Experiment 6A

FV-8/8/02

A SERIES OF CHEMICAL REACTIONS

MATERIALS: 50, 100, 250 and 400 mL beakers; 10 and 100 mL graduated cylinders; stirring rod; 75 mL evaporating dish; watch glass; ring stand; ring and filter support; filter funnel; Büchner funnel; filter paper; suction flask; aspirator; wash bottle; copper turnings; steel wool; 95% ethanol; 7 M nitric acid; saturated sodium hydrogen carbonate solution; 9 M sulfuric acid; ice.

PURPOSE: The purpose of this experiment is two-fold: (1) to illustrate the changes in properties accompanying some chemical reactions; (2) to introduce the use of various types of chemical equipment and techniques.

LEARNING OBJECTIVES: By the end of this experiment, the student should be able to demonstrate the following proficiencies:

1. Write balanced molecular, ionic, and net ionic equations for a given chemical reaction.
2. Identify spectator ions in a chemical equation.
3. Calculate the theoretical yield for a given chemical reaction.
4. Perform gravity and vacuum filtrations.
5. Define the following terms: substance, element, compound, mixture, homogeneous, heterogeneous, solution, chemical reaction, theoretical yield, mother liquor, filtrate, effervescence, and percent yield.

DISCUSSION:

A *pure substance* has a definite and invariant chemical composition. If only a single element is present, the substance is a *pure element*; otherwise, it is known as a *pure compound* and can be referred to not only by a name but also by a formula that lists the symbols of the elements present with subscripts to indicate the relative numbers of atoms. Thus, the formula for sodium carbonate is Na_2CO_3, indicating that in any sample of the compound the number of sodium atoms present is twice the number of carbon atoms, and the number of oxygen atoms is three times the number of carbon atoms. In some compounds, the formulas are written to show the presence of certain groups of atoms that act as units. For example, copper(II) nitrate is written as $Cu(NO_3)_2$ rather than CuN_2O_6, and copper(II) sulfate pentahydrate is written as $CuSO_4 \cdot 5H_2O$ rather than $CuSO_9H_{10}$.

A *mixture* contains two or more pure substances in amounts that can be varied to give a continuous range of properties. If the properties for any given mixture are the same throughout, the *homogeneous* mixture is said to be a *solution*. Liquid and gaseous solutions are recognized by their clarity, whereas heterogeneous mixtures (mixtures that are not solutions), will show turbidity, cloudiness or the presence of solid particles. In general, a mixture has properties that are intermediate between those of the pure substances making up the mixture, whereas a compound has properties that are very different from those of its component elements.

When one pure substance is changed into another, a *chemical reaction* occurs. In such a change, all of the atoms of the original substances are present in the products, but they may have undergone some sort of rearrangement. Often a chemical reaction is accompanied by a noticeable change in the properties of the system. These changes may include the formation of a gas or solid, or a color change.

In this experiment, copper metal will undergo the following series of chemical transformations.

$$Cu\ (s) \rightarrow Cu(NO_3)_2\ (aq) \rightarrow CuCO_3\ (s) \rightarrow CuSO_4 \cdot 5\ H_2O\ (s) \rightarrow Cu\ (s)$$

During each step of the experiment, the student should make complete observations of the changes in color or solubility or the formation of gaseous products.

PROCEDURE:

CAUTION: Concentrated acids will be used in this experiment. The acid reagent bottles should remain by the sink. All spills or drips should be cleaned up immediately. **Be particularly careful about drops of acid on the sides of the bottles**, since these can lead to serious burns.

Record all observations for Parts A-D in the Data Section.

Part A. Conversion of Copper to Copper(II) Nitrate Solution

1. Determine the mass of approximately 0.5 g of copper by weighing the turnings on the top-loading balance. Record the mass in the Data Section using the correct units and number of significant figures.

2. Roll the turnings into a small ball (about the size of a marble) and place it in an evaporating dish. Put the evaporating dish containing the copper in the back of a hood. Pour 7.0 mL of 7 M nitric acid solution over the copper and cover with a watch glass. An obvious reaction will take place, in which the acid solution will take on a blue color and a gas (nitrogen dioxide, NO_2) will be evolved. Record your observations in the Data Section.

3. Let the dish stand in the hood until the copper is completely dissolved and a clear blue liquid remains. (A few specks of metal may fail to dissolve. These are impurities in the copper and can be disregarded.) The clear blue liquid is an aqueous solution of copper(II) nitrate, $Cu(NO_3)_2$. Save this solution for Part B.

