Ions or Molecules? Polymer Gels Can Tell

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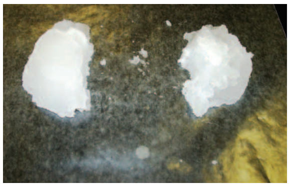
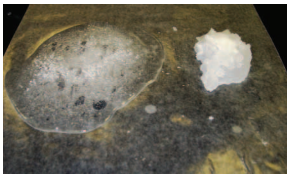
In this Activity, students first prepare a gel using the superabsorbent polymer *sodium polyacrylate* (found in certain diapers) and water. The gel is split into piles and samples of different compounds are sprinkled on the piles. Ionic compounds break down the gel, while covalent compounds have no effect on the gel.



photos by Brett Criswell

Hydrated superabsorbent polymer.



Superabsorbent polymer with ionic compound (left) and covalent compound (right) sprinkled on top.

Background

Superabsorbent polymers (SAPs) are found in a wide variety of products from diapers to toys to "Soil Moist" *(1)*. These products all rely on the ability of SAPs to absorb over 100 times their weight in water and then, in some cases, to release that moisture. For example, Soil Moist plant products absorb water and can be placed in the soil of potted plants, where they release moisture over time. Most commercial formulations today are based on the cross-linking of poly(acrylic acid) [CH_2=CH–COOH]. Manipulation of the type and quantity of the cross-linking agent controls the various characteristics of such polymers. The polymer formed has an ionizable –COOH group (see portion of figure on Student Activity) that is intimately involved in the process of gellation that gives these polymers their water-absorbing capacity. Exposure of the gel to ionic materials can allow diffusion of the ions into the gel matrix, resulting in interference with the polymer–water interactions and breakdown of the gel.

Integrating the Activity into Your Curriculum

This Activity strengthens understanding of the differences between *ionic* and *covalent* compounds. It could be coupled with an investigation of the effect of these two classes of compounds on electrical conductivity when added to water. The Activity also ties in well with a discussion of how science is used in the design of consumer products *(2–3)*.

About the Activity

Students prepare a sodium polyacrylate–water gel that is used to test various compounds. Students choose six compounds to test from a list of eight. The list contains both ionic and covalent compounds chosen because of their availability in local stores. Sand and calcium chloride deicer are available in hardware stores. Sugar, salt, Splenda sweetener, alum (spice aisle), Epsom salt (pharmacy area), and washing soda (laundry aisle) are available in grocery or drug stores. See the accompanying article for other compounds that could be tested *(4)*. Sodium polyacrylate is available from science suppliers such as Educational Innovations (approximate cost is $20/lb). Instructors could also investigate the possibility of extracting the polymer from unused diapers. Based on their observations and the chemical formulas of the tested compounds, students look for patterns to explain the results. All compounds causing the gel to break down (calcium chloride deicer, salt, alum, Epsom salt, and washing soda) have a combination of metals and nonmetals in them (typical of ionic compounds); those having no effect on the gel (sand, sugar, and Splenda) are composed solely of non-metallic elements (typical of covalent compounds). For advanced students, instructors may wish to share the fact that any ionizable substance, such as acids, will break down the gel. Two household examples are vinegar and muriatic acid, which are both covalent compounds, but are electrolytes. Teachers need to be careful with the list of substances used if they wish to keep the covalent–ionic distinction clear.

Answers to Questions

1. Sodium polyacrylate absorbs large volumes of aqueous solutions, such as a baby's urine, and locks the moisture into a gel that can be held away from the baby's skin.
2. Some of the compounds cause the pile to collapse into a watery mess. This process cannot be accurately described as melting for the following reasons (among others): (a) the starting material was not a true solid; (b) generally, no heating occurred ($CaCl_2$ is one counter-example) that could have driven an endothermic melting process.
3. The compounds that cause the gel to break down contain a combination of metals and non-metals and are ionic compounds. Those that have no effect on the gel contain only non-metals and are covalent compounds. Charged particles or ions from ionic compounds can interfere with the stability of the polymer–water interactions in the gel.
4. Ionic compounds broke down the gel and would act as electrolytes in water, producing a conductive solution. Covalent compounds are non-electrolytes and would produce non-conductive solutions.

References, Additional Related Activities, Demonstrations

1. Superabsorbers. *http://www.geocities.com/CapeCanaveral/Cockpit/8107/superabsorbe.html* (accessed Feb 2006).
2. Cleary, Joseph. Diapers and Polymers. *J. Chem. Educ.* **1986**, *63,* 422–423.
3. Buchholz, Fredric L. Superabsorbent Polymers—An Idea Whose Time Has Come. *J. Chem. Educ.* **1996**, *73,* 512–515.
4. Criswell, Brett. A Diaper a Day and What's Going on with Gaviscon? Two Lab Activities Focusing on Chemical Bonding Concepts. *J. Chem. Educ.* **2006**, *83,* 574–576.

