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Dissolving Plastic

by Clair G. Wood

Walter K. was the only patient in his hospital room because his leg injury was not healing properly. Fluid drained from the wound, making it highly infectious. In the corridor, the duty nurse put on a disposable gown, gloves, face mask, and cap, then entered the room to change Walter's bandage. The nurse placed the contaminated dressing in an impenetrable plastic bag, sealed the bag, placed it in a second bag, and labeled the entire package for transport to the incinerator. Such a procedure prevents the infectious material from coming in contact with anyone or anything else in the hospital. Next, the nurse placed Walter's gown, sheets, and pillowcase in an impenetrable plastic laundry bag and sealed the bag. The nurse carried the laundry bag to the corridor, where an assistant held open a larger, second bag into which the nurse placed the plastic laundry bag. The assistant closed the outer bag and labeled it for transport to the hospital laundry.

In the laundry room a worker opened the outer bag, removed the inner bag, and—without opening the plastic laundry bag—tossed it into the washing machine. As it sank in the hot water and detergent, the plastic bag dissolved, releasing its contents.

Plastic films

Most hospitals put laundry in dissolving plastic bags that don't have to be opened and thus prevent the spread of infectious microbes throughout the hospital. Obviously, such laundry bags are not made of ordinary plastic film. They are made of material that is strong and airtight under room conditions but dissolves quickly in hot water. Why does the plastic do this?

Plastic films are made of *polymers* and come in many different kinds. Sandwich bags and trash bags are made of *polyethylene* film. Shower

curtains, umbrellas, and raincoats are often made of *polyvinyl chloride* film (see box, "Polymers"). The chemists who developed these materials knew that a film must be strong, flexible, and *water resistant* to be commercially successfully. It seemed logical that no one would want a film that dissolves in water. On the contrary, however, water-soluble polymers are finding new uses.

Loves the water

The water-soluble laundry bags are made of *polyvinyl alcohol* (PVA). Judging from the name, a chemist would conclude that it is made of many (*poly*) molecules of *vinyl alcohol*. Oddly enough, vinyl alcohol does not even exist. Attempts to prepare it in the laboratory have been unsuccessful because its atoms immediately rearrange to form acetaldehyde, a more stable molecule.

$$CH_2{=}CHOH \Rightarrow CH_3\text{-}CHO$$

Nevertheless, PVA can be made from a related compound by replacing "acetate groups" with "alcohol groups" (see box, "Polyvinyl alcohol"). The result is a long carbon chain, with hydrogen atoms and alcohol groups (-OH) attached. The alcohol groups carry a *dipole*, a fractional electric charge, that attracts water molecules, which also have dipoles. It is the strong attraction of charged molecules that makes PVA dissolve in water.

Dissolving plastic has found several surprising uses. The textile industry uses PVA thread to make "open weave" fabrics. PVA thread is substituted for some of the ordinary threads when the fabric is woven. Upon washing in hot water the PVA thread dissolves, leaving an open structure nearly impossible to achieve directly. However, in most applications, PVA is used as a film.

Film star

Pure PVA is a solid at room conditions. To make a film, PVA granules are dissolved in water, and the solution is spread on a flat, moving belt. A blade spreads the solution uniformly and controls its thickness (see Figure 1). The moving belt carries the solution through a drying oven, where excess water evaporates and the material dries to a colorless solid. After cooling, the film is peeled from the belt and rolled for shipment.

The solubility characteristics of the film depend on the number of acetate groups that are replaced by alcohol groups. If all (or nearly all) the groups are replaced, the material will dissolve in hot water. If some acetate groups remain, the polymer will dissolve in cold or hot water.

(The residual acetate groups weaken the "hydrogen bonding" between alcohol groups.) All of these films are colorless, translucent, and can be sealed with heat and pressure. They are highly *in*soluble in organic chemicals, such as gasoline, grease, fats, and oils.

Lots of uses

PVA films are used for packages that release their contents upon contacting water. Some brands of sanitizers, dyes, and detergents are packaged in dissolving plastic bags. PVA film has recently found a new use in agriculture. At high concentrations, some pesticides and herbicides can be toxic to humans. Farmers typically purchase concentrated chemicals, then mix them with water to prepare the dilute solutions that are applied to crops. Powdered insecticides and herbicides prepackaged in PVA bags are simply dropped into a container of water, and the farmer is never exposed to the powder.

PVA is an unusual material. It is based on a nonexistent alcohol. It dissolves where most plastics don't. Yet creative product engineers and chemists have put it to many uses. Can you think of others?

SIDE BARS

Polymers

Polymers are giant molecules made from *monomers*, small "building-block" molecules. The most widely used polymer, *polyethylene*, is formed from the monomer *ethylene* and is used in trash bags, milk bottles, and countless other products. The *vinyl chloride* monomer forms *polyvinyl chloride*, which is used in rain gear, plastic pipes, and credit cards. The term "vinyl" indicates that part of the molecule has this structure:

$CH_2 = HC-$

The diagrams below are abbreviated; the portion shown in parentheses must be repeated hundreds of times to correspond to a polymer molecule.

Polyvinyl alcohol

Polyvinyl alcohol (PVA) cannot be formed directly. Instead, acetic acid is reacted with acetylene to form vinyl acetate.

Acetic acid + Acetylene $\Rightarrow$ Vinyl acetate

The vinyl acetate molecules join with each other (in a process called *free-radical polymerization*) to form chainlike molecules of polyvinyl acetate.

Vinyl acetate polymerizes to polyvinyl acetate through a free-radical mechanism.

Finally, the polyvinyl acetate is reacted with methyl alcohol to replace the acetate groups with alcohol groups. The reaction conditions, such as time and temperature, determine the percentage of groups that are replaced.

Polyvinyl acetate + Methanol -> Polyvinyl alcohol

PVA is normally water soluble, but when "cross-links" are made between its long molecules (by reaction with formaldehyde), it is rendered insoluble. It can then be spun into so-called "Vinal" fiber, which makes a fine fabric similar to silk. Although popular in Japan, this synthetic fabric is not presently available in the United States.

CAPTIONS

Melt-A-Way brand laundry bags keep working even after they dissolve in the wash. The polymer binds to metal ions in the water, preventing them from interfering with the detergent.

Figure 1. Process for making PVA film.

BIOGRAPHY

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