not uniform over time. The rate of reaction begins slowly until the chemicals penetrate the hair, then drops sharply as the reactants are "used up" and converted to products. Most chemical reactions have very little chemical activity after 20 minutes.*

Thorough saturation of the hair is essential to proper processing in all permanent waves, but especially on resistant hair. Regardless of the strength of the solution, resistant hair may not become completely saturated with just one application of waving solution. Continue to apply solution slowly until the hair is completely saturated. If the hair is not saturated sufficiently, it will not process properly. If the curl development is not sufficient after ten minutes and the hair is not wet and completely saturated, reapplication of the waving solution may be necessary.

Stronger solutions will process the hair more, but processing the hair more does not necessarily mean more curl. A properly processed permanent wave should break and rebuild approximately 50 percent of the hair's disulfide bonds. If too many disulfide bonds are broken, the hair may not have enough strength to hold the desired curl. Weak hair equals a weak curl.

Contrary to what many believe, over processed hair is not overly curly. If too many disulfide bonds are broken, the hair will be too weak to hold a firm curl. Over processed hair usually has a weak curl or may be completely straight. Since the hair at the scalp is usually stronger than the ends, overprocessed hair is usually curlier at the scalp, and straighter at the ends. If the hair is overprocessed, processing it more will make it straighter.

Underprocessed hair is exactly the opposite. If too few disulfide bonds are broken, the hair will not be sufficiently softened and it will be unable to hold the desired curl. Underprocessed hair usually has a weak curl, but it may also be straight. Since the hair at the scalp is usually stronger than the ends, underprocessed hair is usually straighter at the scalp, and curlier at the ends (Fig. 13–32). If the hair is underprocessed, processing it more will make it curlier.

Figure 13-23 *Hairline protected by cotton strips or neutralizing band.*

Figure 13-24 *Application of waving lotion.*

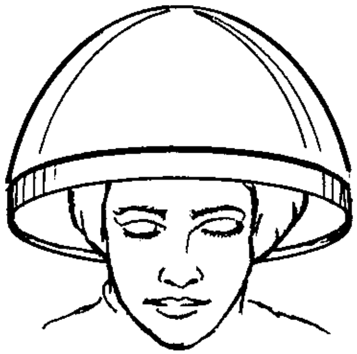

Figure 13-25 *Placing a client under a pre-heated dryer accelerates processing.*

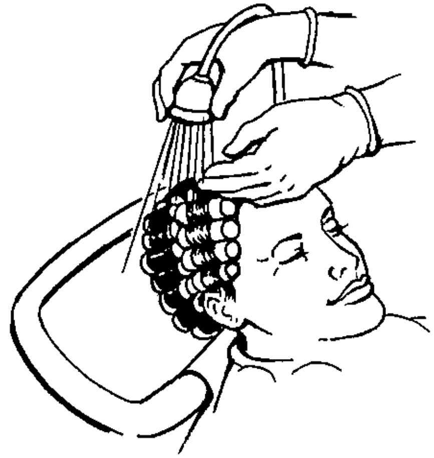

Figure 13-26 *Thorough rinsing with warm water is essential to remove all traces of excess cold-waving solution from the hair.*

Figure 13-27 *When rinsing is completed, the neutralizer is carefully applied to the hair on the rods.*

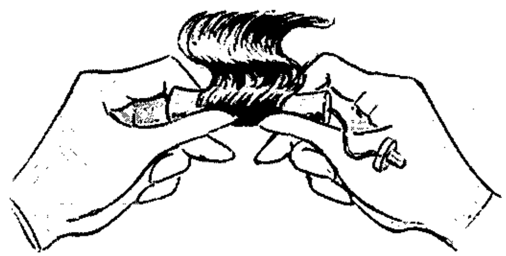

Figure 13-28 *Method of taking a test curl to determine processing time.*

It is important to develop a foolproof system for timing permanent waving services. Use a timer with an alarm. Check the wave development progress often. This improves the quality of service and will help avoid overprocessing. Improper timing may cause delayed action chemical burns that might not appear until several hours later.

