INVESTIGATION 6

What's in That Bottle?

■ CENTRAL CHALLENGE

You will determine the type of bonding in unlabeled chemicals using physical and chemical properties of substances containing ionic, molecular (polar and nonpolar covalent), and metallic bonds.

■ CONTEXT FOR THIS INVESTIGATION

There is a problem in the chemical storeroom. The high humidity in the storeroom caused the labels on some of the chemical bottles to fall off. The labels are lying all over the shelves and it is your job, as a chemistry intern, to design a method that will help identify the chemicals so the labels can be put onto the correct bottles. The unlabeled chemicals are all solids but may be ionic compounds, nonpolar or polar covalent compounds, or metals. There are at least four unlabeled bottles that represent at least one of each type of bond. If the type of substance, or, even better, the identity can be determined, disposal will be less costly to the school. Once the properties of the unknown compounds are determined, you will be given information that can help identify the name of each chemical within the unlabeled bottles.

■ PRELAB GUIDING QUESTIONS/SIMULATIONS

Answer Questions 1–2 using Table 1.

Table 1. Properties and Bond Types of Solid Compounds

Compound	Observations	MP (°C)	Solubility in 25°C Water	Types of Elements Metal (M), Nonmetal(NM)	Type of Bond
Potassium chloride (KCl)	White solid	993	Yes	M/NM	Ionic
Sucrose ($C_{12}H_{22}O_{11}$)	White solid	186	Yes	NM/NM	Polar covalent
Iodine (I_2)	Dark gray solid	114	Slightly soluble	NM/NM	Nonpolar covalent
Zinc (Zn)	Gray, shiny metal	1535	No	M	Metallic

1. Compare the type of bond with regard to the properties below using Table 1 and explain any relationships. HINT: Think of what is happening between the bonded atoms as well as what occurs between the particles.
   a. melting point
   b. solubility in 25°C water
2. Predict the properties of each substance below based on Table 1.

Compounds	Bond Type: Nonpolar Covalent, Polar Covalent, Metallic, Ionic	Relative Melting Point (High or Low)	Solubility in Water
Hexane (C_6H_6)			
Bromobenzene (C_6H_5Br)			
Sodium chloride (NaCl)			
Iron (Fe)			

EXPLANATION TO STRENGTHEN STUDENT UNDERSTANDING

There are few greater potential hazards around the laboratory than that of unmarked or improperly labeled chemicals. Many schools house unused, unlabeled, and improperly stored chemicals. These chemicals can pose a risk to humans and the environment. All chemicals must have complete identification securely fastened to their containers. Chemicals of unknown stability and those that deteriorate over time should have a preparation date clearly indicated on the label.

The chemistry storerooms in schools need to be cleaned out periodically and chemicals properly disposed of. Most chemicals should not be flushed down the drain or thrown into the garbage. Proper disposal of chemicals is costly. If the identity of a substance is not known due to poor labeling or lack of a label, the cost of proper chemical disposal can increase. There are many accidents associated with chemicals that are thrown out and inadvertently mix.

Disposal of unlabeled bottles is dangerous and therefore very expensive and closely regulated by law. The purpose of proper labels is to indicate the source, supplier or manufacturer of the chemicals, the production date, CAS (Chemical Abstract Service) number of the chemical, and to warn of possible hazards. The MSDS (Material Safety Data Sheet) provides personnel with procedures for handling and cleaning up each substance in a safe manner along with details on their physical and chemical properties and toxicity.

PREPARATION

Materials

Potential unknown solids:					
Ammonium chloride (NH_4Cl)	Magnesium oxide (MgO)	Benzoic acid (C_6H_5COOH)	Aluminum	Wax/paraffin	Magnesium
Calcium carbonate ($CaCO_3$)	Potassium nitrate (KNO_3)	Urea ($(NH_2)_2CO$)	Calcium	Iodine (I_2)	Zinc
Copper (II) sulfate, anhydrous ($CuSO_4$)	Sodium carbonate (Na_2CO_3)	Sucrose ($C_{12}H_{22}O_{11}$)	Copper	Sodium acetate ($NaC_2H_3O_2$)	Sodium hydrogen carbonate ($NaHCO_3$)
Copper (II) sulfate pentahydrate ($CuSO_4 \cdot 5H_2O$)	Sodium chloride (NaCl)	Salicylic acid ($C_6H_4(OH)COOH$)			
Materials for testing:					
95% Ethanol, (C_2H_5OH) 30 mL dropper bottle	Ice	Magnifying lens	Capillary tube	Beaker, 100 mL	Small test tubes and rack
Hexanes, 30 mL dropper bottle	Phenolphthalein (dropper bottle)	Ring stand	Thermometer clamp	Thermometer	Conductivity meter or tester (metals and aqueous only)
Distilled Water, 30 mL dropper bottle	pH paper and glass rod	Wooden splints	Orthodontic rubber band	Canned food lid	Relevant MSDS for all knowns and unknowns used
0.1 M sodium hydroxide (NaOH) 30 mL dropper bottle	Corks for test tubes	Magnet	Cotton swabs	Well plate or micro well plate	Tongs
0.1 M hydrochloric acid (HCl) 30 mL dropper bottle	Hot plate	Disposable gloves	Wire gauze	Sandpaper	Toothpicks
Universal indicator (dropper bottle)					

