

Name _____ Period _____ Article # _____

SHAMPOO – pH and Solubility

Read the accompanying article “pH and Hair Shampoo,” *ChemMatters*, April 1983, pp. 8-9.
Answer the following questions completely.

1. What are the three main functions of sebum secreted by the scalp?
 - (1)
 - (2)
 - (3)
2. Use the concept of “like dissolves like” to explain how detergent removes grease from your hair.
3. What are the three types of connections between protein chains in your hair?
 - (1)
 - (2)
 - (3)
4. Which connection(s) are broken by water?
5. Which connection(s) are broken in strongly acidic solutions?
6. Which connection(s) are broken in slightly alkaline solutions (pH 8.5)? How does this affect the hair?
7. Which connection(s) are broken in strongly alkaline solutions (pH 12)? How does this affect the hair?
8. What is the optimum pH range for hair strength? _____
9. How do acid rinses counteract the effect of alkaline shampoos?
10. How do conditioning rinses counteract the effect of alkaline shampoos?

Commercial hair shampoo advertisements often mention the topic of pH (see card insert in this issue for an explanation of pH). Does the control of pH make your hair cleaner, shinier, bouncier, or stronger?

Hair Cleansing

The sebaceous glands in the scalp secrete a continuous flow of sebum, a greasy, semiliquid substance composed primarily of glycerides (50%). Waxes, fatty acids, and squalene, an intermediate in the biosynthesis of cholesterol, are the other major constituents of sebum. The sebum serves several functions. First, it coats the cuticle, or outer layer of the hair, preventing loss of water from the inside of the shaft. This water inside the shaft keeps the hair soft and flexible. Second, the sebum coating makes hair look smooth and shiny. It also prevents the growth of bacteria, such as streptococci, and spread of fungus infections, such as ringworm, on the scalp.

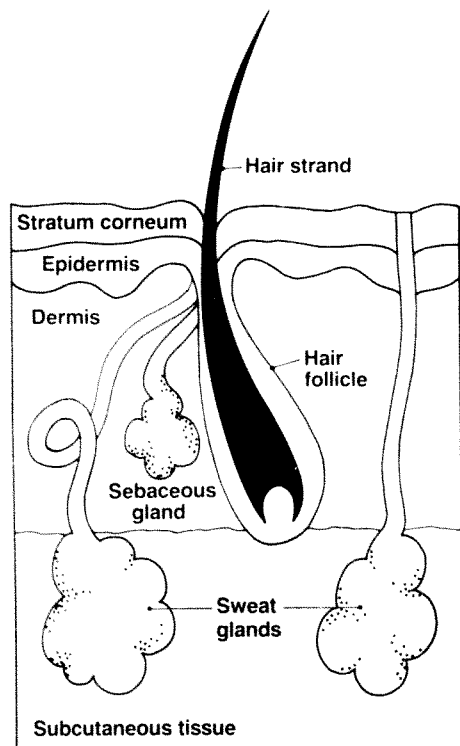
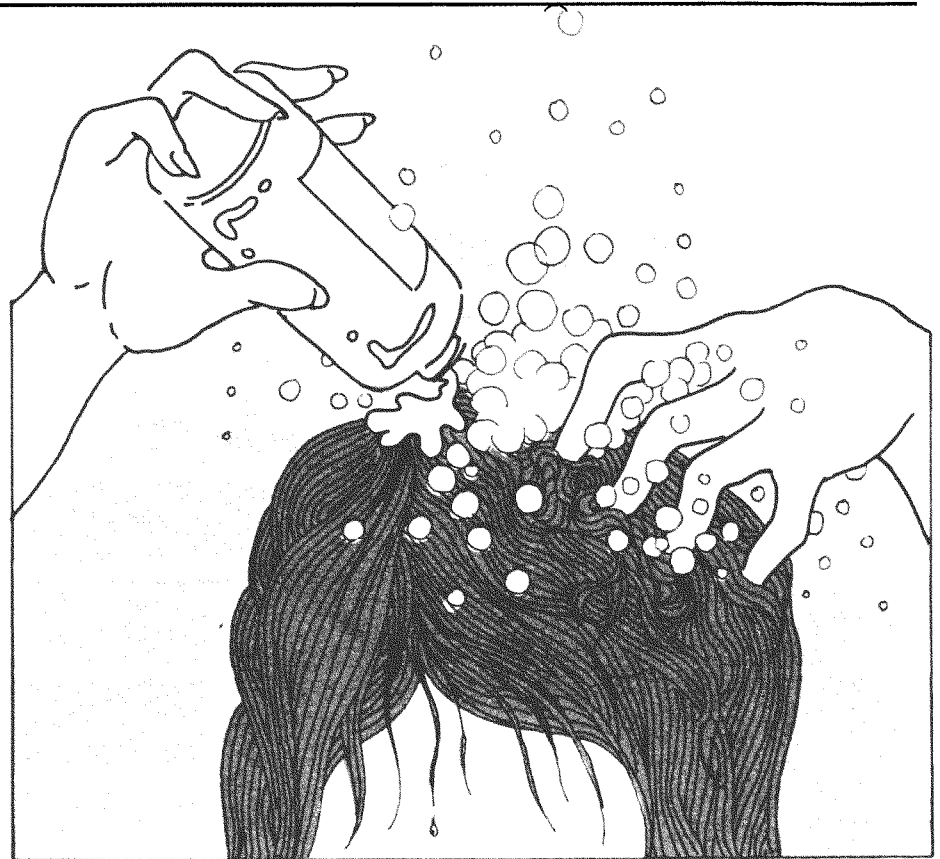