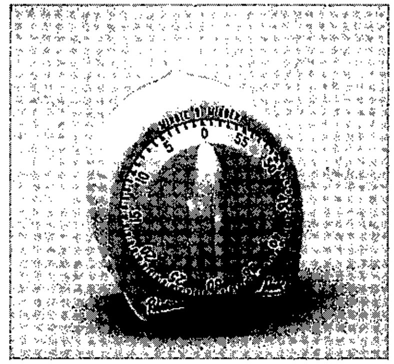

Figure 13-29 *Proper timing is essential when performing a perm service.*

Figure 13-30 *The temperature of the perming process can have an important bearing on effective waving.*

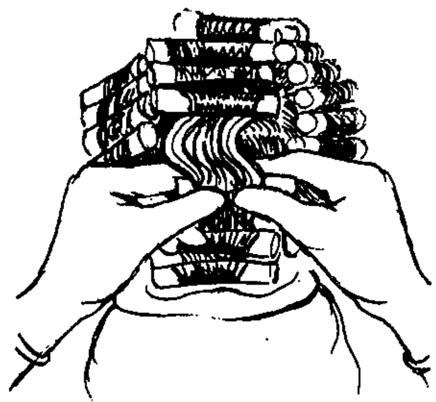

Figure 13-31 *Improper winding technique can cause perm failure.*

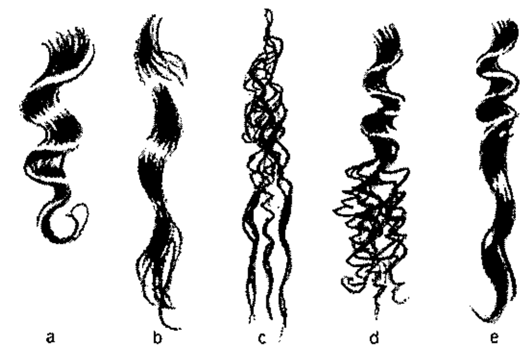

Figure 13-32 *Curl results: a. good results; b. underprocessed curl; c. over-processed curl; d. porous ends; e. improper winding.*

NEUTRALIZATION

Proper neutralization performs two important functions. A neutralizer gets its name because it neutralizes any waving solution that remains in the hair. Neutralization also rebuilds the disulfide bonds that were broken by the waving solution.

The name **neutralizer** is not accurate because the chemical reaction involved is oxidation. Neutralizers are actually oxidizers. The most common neutralizer is hydrogen peroxide. Concentrations vary between 5 volume (1.5 percent) and 10 volume (3 percent). Other types of neutralizers are sodium bromate ($NaBrO_3$), and sodium perborate ($NaBO_3$). Non-peroxide neutralizers are more stable than peroxide, but they aren't more effective or less damaging.

Although the neutralizer will neutralize any remaining waving solution, the chemical reaction involved is oxidation. Remember that exothermic waves get hot when an oxidizer is mixed with the waving solution, and oxidation reactions also lighten hair color, especially at a high pH. To avoid scalp irritation and unwanted lightening of hair color, always rinse the hair for at least five minutes, prior to applying the neutralizer.

After a thorough rinsing and before applying the neutralizer, most manufacturers recommend that the hair be blotted with towels to remove excess moisture. Excess water left in the hair dilutes the neutralizer and prevents uniform saturation.

Neutralization also rebuilds the disulfide bonds that were broken during processing. You should remember from earlier in this chapter that the waving solution breaks disulfide bonds by adding hydrogen atoms to the sulfur atoms in the disulfide bond. Neutralization rebuilds the disulfide bonds by removing those extra hydrogen atoms.

The hydrogen atoms in the disulfide bonds are so strongly attracted to the extra oxygen atom in the neutralizer that they release their bond with the sulfur atoms and join with the oxygen (Fig. 13–12). Each oxygen atom attaches to two hydrogen atoms to rebuild one disulfide bond and make one molecule of water ($H_2 + O \rightarrow H_2O$). The water is removed in the final rinse and the sulfur atoms form new disulfide bonds in their new curled position.

