Shell Game

Fun with Polymers

Introduction

It would be hard to argue that any polymer has had a greater impact in the past 40 years than sodium polyacrylate, the main "ingredient" in modern disposable diapers! Sodium polyacrylate is an example of a *superabsorbent polymer*. It has been estimated that sodium polyacrylate will absorb approximately 800 times its own weight in distilled water, or 300 times its weight in tap water. Play this version of a classic "shell game" to demonstrate the properties of this modern marvel.

Concepts

- Polymers
- Cross-linking
- Superabsorbents
- Osmosis

Materials

Distilled or deionized water, 300 mL

Sodium polyacrylate, 0.5 g

Sodium chloride, 1 g (optional)

Plastic cups, opaque, 300-mL (10 oz.), 3

Safety Precautions

Sodium polyacrylate is a commercial polymer with a wide variety of modern uses and applications. Although nontoxic, the polymer may irritate the eyes and skin. Wear chemical splash goggles or safety glasses whenever working with chemicals, heat or glassware in the laboratory. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

Obtain three opaque plastic cups. Before class, or out of sight of the students, add about 0.5 g (one teaspoonful) of sodium polyacrylate into one of the plastic cups.

Procedurev

1. Place all three plastic cups upright on the demonstration table or lab bench.
2. Pour distilled water into one of the empty cups (not the one containing the polymer) until the cup is about one-half full.
3. Instruct the students to watch carefully in order to keep track of which cup contains the water.
4. Rearrange the cups a number of times. Ask students to identify the cup containing the water. Most students will identify the correct cup. Ask them if they are willing to place a wager on the guess. To make it more interesting, tell students that if you lose, they must continue to bet "double or nothing" until everyone is satisfied.
5. Pour the water from one cup into the second empty cup.
6. Rearrange or shuffle the cups again, increasing the speed and number of movements, and repeat the process (wagers) a few times.
7. To complete the activity, pour the water into the cup containing the sodium polyacrylate. Rearrange the cups several times, reminding students to keep track, to give the polymer time to "set" (absorb the water).

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8, Turn each empty cup upside down—obviously these cups do not contain the water.

9. Leave all the cups upside down and pour a bit more water into the cup with the polymer. Wait a moment or so, then turn this cup upside down as well. *(The water has "disappeared!")*

10. Observe the appearance and texture of the polymer gel and discuss the properties of superabsorbent polymers.

11. *(Optional)* Add about 1 g of sodium chloride to the polymer gel and observe any changes in the appearance of the gel. *(The gel will turn into a wet slush or slurry.)*

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manua*l for general guidelines and specific procedures governing the disposal of laboratory waste. The polyacrylate gels may be disposed of in the trash according to Flinn Suggested Disposal Method #26a.

Tips

- The shell game is also referred to as a "three-card monty."
- Shell games (with real money being wagered and usually lost) are popular at summer fairs or festivals. As the presenter slowly builds up speed, the players rarely have a chance of winning. The hand is faster than the eye!
- Sodium polyacrylate is an obvious choice for student pranks. Remember that all chemicals should be stored under lock and key to prevent unauthorized access.

Discussion

Sodium polyacrylate is an example of a superabsorbent polymer. It is obtained by the co-polymerization of two related monomers, sodium acrylate and acrylic acid, in the presence of a *cross-linking agent* (Figure 1). The two monomers form a random copolymer, with the sodium acrylate and acrylic acid repeating units randomly distributed within a typical polymer molecule. The cross-linking agent is a reactive molecule that can "insert" itself into two or more growing polymer chains as the polymerization reaction continues. The cross-linking agent thus serves to tie together several polymer chains into a large, three-dimensional, polymer network.

