ION EXCHANGE AND ZEOLITES

Ions are particles that have an electrical charge. Ion exchange depends on the fact that particles with opposite electrical charges are attracted to each other (i.e., positively charged particles attract negatively charged particles and vice versa). The ions that make hard water, usually high concentrations of calcium (Ca^{2+}) and magnesium (Mg^{2+}), react with soap molecules to form an insoluble material. As a result, soap does not lather well and loses its effectiveness as a cleanser. The ion exchange process replaces the Ca^{2+} and Mg^{2+} with sodium (Na^{+}), which does not react with the soap molecules. This is the purpose of home and municipal water softening systems.

Purpose:

What is the purpose of this activity?

(To enhance understanding of how the chemical process of ion exchange can remove undesired ions from water.)

Hypothesis:

In which solution do you expect to observe the greatest degree of ion exchange? How will you know that ion exchange has taken place?

(Answers will vary, but encourage students to be specific.)

Materials:

237 milliliters (1 cup) cation exchange resin or zeolite
3 bottles that will hold 474 milliliters (2 cups) of water, caps or stoppers for the bottles
soap flakes (not detergent) (pea sized shavings of Ivory® soap bars will work)
hard water (or 1-liter [2 pints] distilled water + 3.3 grams [0.1 ounce] Epsom salts)
clean, dry 1-liter plastic soda bottle
cheesecloth
strong rubber bands
knife
scissors
support stand for soda bottle
measuring cup
1/4 teaspoon measuring spoon

Procedure:

1. Pour 237 milliliters (one cup) of the hard water into one of the glass bottles.
2. Add 1.2 milliliters (1/4 teaspoon) of soap flakes. Allow this mixture to stand for three minutes.
3. Cap the mixture and shake.
4. Observe and describe the quantity and the quality of the suds. (Are there many? How long do they last?)
5. Cut the bottom off the soda bottle to create a funnel.
6. Cap the bottle/funnel, put it in the stand, and pour 237 milliliters (one cup) of the hard tap water into it. Allow it to stand undisturbed for three minutes.
7. Cover the mouth of the second glass jar with several layers of cheesecloth and secure the cheesecloth with several rubber bands. Remove the cap from the bottle/funnel, allow the water to run through the cheesecloth, and collect the water in the glass bottle.
8. Repeat steps 1 - 4 using the liquid you collected in the second glass jar. Compare your results with the results in step 1. Did the type of container or the cheesecloth have any effect on the results?
9. Put the cap on the bottle/funnel. Place 237 milliliters (1 cup) of the exchange resin in the funnel.
10. Pour 237 milliliters (1 cup) of hard tap water into the funnel and allow it to stand for three minutes.
11. Cover the mouth of the third bottle with several layers of cheesecloth and secure the cheesecloth with several rubber bands. Remove the cap of the funnel and allow the water to run through the cheesecloth into the third glass bottle.
12. Repeat steps 1 - 4 using the liquid you collected in the third glass jar. Compare your results with the results from the liquid in jars one and two.

Observations:

Jar #1: Hard water and soap

(Soap will not dissolve well. There will be a few short-lived suds.)

Jar #2: Hard water and soap filtered through cheesecloth

(Soap will not dissolve well. There will be a few short-lived suds.)

Jar #3: Hard water and soap filtered through zeolites and cheesecloth

(Soap will dissolve fairly easily. There will be numerous, long-lasting suds.)

Conclusion:

1. Compare the suds created in the three jars. Which had the most and longest lasting suds?

   (The third jar had the most and longest-lasting suds.)

2. Did pouring the water through the cheesecloth have any effect on the quality of the soap suds? Why or why not?

   (No. Suds quality did not improve after pouring the water through the cheesecloth. This physical filtering did not remove the magnesium ions.)

3. Did pouring the water through the resin have any effect on the quality of the soap suds? Why or why not?

   (Yes. The quality and quantity of suds improved after exposing the hard water to the resin. The resin must have chemically removed the Mg^{2+} ions from the hard water.)

4. Why might ion exchange capability be an important consideration when siting the high-level waste repository?

   (If rocks surrouding the repository have ion exchange capability, they would present a natural barrier to the movement of radionuclides by exchanging harmless ions within their structure for the radionuclides moving past them.)