When the neutralizer removes the extra hydrogen atoms, each sulfur atom forms a new bond with its nearest neighboring sulfur atom. This is not the same pair that was originally bonded, but a newly created pair, which will hold the hair in the new shape (Fig 13–33).

The neutralizer in a permanent wave performs the same function as a hairdryer does in a wet set. In a wet set, the hydrogen bonds are broken by water. When the water is removed by drying, the hydrogen bonds are reformed. The hairdryer simply speeds up the drying process, which makes the hair dry quickly. The hairdryer isn't needed in a wet set. Given enough time, the hair would dry on its own. Once the hair is dry, the hydrogen bonds are reformed.

When neutralizing a permanent wave, the neutralizer adds oxygen to the hair and rebuilds the disulfide bonds. The neutralizer provides a high concentration of liquid oxygen, which simply speeds up the process and rebuilds the disulfide bonds quickly. At one time, neutralizer was called instant neutralizer.

Once a permanent wave is processed, rinsed, and blotted, it's ready for neutralization. Although liquid neutralizer is usually used, it's not really necessary. Neutralization can take place naturally without a liquid neutralizer. If the hair has

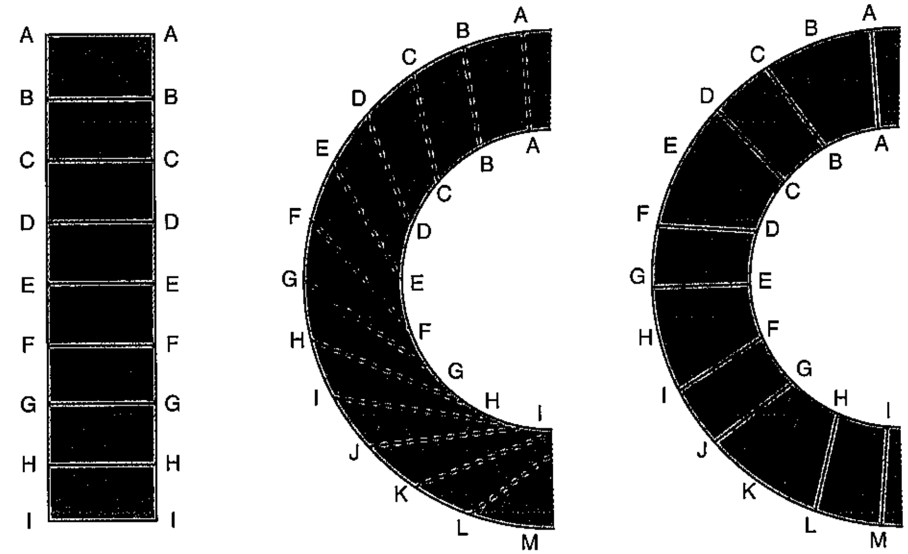

Figure 13-33 *Diagram shows the tension placed on the side bonds when hair is stretched around the perm rod. The broken side bonds are then reformed, into their new shape, as different pairs.*

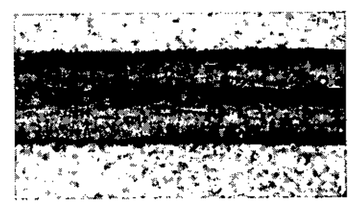

Figure 13-34 *Hair in cold-wave neutralizer (pH 3.0). Note droplets of conditioner in o/w type.*

been properly processed, rinsed, and blotted, it can be left to neutralize on its own. Given enough time, the hair draws oxygen from the atmosphere, which performs the same function as the oxygen in the liquid neutralizer. Once the hair is dry, neutralization is complete. It's really not any different than letting a wet set dry on its own without a hairdryer.