Part B. Conversion of Copper(II) Nitrate Solution to Copper(II) Carbonate

1. Add 40 mL of saturated sodium hydrogen carbonate solution, $NaHCO_3$, to a 250 mL beaker.

2. **Slowly, and with vigorous stirring**, pour a small amount of copper(II) nitrate solution prepared in Part A into the sodium hydrogen carbonate solution. Continue adding small amounts of the copper(II) nitrate solution until all of the solution is transferred. During pouring, spattering and foaming caused by the CO_2 gas can be prevented by vigorous stirring. If any undissolved material remains in the dish, try not to pour it into the beaker. When the solutions have been combined in the 250 mL beaker, continue to stir vigorously until the bubbling subsides.

3. Place about 50 mL of distilled water in a 400 mL beaker and heat with a Bunsen burner until it boils gently.

4. Place the large beaker containing the hot water on the lab bench and place the smaller beaker (from step B.2) inside it. To prevent the beakers from sticking together, the lips of the beakers should <u>not</u> be aligned. The aim is to achieve a "double-boiler" effect.

5. Heat the pastel blue mixture in the double-boiler for about 10 minutes. The color will change to milky blue-green and the suspended solids will go to the bottom of the beaker leaving a colorless solution above. If the solution is not colorless, add an additional 10 mL of sodium hydrogen carbonate solution to complete the precipitation of Cu^{2+} ions from the solution. Carefully remove the small beaker from the larger one and allow it to cool sufficiently on the lab bench until it can be handled without discomfort. The blue-green sludge is copper(II) carbonate, $CuCO_3$. Save this mixture for Part C.

Part C. Conversion of Copper(II) Carbonate to Copper(II) Sulfate Pentahydrate

1. While the copper(II) carbonate is cooling, prepare a filter for gravity filtration. Using a large piece of filter paper, first fold it in half and then in quarters. Open it so that three thicknesses of paper are on one side and place it in the funnel. Wet the cone with a little distilled water to help make it adhere to the funnel. Work out any air pockets that can be seen since an effective, rapid-filtering funnel depends on a snug fit. Place the funnel in a funnel support attached to a ring stand so that the stem rests against the inside wall of the receiving vessel above the final liquid level. Use any beaker as the receiving vessel.

2. When the beaker containing the copper(II) carbonate suspension is cool enough to handle, stir the solution with a stirring rod and filter it. The filtrate should be clear and colorless. It is a solution of sodium nitrate, $NaNO_3$, plus any unreacted sodium hydrogen carbonate.

3. Use a spatula to transfer the copper(II) carbonate still sticking to the sides of the 250 mL beaker to the filter paper. With a wash bottle, *rinse the beaker with as little distilled water as possible* and add this to the filter. Let the filter drain, then add another 5 or 10 mL of water directly to the filter to wash the precipitate. Let the filter drain thoroughly.

4. Remove the filter paper and its contents from the funnel and hold the opened filter paper over a clean 100 mL beaker. *Use as small a quantity of water as possible in the next step (not more than 10 mL)!* With quick, short squirts of water from your wash bottle, detach the sludge from the paper and rinse it into the beaker.

5. Using a 10 mL graduated cylinder, obtain 3 mL of 9 M sulfuric acid. Add this concentrated acid slowly and with vigorous stirring to the copper(II) carbonate/water mixture. There will be considerable effervescence due to the formation of carbon dioxide. When all of the acid has been added, the solid should be completely dissolved and the solution should be clear and pale blue.

6. While stirring, add 30 mL of ethanol (C_2H_5OH) to your clear blue solution. Within a few seconds, the solution should become cloudy with light blue crystals spontaneously forming. Stir vigorously and then allow the mixture to sit for a few minutes until precipitation is complete. If no precipitate forms, add an additional 20 mL of ethanol and cool the solution in an ice bath.

7. Place a small piece of filter paper in a Büchner funnel. Filter the crystals from the mother liquor, being careful to transfer all the crystals to the funnel. Rinse the beaker with a few milliliters of ethanol. *Do not use any water*. The light blue crystals are copper(II) sulfate pentahydrate, $CuSO_4 \cdot 5H_2O$. The filtrate is pale blue in color indicating that some of the copper sulfate remains in solution. Keep the solid under suction for a few minutes to be sure that all of the ethanol has been removed and the crystals are completely dry. Transfer the crystals from the funnel onto a paper towel. Fold the paper towel over the crystals and press any remaining liquid out of the crystals.

8. Transfer the product to a previously weighed weighing boat and determine the mass of the copper(II) sulfate pentahydrate on the top-loading balance. Record the mass in the Data Section. Save the crystals for Part D.

9. If there is a microscope available, view a few of your crystals with the microscope.

Part D. Conversion of Copper(II) Sulfate Pentahydrate to Copper

1. Transfer your copper(II) sulfate pentahydrate crystals from Part C to a clean 100 mL beaker and dissolve them in 5-10 mL of distilled water.

