

The Science of Reactive Hair Care Products

A review of changing natural hair appearances to meet consumer expectations is offered in this chapter.

key words: permanent wave, relaxer, oxidative color, bisulfite, disulfide, oxidation, alkaline, relaxers, pigmentation

Background

The physiological function of hair on humans is insignificant compared to its psychological significance. Humans place great social value on the color, texture, shape and appearance of hair. The properties that are prized vary from time to time and culture to culture, but what remains constant is that people generally want their hair to be different in some regard than it exists in its natural state. This very basic desire to alter the appearance of the hair has resulted in the need for many different procedures and processes for safely altering the hair. Providing the desired color, tint, texture, straightness, and other cosmetically appealing properties to the hair while avoiding damaging the hair and causing irritation of safety issues to the hair is a key challenge to the cosmetic chemist and the topic of this chapter.

During formal education, chemists are taught how to control chemical reactions. In making the transition from academia to the cosmetic industry, chemists may be surprised to find that reactions are generally undesirable in personal care products because they may well have negative effects associated with the reaction. Unwanted reactions in a cosmetic product may interfere with its stability and, even more important, the wrong reaction could have dangerous side effects on hair and skin. Most of the procedures and processes carried out by the cosmetic chemist do not include reactive processes. Wetting, foaming, conditioning, and emulsification performed on the hair are physical processes caused by selection of the proper molecule added to the formulation.

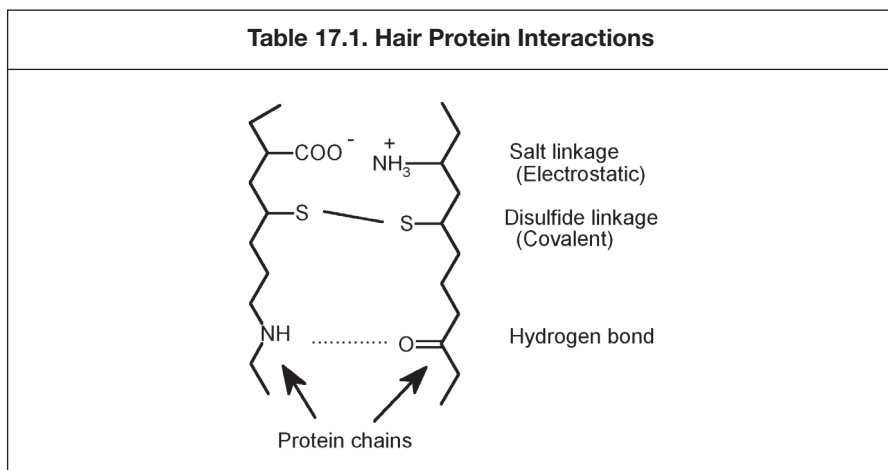
Nonetheless, reaction chemistry does play an important role in at least one major category of personal care products. These products are intentionally designed to cause reactions that have beneficial effects on hair: relaxers, permanent-waving products and oxidative hair colors. This chapter introduces this class of reactive hair care products and their chemistry.

A. Permanent Waving

In the interest of fashion, a wide variety of changes are made to hair in its natural state to provide properties that are of interest. The first to be addressed is shape. Almost an unlimited amount of curl can be placed into, or removed from the hair. It is desirable to style hair into attractive configurations and to have it hold its shape for an extended period of time. Shaping hair (providing it with wave), has been practiced for centuries in one form or another.¹ In the early 1900s, waving was accomplished by heating hair with cumbersome and dangerous electrical devices.² During the past 50 years, cosmetic science has developed increasingly effective chemical techniques to impart a lasting wave or curl to hair. This process is known as permanent waving or perming. The adjective “permanent” is a bit of a misnomer because the wave only affects existing hair at the time of treatment; as new hair grows out of the scalp, it will grow in its original, unwaved configuration. Permanent-wave products are available in different forms known as acid, cold or neutral waves. The technology employed in these products is based primarily on two types of chemicals: thioglycolates and bisulfites.

Before beginning the discussion of how permanent waves work, it should be understood by the reader that the science of reactive hair care products is very involved and that this chapter is meant only as an introduction for the uninitiated chemist. A number of technical articles describe these processes in detail.^{3,4,5} To understand the basics of permanent waving, it is important to realize that hair is composed of helical protein structures. Protein structures are made up of amino acids linked in a peptide bond. The sequence of the amino acids is referred to as primary structure. This structure cannot be modified without destroying the hair. However, what can be modified is the interaction of sulfur rich amino acids. These amino acids can bond with each other and form crosslinked protein polymers by sulfur-sulfur bonds. This reaction results in a structure to the protein that alters the shape of the hair. The structure of hair showing the sulfur-sulfur interaction is shown in **Table 17.1**.

Table 17.1. Hair Protein Interactions



These bonds are responsible for hair's structure, and they can be disrupted by certain reducing reactions. (An experienced chemist will note that this explanation is a simplified version of what is, in reality, a very complex process.)⁶

As previously noted, the most common reducing agents are thioglycolic acid derivatives and bisulfite. These chemicals are used more than any others because they have the best history of efficacy and have been the workhorses of the permanent wave industry since the 1940s. Highly effective permanent-waving solutions can be formulated by combining these reactive agents with other ingredients to control pH and viscosity.

The process: The first step in the perming process is to physically rearrange the original configuration of the hair on curlers or rods. The size of the rod determines the size of the curl. Before rolling hair onto the plastic rods, thin sheets of tissue paper, known as "end wraps," are used to cover the ends of the hair. These end wraps help the hair hold the proper configuration and protect the fragile ends by absorbing excess perming solution.

When all the plastic rollers are in place, apply the perming solution and work into the hair. During this stage of the process, the sulfur-sulfur bonds of the hair break. The length of time required for this stage depends on a number of factors, including the strength of the perm solution, the degree to which the hair will be restructured and the condition of the hair. During this processing step, the hair is plasticized as the disulfide bonds controlling its original structure are disrupted. Some types of perming products require the use of heat from a hair dryer to accelerate the reaction.

After a set amount of time, the hair is rinsed with water to stop the reducing action. Next, a neutralizing solution is added to oxidize the protein residues. This oxidation step relinks the sulfur-sulfur bonds. However, because the hair has been stretched and curled on plastic rods, the newly rearranged disulfide bonds hold the hair in a curled arrangement even after removing the plastic rods.

Achieving a good permanent wave depends on proper control of the reduction and oxidation reaction kinetics so hair is not under- or over-processed. A detailed discussion of protein reaction kinetics is beyond the scope of this chapter but several excellent references are provided for the technically ravenous reader.⁷ It is important for the chemist to understand that the perming process causes significant damage to hair because of the breakage of the bonds and the swelling that ensues. This swelling action results from exposure to the highly alkaline materials and can cause significant cross-sectional or lateral damage. Damage can also occur when treating improperly wrapped hair with a reducing solution.

Permanent wave formulations: In general, perms contain a number of ingredient classes (**Table 17.2**).⁶

These ingredients are formulated into three general types of perms: alkaline, acid and bisulfite. Alkaline perms, also known as cold waves, use thioglycolic acid as the active. This name may seem like a misnomer, but the name is derived from the final pH of the product. Alkaline perms typically have a pH greater than 9. Borish gives examples of commercial products in each of these categories.⁸ He also