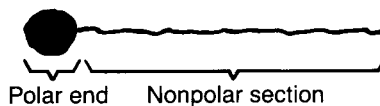
Figure 1. A layer of skin in cross section showing the hair follicle and hair strand



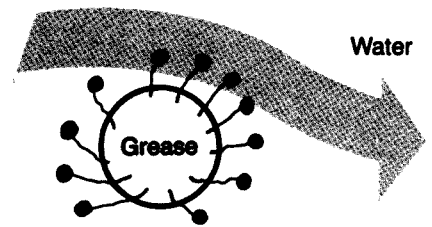
However, because sebum is sticky, it attracts dirt, eventually making hair look dull and dirty. Shampoos are supposed to remove the dirt and excess sebum, leaving a light coating of sebum on the hair and the scalp. How well a shampoo cleans depends on the detergent used in the shampoo.

A detergent molecule contains two major sections: a polar and a nonpolar portion.

The nonpolar portion is soluble in grease and oil, which are also nonpolar, while the polar end is soluble in water, a polar solvent. A simplified representation of a detergent molecule is as follows:



The detergent coats the grease, allowing the grease to be dispersed in water. The grease can therefore be rinsed away with additional water.



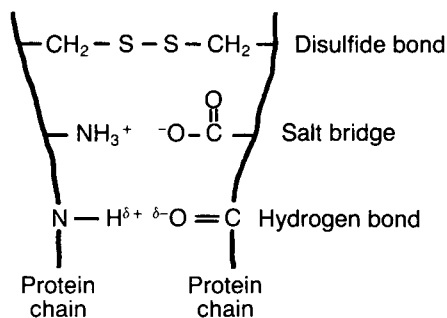
Detergent molecules produce alkaline solutions (solutions with a pH greater than 7) when reacted with water. However, this does not necessarily mean that a very alkaline pH is desirable in a shampoo. The effects of an alkaline pH on the *nature* of hair must also be considered.

Hair Damage

Each strand of hair consists of many long, parallel chains of amino acids. These chains, or polymers, of amino acids are made of proteins. There are three ways in which these long chains can connect to each other: 1) hydrogen bonding; 2) salt bridges between

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acid and base groups; and 3) disulfide bonds. These three types of attachments, called "side-chain bonding," are shown holding two protein chains together in the following figure:



Water will reversibly break the hydrogen bonds. This makes wet hair easy to shape and set. When the water evaporates, hydrogen bonds form at new positions, holding the hair in this set.

In strongly acidic solutions where the pH is 1.0 to 2.0 both hydrogen bonds and salt bridges are broken. The disulfide bonds, however, can still hold the protein chains together in the strand of hair.