All safety precautions previously described for oxidizers should be used. There are many different methods for applying and neutralizing permanent wave products. It is important to follow manufacturer's instructions and the rules of working safely. This is especially true for perm rinsing and neutralizing.

Proper rinsing and neutralization are vital to the success of the permanent wave. Reducing agent is found deep within the cortex. The waving process can only be halted by completely rinsing and neutralizing the hair. Improper neutralization may cause a 20 percent loss of hair strength. Scalp burns can also result from improper rinsing and neutralization. The client may not feel pain until several hours later (Figs 13–24 and 13–25).

Use only the manufacturer-recommended neutralizer with the perm lotion. Never mix brands or systems.

Powdered neutralizers contain oxidizers, usually sodium bromate or sodium perborate. Follow all safety precautions previously described for powdered oxidizers. Wear a dust mask while mixing or measuring these products and work in a properly-ventilated area. Be sure to wear safety glasses and gloves, as these chemicals are potential eye and skin hazard.

Caution: Serious accidents can occur when hairstylists mistakenly use neutralizers instead of water as permanent wave lotion rinses. Intense heat can be generated if the hair is not first rinsed thoroughly with water. This error may seriously burn a client's scalp.

WAVE SAFETY

Ammonium thioglycolate (ATG) and ammonia are responsible for the odor associated with permanent waves. Permanent wave odors are a great concern to hairstylists and clients. Many fear the odor is dangerous to their health, but odors themselves are not a danger. *In fact, odors can help you work more safely. Never judge a product's safety by its odor.*

An odor is caused by vapors touching the highly sensitive detectors in the nose. After the vapors leave the nose and enter the lungs, odor is no longer important. The lingering perm solution odor is from sulfur in the ATG. Hair and eggs both contain high amounts of sulfur, which is why perm odor is often described as smelling like rotten eggs.

Manufacturers often put fragrances into perms to help mask the odor. The reason is to remove some of the offensive smell, not to make the product safer. Simply removing or covering odors does not make the air any safer. Odors are no indication of a product's safety. In fact, odors can warn against overexposure.

Don't be fooled into believing that nicer smelling products are better or safer. The opposite is true, as well. Don't assume that foul smelling chemicals are dangerous to breathe. Permanent wave solutions are an excellent example. Perms smell foul, but the odor is not dangerous. Consult the MSDS to determine a product's potential hazards. Hazardous chemicals don't always smell unpleasant. Many are rather agreeable.

Of course, as previously discussed, always work with proper ventilation. Lowering inhalation exposure time is an important way to protect your health.

Many hairstylists take steps to avoid perm odors but fail to wear gloves or safety glasses. The real potential hazard for both alkaline and acid balance products is skin irritation and eye damage.

Figure 13–35 *Examples of hair damage caused by improper permanents.*
(Courtesy: A. Langsam)

