

## EXPERIMENT 5

# Analysis of Hard Water

### INTRODUCTION

The purpose of this laboratory exercise is to demonstrate the properties of alkali and alkaline earth (elements from the first two columns of the periodic table) salts in aqueous solutions and to draw conclusions regarding which group of metal ions is responsible for giving water the property we call "hardness". You should also think about how the term "hard water" was originally coined.

The amount of minerals in the tap water in most cities or rural homes will vary, depending on the geological conditions in the area where the water originates. If water flows through areas that are rich in limestone deposits, it will dissolve the minerals in limestone. What minerals are found in limestone? The relative concentration of minerals in your water supply can be estimated when you boil a pot of water to dryness. If there is a lot of scale (white residue) remaining in the pot, that means the water is heavily laden with minerals. If there is very little residue after boiling to dryness, then the water would have a low mineral content. Most of the minerals found in water are not toxic, and in fact, are usually beneficial, such as calcium, magnesium, potassium, sodium, and chloride to name a few.

### MATERIALS NEEDED

Well trays (24 well), 12 large test tubes (18 x 150 mm), table salt (in a commercial container from supermarket), Epsom salts (Magnesium sulfate, in a commercial container from a pharmacy or supermarket), calcium chloride (solid), granulated sugar (from the supermarket), sodium carbonate (or washing soda) solution, soap solution, detergent solution, Eriochrome Blue Black R reagent, Magneson reagent, silver nitrate reagent, barium chloride reagent, conductivity testers to test electrical conductivity of the solutions.

### PROCEDURE

Begin by taking common table salt (NaCl or sodium chloride) and comparing its properties with some other mineral salts, magnesium sulfate (MgSO<sub>4</sub> or Epsom salts) and calcium chloride (CaCl<sub>2</sub>). You will also compare one property of these salts with common table

sugar, namely that of electrical conductivity. Add to 4 separate test tubes, about 0.5 gram of each salt ( $\text{NaCl}$ ,  $\text{MgSO}_4$  and  $\text{CaCl}_2$ ) and 0.5 g of table sugar (sucrose) and dissolve each in 9.5 mL of distilled water. Stir until the salt is dissolved. What is the percent concentration of each chemical substance in the water? You may use screw cap vials to save each solution for further experimentation (label each vial).

### Part 1. Testing Water Hardness.

Add soap solution to 6 separate large test tubes to give about the same amount of solution in each tube (about 1/3 full). Add the same amount of detergent solution to 3 other test tubes. To 3 of the test tubes containing soap solution, add about 3 mL of sodium carbonate solution. Place your thumb over the end of one test tube from each group (soap; soap + sodium carbonate; and detergent) and shake vigorously to make suds. Compare the amount of sudsing in each tube and record it in your notebook.

Add about 10 drops of  $\text{NaCl}$  solution you made above into one test tube of soap, the same amount of  $\text{NaCl}$  to one test tube of soap + sodium carbonate and the same amount again to one test tube of detergent to see what effect salt ( $\text{NaCl}$ ) has on each solution. Record your observations in your notebook. Test the other two salt solutions ( $\text{MgSO}_4$  and  $\text{CaCl}_2$ ) in the same way, using separate soap, soap + sodium carbonate and detergent solutions to test each salt. Look closely for any changes in the soap or detergent solutions, especially noting whether there is any flocculence, cloudiness or scum floating on top. Then shake each test tube vigorously to see if there is any effect on the foaming of the solutions. Record your observations in your notebook. Draw conclusion regarding which ions ( $\text{Na}^+$ ,  $\text{Mg}^{2+}$  or  $\text{Ca}^{2+}$ ) are responsible for causing "hard water" and which of the substances used in this part would be considered a water softener.

### Part 2. Testing Conductivity and Analysis of Specific Ions.

In this part of the experiment you will test the electrical conductivity of various solutions and test tap water for various ions. In order to determine what you should observe for a positive test in each case, you will use solutions containing the ions that are being tested. These tests are easily done in a tray containing small test wells. You will test for  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Cl}^-$  and  $\text{SO}_4^{2-}$  ions.

You will test 6 different solutions for each ion; these will be the four solutions you prepared in Part 1 above (NaCl, MgSO<sub>4</sub>, CaCl<sub>2</sub> and sugar), tap water, and deionized water. Set up your test well tray as shown below. You may wish to substitute a water sample of your own for tap water (e.g., sea water, urine, etc).

	NaCl Soln	CaCl <sub>2</sub> Soln	MgSO <sub>4</sub> Soln	Sugar Soln	Tap Water	Deionized Water	
	1	2	3	4	5	6	
A							CalRed
B							Magon
C							AgNO <sub>3</sub>
D							BaCl <sub>2</sub>

You should add several drops of each of the salt solutions you prepared in the first part of this experiment to all the wells in their respective columns of the well tray (as indicated in the table above). In other words, add sodium chloride solution to all 4 wells in column 1 so each well is 1/2 to 2/3 full. Add calcium chloride solution to all 4 wells in column 2, and so on, as indicated in the top row of the above diagram.

After adding the test solutions or water to each well, use the conductivity tester to measure whether each solution will conduct electricity. Is it necessary to test all 24 wells in the well tray? Notice that the light indicates conduction of electrons between the leads of the tester. Record your observations in your notebook and draw conclusion regarding the relative electrical conductivity of each solution.

After measuring the conductivity, add a few drops of the appropriate test reagents to each well in rows, as shown along the right border of the above diagram; CalRed is a color reagent for calcium ion. Add 3 or 4 drops of this reagent to each well in row A and notice any color changes that take place. Magon (or Magneson) is the reagent for magnesium ion. Add 3 or 4 drops of this reagent to each well in row B and note any color changes. The silver nitrate reagent will give a positive test for halide ions, including Cl<sup>-</sup> ion. (What are some other halide ions?) Add 3

or 4 drops of silver nitrate reagent to each well in row C and notice what happens. Which wells contain chloride ion? What do you observe in those wells? Do you see a similar thing happen in the deionized water well or in the sugar well? What about the tap water well? Barium chloride will give a positive test for sulfate ions. Add 3 or 4 drops of this reagent to each well in row D. What do you observe in the well containing  $\text{MgSO}_4$ ? Do you observe the same reaction in any of the other wells?

Record your observations in your notebook and determine whether any of these ions are present in the tap water, the deionized water or the sugar solution.

Questions to answer in your notebook:

1. Does the sodium carbonate have any effect on the sudsing action of soap alone? Does it have any effect on the interaction of  $\text{Ca}^{2+}$  or  $\text{Mg}^{2+}$  ions with the soap? Explain these effects considering the results of the previous experiment, where you blew  $\text{CO}_2$  into the lime water containing  $\text{Ca}^{2+}$ .
2. Describe the chemical reaction occurring in the test tubes where the soap is precipitating or aggregating after adding some of the salts. Why isn't there any precipitation in the tubes with detergent?
3. Of the metal ions studied in this experiment, which ones would you classify as causing "hard water"?
- 5.\* Why is sodium carbonate considered to be a water "softener"? How does it work? You may want to check some products you have at home, such as shampoo or bath oil to see if they contain water softeners, such as sodium carbonate, sodium edetate (EDTA), and sodium phosphates.
6. Briefly describe the results of the conductivity test for each solution, explaining what chemical property of each solution causes the tester to light up or not light.
7. What causes the color to appear in the positive tests for calcium and magnesium?
8. What causes the precipitate to appear in the positive tests for the sulfate and chloride ions?