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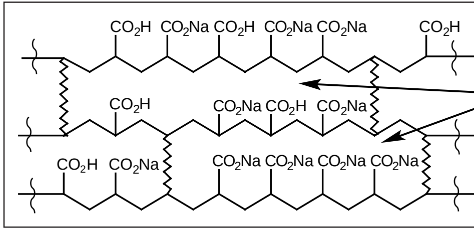
A disposable diaper is an item that doesn't seem to get a lot of respect. It gets sat upon, soiled, and tossed in the garbage, all in the space of a few hours. But have you ever stopped to think what a marvelous item it is? It is able to absorb and contain large amounts of liquid, and hold that moisture away from a baby's sensitive skin, while still being thin enough to allow a baby free movement while crawling and walking. How is it able to do that? Many disposable diapers contain, among other materials, superabsorbent polymers. These polymers are able to absorb more than 100 times their weight in water. Some of these polymers are based on the cross-linking of poly(acrylic acid). The acrylic acid monomer, or unit, is repeated over and over again in the polymer. Different strands of the polymer then cross-link to each other, creating a network (see figure). Water can then diffuse into this network. In this Activity, you will use a superabsorbent polymer frequently found in diapers to investigate the effect of different solid compounds on the hydrated polymer. Be ready to observe some surprising results! Based on your observations and the chemical formulas of the tested solid compounds, you will identify a pattern of which type of solid compounds do and do not produce the observed effects.



Cross-linked network of neutralized polyacrylate. From *JCE* **1997**, *74*, 95.

Try This

You will need: sodium polyacrylate powder (obtain from your instructor), plastic cup, measuring spoons or graduated cylinder, distilled water, spoon, piece of wax paper at least 12 in. on each side, at least six of the following compounds: sand [silicon dioxide, SiO_2]; calcium chloride deicer [$CaCl_2 \cdot 2H_2O$]; sugar [sucrose, $C_{12}H_{22}O_{11}$]; salt [sodium chloride, NaCl]; Epsom salt [magnesium sulfate, $MgSO_4 \cdot 7H_2O$]; Splenda-brand sweetener (sucralose, $C_{12}H_{19}Cl_3O_8$); alum [potassium aluminum sulfate, $KAl(SO_4)_2 \cdot 12H_2O$]; washing soda [sodium carbonate, $Na_2CO_3 \cdot 10H_2O$].

Be Safe! Superabsorbent polymer dust can dry and irritate eyes, nose, and mouth. Avoid making dust and avoid direct contact with the polymer.

__1. Obtain a teaspoon (5 mL) of sodium polyacrylate powder from your instructor. This water-absorbing polymer is used in certain diapers and other commercial products. Place the powder into a plastic cup.

__2. Add two tablespoons plus two teaspoons (40 mL) of distilled water to the powder. Stir with a spoon. Observe and record the appearance of the mixture.

__3. Repeat step 2 with a second and third 40-mL portion of distilled water.

__4. Scoop the resulting mixture onto a piece of wax paper that is at least 12 in. (~30 cm) on each side. Divide the mixture into six equally sized piles. Move the piles so that they are at least 3–4 in. (~8–10 cm) away from each other and from the edges of the wax paper.

__5. Choose six compounds that you wish to investigate from the list of compounds above. Create a data table to record the effect of each compound on its pile.

__6. Obtain your six choices one at a time. Sprinkle ~1/2 teaspoon (~3 mL) of the chosen solid compound over the surface of one of the piles you created in step 4. Observe and record what happens to the pile. Repeat for the remaining five compounds.

__7. Discard your testing materials by carefully sliding the wax paper into a garbage bag.

Questions

1. Sodium polyacrylate may be found in certain brands of diapers. What function do you think it serves in these products?
2. What effect did some of the compounds have on the piles of sodium polyacrylate–water? Some might describe this effect as melting; why is this description not appropriate?
3. Based on your observations and the chemical formula for each compound, identify the pattern concerning those compounds that had an effect on the piles and those that did not. What difference in the nature of the compounds giving these two results could explain this pattern?
4. What would you observe if you tested the electrical conductivity in water of those compounds that produced the effect discussed in Question 2? What would you observe if you tested the compounds that had no effect?

Information from the World Wide Web *(accessed Feb 2006)*

Superabsorbent Polymers: Applications & Benefits. *http://www.creativechemistry.com/applications.cfm*
Chemical Bonding. *http://www.visionlearning.com/library/module_viewer.php?mid=55*
Chemical Compound. *http://en.wikipedia.org/wiki/Chemical_compound*