2. Cut a small amount of steel wool (iron metal). (Do not bring the steel wool near the balances.) Spread the steel wool apart and add it to your copper(II) sulfate solution. Stir until the blue color of the solution disappears. If the blue color takes a long time to disappear, add more steel wool. The liquid remaining at the end of the experiment is a solution of iron(II) sulfate, $FeSO_4$.

Clean-up:

1. Glassware that cannot be cleaned with water (i.e., the 250 mL beaker from Part B) must be cleaned in the acid bath in the hood and then rinsed in water.

2. Discard the copper metal and dirty filter papers in the trash.

3. Wash all glassware.

4. Before leaving, return all equipment to the bins from which they were originally obtained. At your station, leave on the bench top only the material that was originally there.

Name _____ Section _____

Partner _____ Date _____

DATA SECTION
Experiment 6A

Part A. Conversion of Copper to Copper(II) Nitrate Solution

Mass of copper _____

Formula	Complete Observations
Cu (s)	
Dilute HNO_3 (aq)	
$Cu(NO_3)_2$ (aq)	
NO_2 (g)	

Part B. Conversion of Copper(II) Nitrate Solution to Copper(II) Carbonate

Formula	Complete Observations
$NaHCO_3$ (aq)	
$CuCO_3$ (s)	
CO_2 (g)	

Part C. Conversion of Copper(II) Carbonate to Copper(II) Sulfate Pentahydrate

Formula	Complete Observations
$NaNO_3$ (aq)	
H_2SO_4 (aq)	
$CuSO_4$ (aq)	
$CuSO_4 \cdot 5H_2O$ (s)	

Mass of weighing boat _____

Mass of weighing boat + copper(II) sulfate pentahydrate _____

Mass of copper(II) sulfate pentahydrate _____

Part D. Conversion of Copper(II) Sulfate to Copper

Formula	Complete Observations
Fe (s)	
$FeSO_4$ (aq)	
Cu (s)	

DATA TREATMENT
Experiment 6A

Balancing Chemical Equations:

Balance the chemical equations for each of the reactions carried out in the procedure. In addition to each balanced molecular chemical equation, write an ionic equation and a net ionic equation. Information on all the products formed in the reactions is included in the experimental procedures. Remember that water can be a starting material or a product.

Part A. Conversion of Copper to Copper(II) Nitrate Solution.

Molecular Equation: ____ Cu (s) + ____ HNO_3 (aq) → _____ H_2O (l) + ___$Cu(NO_3)_2$ (aq) + ____NO_2 (g)

Complete Ionic Equation:

Net Ionic Equation:

Part B. Conversion of Copper(II) Nitrate Solution to Copper(II) Carbonate.

Molecular Equation:
___ $NaHCO_3$ (aq) + ___ $Cu(NO_3)_2$ (aq) → ____$CuCO_3$ (s) + _____ H_2O (l) + ____CO_2 (g) + ___ $NaNO_3$ (aq)

Complete Ionic Equation:

Net Ionic Equation:

Molecular Equation: ____ $NaHCO_3$ (aq) + ___ HNO_3 (aq) → ____ H_2O (l) + ___ CO_2 (g) + ___ $NaNO_3$ (aq)

Complete Ionic Equation:

Net Ionic Equation:

Part C. Conversion of Copper(II) Carbonate to Copper(II) Sulfate Pentahydrate.

Molecular Equation: ____ $CuCO_3$ (s) + ____ H_2SO_4 (aq) + ____ H_2O (l) → ___ $CuSO_4 \cdot 5H_2O$ (s) + ____ CO_2 (g)

Complete Ionic Equation:

Net Ionic Equation:

Part D. Conversion of Copper(II) Sulfate to Copper.

Molecular Equation: ____ $CuSO_4$ (aq) + ____ Fe (s) → ____Cu (s) + _____$FeSO_4$ (aq)

Complete Ionic Equation:

What is the *spectator ion* in this equation? _____

Net Ionic Equation:

QUESTIONS
Experiment 6A

Calculation of the Percent Yield of Copper(II) Sulfate Pentahydrate:

1. How many moles of copper(II) sulfate pentahydrate can be theoretically produced from one mole of copper metal using this series of reactions? Show your reasoning.

2. Using the information from Question 1, determine the theoretical yield of copper(II) sulfate pentahydrate (in grams) from the amount of copper you used in Part A of the experiment.

3. Use your actual mass of copper(II) sulfate pentahydrate from Part C to calculate your percent yield for the overall conversion of copper to copper(II) sulfate pentahydrate in this experiment.

4. The percent yield of copper(II) sulfate pentahydrate determined in Question 3 was probably not 100%.

   a. Explain what could have occurred in the experiment to cause the yield to be less than 100%.

   b. On the other hand, explain what could have occurred in the experiment to make the final yield greater than 100%.