At a slightly alkaline pH of 8.5, some disulfide bonds are broken. This causes the cuticle or outer surface of the hair strands to become ruffled. This roughness catches light unevenly and makes the hair look dull. Repeated washing with slightly alkaline shampoo will damage the hair by breaking more and more of these disulfide bonds. This is one cause of the dreaded "split ends."

At a pH of 12, which is a strongly alkaline solution, all three types of bonds are broken, and the hair dissolves! Commercially available depilatories, such as Neet® and Nair®, contain strong alkaline ingredients.

Hair is normally acidic. Human skin has a pH between 3.0 and 5.0, and hair has its maximum strength in a pH range of approximately 4.0 to 5.0. Shampooing often leaves hair alkaline. To restore the hair's naturally acidic pH, acid rinses can be used. The old-fashioned acidic rinses such as lemon

juice, which contains citric acid, and vinegar, which contains acetic acid, are generally sufficient to counteract the temporary effects of alkaline shampoos.

Commercial treatment such as bleaching, dying, or a permanent, as well as blow drying and the use of electric curlers, can also leave the hair without its protective sebum. Conditioning rinses put back this oily coating, often penetrating the hair shaft itself. Because conditioners cling best to the damaged portion of the hair where the cuticle has become ruffled, thorough rinsing usually removes the conditioner from healthy sections of the hair, and the conditioner works only where it is needed. Too much or too heavy a conditioner will not damage hair, but it can make the hair stickier. The dirt attracted to this sticky hair often may make more shampooing necessary.

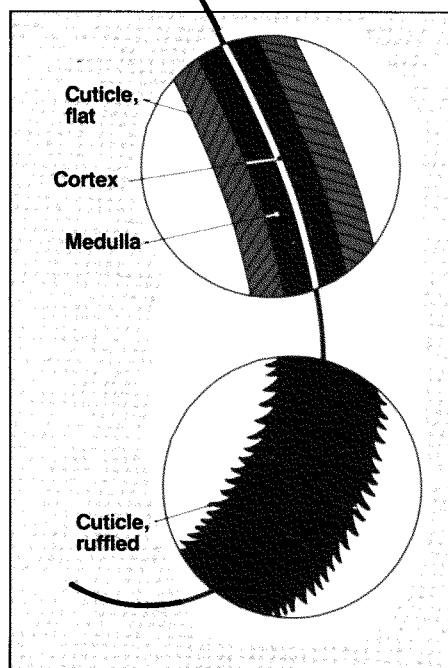


Figure 2. A hair is a cortex, surrounding a hollow medulla, sheathed by a scaly cuticle layer. If harsh shampoos ruffle the cuticle (bottom) hair tangles and looks dull. Bleaching, curling, and blow drying can damage the cuticle, exposing the cortex to damage. Conditioners or sebum from the scalp make the cuticle lie flat (top).

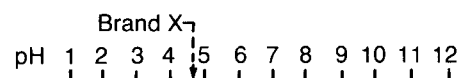
Shampoos that are "acid balanced" and promise to maintain the normally acid pH of hair usually contain an acid such as citric acid to counteract the alkalinity of detergents. Conditioning shampoos contain an oil such as lanolin. Since shampoos are designed to remove oil from the hair, the effectiveness of such conditioning shampoos is debatable.

An Experiment

What are the pH values of some hair shampoos?

Determine the pH of your shampoo using pH paper or a pH meter. You may wish to determine the pH of the shampoo itself and also determine the pH of a dilution of the shampoo with water. Why? (A suggested dilution is 1.0 mL of shampoo with 9.0 mL of water.)

Compare the pH value of your shampoo with other values from your class. What pH range of results was obtained? You may wish to chart the class results as shown below:



The experiment can be repeated using rinses or conditioners in place of the shampoos.

Questions

1. Do shampoos of similar pH contain similar ingredients?
2. Is there any relationship between pH and the "tear-free" property of baby shampoo?
3. Do the "acid-balanced" shampoos have different pH values than normal shampoos?

References

- Corcoran, F.; Akona, K. "The pH of Hair Shampoos: A Topical High School Experiment." *Journal of Chemical Education*, 54:553-54, 1977.
- Rinzler, C. A. "The New and Improved Chemistry of Cosmetics." *Science* 82, 3:54-61, April 1982.