Safety and Disposal

Safety goggles should be worn at all times in the laboratory. Be cautious of acidic and basic solutions since they can cause skin burns and eye damage. Liquids and solids are to be disposed of in properly labeled waste containers per MSDS guidelines. It is recommended that the lab be done on a small scale to minimize solvent and chemical exposure. If hexanes and iodine are used, it is advisable for the teacher to leave these compounds in the hood for student use and to use and exercise appropriate safety precautions. A recommended site for MSDS information is *http://www.ehso.com/msds.php*

PRACTICE WITH INSTRUMENTATION AND PROCEDURE

The purpose of this portion of the lab is to identify properties that allow one to determine the type of bonding in a substance and to carry out tests that allow one to characterize these properties.

Procedure

Given four to six known compounds, you will choose at least four different tests, qualitative or quantitative, to study the physical and chemical properties of each of the given substances. Based on your results you will develop a system that will help determine whether an unknown solid is ionic, covalent (polar or nonpolar), or metallic using these tests. Characteristics to consider testing include: color, solubility in water, conductivity of the solid, conductivity in water, pH of the solution in water, solubility in ethanol, solubility in hexanes, high/low melting point (order of melting if qualitative, or quantitative value), reaction with 0.1 *M* HCl, reaction with 0.1 *M* NaOH, and magnetism.

Select at least four tests and write a detailed procedure to carry out the tests. Refer to the Materials section for guidance on available materials. Create a data table to record results.

Practice Questions

1. Based on the Practice Instrumentation and Procedure data, list the general properties associated with each bond type (metallic, ionic, polar covalent, nonpolar covalent).
2. Go to two other groups and compare your answers. Write a brief statement about what you learned from discussing results with other groups or as a class.
3. How can your experimental procedure be improved? List what your team/group would do differently. If any additional materials are needed, please inform the teacher.
4. Design a flowchart using your experimental procedure that can help you identify unknown compounds.
5. You are given a blue crystalline solid. Using your flowchart, explain how the type of bond can be determined, and what you might observe in the lab.

INVESTIGATION

Procedure

The knowledge acquired in the Practice section for known compounds will now be applied in order to determine the type of bond for four to six unknown solids. Given four to six unknown compounds, you will choose at least four different tests to study physical and chemical properties of the substances. Based on your results, you will develop a system that will help determine whether an unknown solid is ionic, covalent (polar or nonpolar), or metallic using these tests. Characteristics to consider testing include: color, solubility in water, conductivity of the solid, conductivity in water, pH of the solution in water, solubility in ethanol, solubility

in hexanes, high/low melting point (order of melting if qualitative, or quantitative value), reaction with 0.1 *M* HCl, reaction with 0.1 *M* NaOH, and magnetism.

Select at least four tests, quantitative and qualitative, and write a detailed procedure to carry out the tests. Refer to the Materials section for guidance on available materials. Create a data table to record results.

Data Collection and Computation

After you have completed your procedure, identify the bond type in each unknown.

Obtain a list of all of the unlabelled bottles (the unknowns) from your instructor. Using your results and the MSDS for the unknowns, identify the four to six chemicals you tested. Check your results with your instructor.

Argumentation and Documentation

1. To what extent do you believe the classification of your unknown is reliable? Justify your claim with evidence.
2. Discuss in your group the two most significant tests done to identify each of the types of bonds.
3. Go to another group and compare your answers for Questions 1 and 2. Do you need to revise the answers?
4. Obtain the MSDS of your substances to summarize the toxicity and method of disposal for each of your "unlabeled bottles."

POSTLAB ASSESSMENT

You may find it necessary to talk to other groups to compare findings as you complete these questions.

1. How do the melting points of ionic compounds compare to those of covalent compounds? What evidence from the investigation supports your conclusion?
2. When the solids were placed in water were all the results the same? What types of solids conduct electricity in water? Use your investigations to explain what happened.
3. Explain how you were able to determine each unknown as being an ionic, metallic, or covalent (polar or nonpolar) compound.
4. If the solid is ionic, explain why you cannot make the general statement that "all ionic compounds are soluble in water." What evidence from the investigation supports your conclusions?
5. Why was it necessary to use distilled water and not tap water?
6. Metal oxides dissolved in water show a pH in what range? In contrast to these metal oxides, do nonmetal oxides produce the same pH range?
7. Wax is a saturated hydrocarbon, a covalent compound. Wax is not soluble in water yet sugar is also a covalent compound and is soluble in water. Look at the structure of both compounds and explain what could justify these results.

SUPPLEMENTAL RESOURCES

Links

Carpi, Anthony. "Chemical Bonding." Vision Learning. Accessed July 27, 2012. *http://visionlearning.com/library/module_viewer.php?c3=&mid=55%20*

"Tutorial 2.1: Chemical Bond Formation." W. H. Freeman & Co. Accessed July 27, 2012. *http://bcs.whfreeman.com/thelifewire/content/chp02/02020.html*