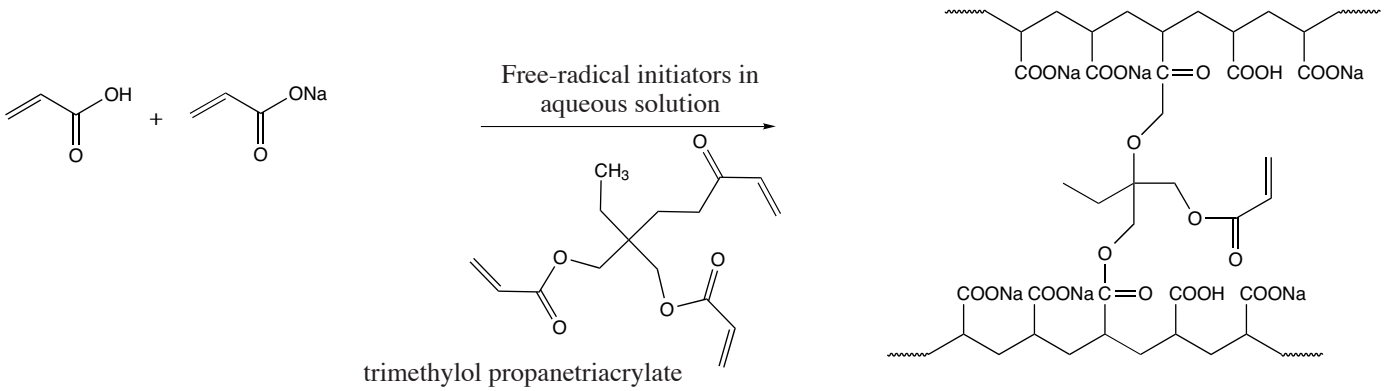

Figure 1. Polymerization Reaction for Sodium Polyacrylate.

Extensive cross-linking makes the polymer insoluble in water and creates a membrane-like barrier on the surface of the polymer that allows water to flow to the inside. The presence of CO^{2-} groups in the polymer structure means that there is a also high concentration of sodium ions within the polymer network. This creates a concentration imbalance or gradient when the polymer is added to water. Superabsorbents thus operate on the principle of osmosis—the passage of water through a membrane permeable only to the water. Here, osmotic pressure results from the difference in sodium ion concentration between the inside of the polymer and the solution in which it is immersed. This osmotic pressure forces water into the solid polymer lattice in an attempt to equilibrate sodium ion concentration inside and outside the polymer. Once inside the polymer network, the water molecules form hydrogen bonds with the ionic CO^{2-} groups, creating a thick, viscous, translucent gel. The amount

of water that can be absorbed by the polymer depends on the ratio of CO^{2-} and CO_2H, the amount or extent of cross-linking, and the concentration of sodium ions. The electrolyte concentration of the water will also affect the osmotic pressure and thus the amount of water absorbed by the polymer. For example, sodium polyacrylate will absorb approximately 800 times its own weight in distilled water, but will only absorb about 300 times its own weight in tap water, due to the high ion concentration of tap water.

Sodium polyacrylate is the main ingredient in high-absorbency diapers. (It can absorb about 30 times its own weight in urine). It is also commonly used in alkaline batteries, feminine hygiene products, nursery potting soil, water beds, and as a fuel filtration material to remove moisture from automobile and jet fuels.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
- Evidence, models, and explanation
- Form and function

Content Standards: Grades 5–8
- Content Standard A: Science as Inquiry
- Content Standard B: Physical Science, properties and changes of properties in matter
- Content Standard F: Science in Personal and Social Perspectives; science and technology in society

Content Standards: Grades 9–12
- Content Standard A: Science as Inquiry
- Content Standard B: Physical Science, structure and properties of matter
- Content Standard F: Science in Personal and Social Perspectives, science and technology in local, national, and global challenges

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Shell Game* activity, presented by Irwin Talesnick, is available in *Fun with Polymers*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Shell Game* are available from Flinn Scientific, Inc.

Materials required to perform this activity are available in the *Wacky World of Superabsorbent Polymers—Chemical Demonstration Kit* available from Flinn Scientific. Materials may also be purchased separately.

Catalog No.	Description
AP6303	Wacky World of Superabosorbent Polymers—Chemical Demonstration Kit
W0012	Sodium Polyacrylate, Powder, 25 g

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.