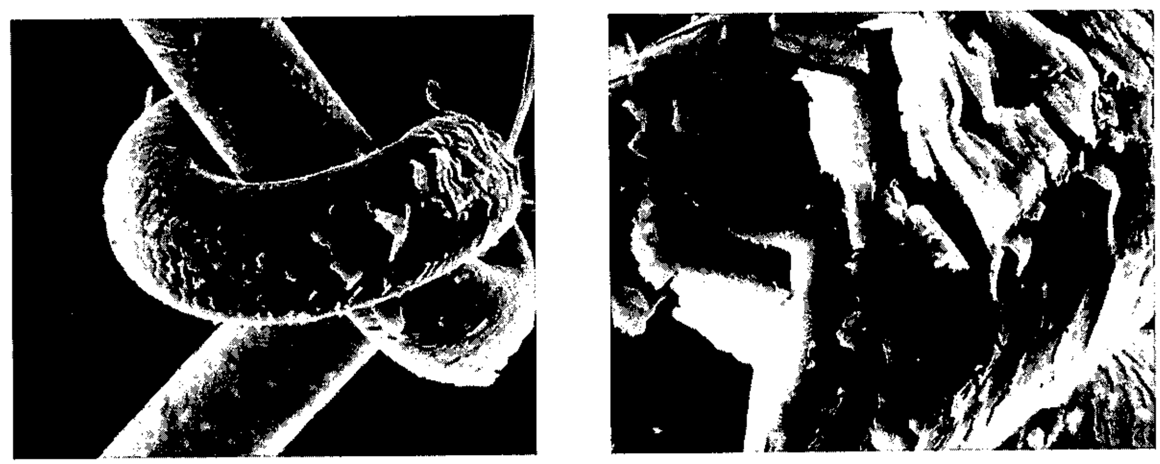

Figure 13–36 *Permanent-waved hair tied into a knot, shown at 630 times (left) and 1,600 times (right) magnification, emphasizes the cuticle damage caused by permanent waving.*
(Courtesy: Gillette Company Research Institute, Rockville, Maryland)

Scalp irritation (irritant contact dermatitis) may result from contact with the highly alkaline perm lotions.

Carefully examine the scalp and hair before beginning a perm procedure. Look for signs of scalp irritation, redness, tender or puffy tissue, open sores, excessive dryness, or other skin problems. If you spot a problem, advise the client to see a dermatologist before proceeding.

Alkaline substances are serious eye hazards. They may chemically react with eye protein and create a water-insoluble film. This film makes it difficult to flush the eye properly.

Permanent wave lotions and neutralizers are potentially dangerous to the eyes. Should eye contact occur, flush the eye immediately with warm, running water; then call a physician! Some chemicals have delayed effects and cause damage many hours later, if not properly treated.

To avoid accidents, wear proper eye protection. Use cotton bands to prevent products from dripping into the client's face. Clients expect you to protect their health.

Perm Problems

Hair is the fastest growing appendage of the human body. Anything that affects our general health also affects our hair. Diet, exercise, medications, and stress all affect the growth of our hair. The quality of any permanent wave corresponds to the quality of the hair. Strong hair usually produces strong curls, but weak hair usually produces weak curls.

Although it is sometimes suggested that factors such as menstrual cycle, pregnancy, surgeries, medication, etc., affect the final outcome of permanent waves, these beliefs have no scientific basis. The hair emerges from the scalp fully formed and keratinized. It is doubtful that hair that originated in the scalp years ago could be affected by one's menstrual cycle or pregnancy. No one has yet to prove a link between medications and permanent waving.

Permanent waving of hair involves science. More than likely, excuses for poor outcomes are simply that; excuses for doing a poor job.

Several factors for possible permanent wave failure are listed below:

1. Taking too large or too small a section
2. Using too much alkali product or improper mixing
3. Improper winding techniques or using the wrong rod size
4. Too short or long of a processing time
5. Failing to do a test curl
6. Improper rinsing and neutralizing
7. Incorrectly judging the hair's porosity, elasticity, and texture
8. Using the wrong product for the client's hair type
9. Not following manufacturer's directions
10. Not paying enough attention to directions and/or procedure

These reasons for perm failure make more sense than the excuses. If you patronize a fine restaurant and the food is terrible, would you blame the chef, or the ingredients? The same holds true for beauty salons. Clients come to the salon expecting professional results. They are looking for something better than they can do at home. Be sure you can provide the professional services clients are seeking.

Review Questions

1. List and define the four major types of chemical bonds of the hair.
2. What part do reduction reactions play in permanent waves?
3. How do reducing agents and oxidizers work together to create a permanent wave?
4. Define hair shape and how it can be altered.
5. What are the major differences between alkaline and acid-balanced perms?
6. Explain why perm solutions have a strong characteristic odor.
7. Why are alkaline materials generally considered eye hazards?
8. Why is it important not to add additional alkaline material to perm lotions?
9. What could happen if perm lotion is not rinsed completely from the hair before neutralizing?
10. List all of the reasons why perms fail.

Discussion Questions

1. What types of permanents contain potential sensitizers. How should hairstylists deal with this problem?
2. Discuss the action of reducing agents on the hair. How do they work?