Chemistry CP

Name:

Minilab: Determining an Empirical Formula

Section:

An ionic compound is composed of ions – atoms or groups of atoms that have a positive or negative charge. Oppositely charged ions arrange themselves into an extended, three-dimensional structure called a crystal lattice. The net attractive forces among oppositely charged ions in the crystal structure are called ionic bonds. Although composed of charged ions, ionic compounds are electrically neutral. The ratio of oppositely charged ions in the crystal structure is such that the positive charge contributed by the cations in equal to or balanced by the negative charge contributed by the anions. There is no net or overall charge on an ionic compound.

The *empirical formula* of an ionic compound indicates the smallest whole number ratio of each type of ion in the crystal structure and is called a formula unit. For example, magnesium chloride has the empirical formula $MgCl_2$. Magnesium cations (Mg^{2+}) and chloride anions (Cl^-) combine in a 1:2 ratio to form the $MgCl_2$ formula unit. The overall charge on ionic compounds is always zero.

Many ionic compounds can be prepared in the lab using *precipitation reactions*. When solutions of two ionic compounds are combined, the ions may rearrange to form a new ionic compound that is insoluble in water. For example, barium ions (Ba^{2+}) combine with sulfate ions (SO_4^{2-}) in a 1:1 ratio to form barium sulfate ($BaSO_4$). This ratio can be observed experimentally in the lab by mixing $BaCl_2$(aq) and Na_2SO_4(aq) solutions containing equal amounts (concentrations) of barium and sulfate ions, respectively. The maximum amount of precipitate will be obtained when equal volumes (a 1:1 ratio) of the two solutions are combined. A similar approach can also be used to determine the formula of an unknown ionic compound.

The purpose of this experiment is to determine the empirical formula of an unknown ionic compound. Two solutions containing equal amounts (concentrations) of two reactant ions will be combined in a series of reactions. In each reaction, the totally volume of the two solutions will be held constant while the volume ratio of the reactants is varied. The amount of precipitate obtained in each reaction will be measured and plotted against the volume ratio to find the empirical formula of the product.

Hypothesis: Based on your knowledge of chemical formulas, predict the ratio of the ions in the compound formed from the copper(II) ion and the phosphate ion. Explain how you arrived at your prediction.

Materials

- 0.1 M copper(II) chloride solution, $CuCl_2$,
- Micro-stirring rod
- 0.1 M sodium phosphate solution, Na_3PO_4,
- Marking pen or wax pencil
- Metric ruler, marked in mm
- Pipets, Beral-type, 2
- 96-well reaction plate
- Test tubes, small, 7

Roles

Project Manager _____

Materials Manager _____

Quality Control Manager _____

Pre-Lab Questions

1. Many common drugstore chemicals are ionic compounds. Write the correct empirical formula for each of the following compounds.

Common name:	Milk of magnesia	Washing soda	Epsom salt
Chemical name:	Magnesium hydroxide	Sodium carbonate	Magnesium sulfate
Chemical Formula			

2. Solutions of iron(III) chloride and sodium hydroxide were mixed in a series of precipitation reactions, as described in this experiment. The data from this experiment are given in Table 1. What lowest whole-number volume ratio of reactants gave the most precipitate? Explain.

Table 1.

Test tube	**1**	**2**	**3**	**4**	**5**	**6**	**7**
$FeCl_3$, 0.1 M, mL	5	10	12	15	17	20	24
NaOH, 0.1 M, mL	55	50	48	45	43	40	36
Volume of precipitate, mL	1	10	14	20	4	1	0

Safety Precautions

Copper(II) chloride and sodium phosphate solutions are skin and eye irritant; additionally, they are slightly toxic by ingestion. Avoid contact of all chemicals with eyes and skin. Wear chemical splash goggles and chemical-resistant gloves and apron. Wash hands thoroughly with soap and water before leaving the lab.

Procedure

1. Obtain seven micro test tubes place them in a test tube rack or in a 96 well-reaction plate (which is conveniently labeled!)
2. Obtain two micropipets: one filled with 0.1M copper(II) chloride solution and another filled with 0.1M sodium phosphate. Record the color of each solution in the data table.
3. Carefully add the appropriate number of drops of copper(II) chloride solution to each test tube #1-7, as shown in Table 2. *Note:* Exact volumes are very important – hold the pipet vertically to obtain uniform size drops.
4. Carefully add the appropriate number of drops of sodium phosphate solution to each test tube, as shown in Table 2.

Table 2.

Test Tube	**1**	**2**	**3**	**4**	**5**	**6**	**7**
$CuCl_2$, 0.1M drops	9	8	6	5	4	2	1
Na_3PO_4, 0.1M drops	1	2	4	5	6	8	9

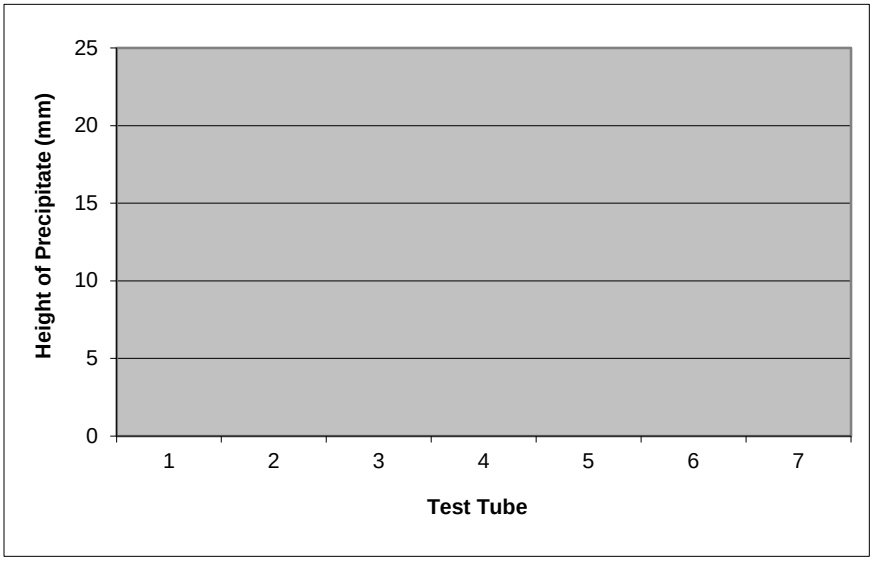
5. Use a *clean* micro-stirring rod to stir each reaction mixture in test tubes #1-7. Let the tubes sit undisturbed for 10-15 minutes to allow the precipitates to settle.
6. During this time, determine the volume (drop) ratio of copper(II) chloride and sodium phosphate solutions in each test tube. Write this ratio in the data table. *Example:* In test tube #1, 3 drops of $CuCl_2$ and 27 drops of Na_3PO_4 correspond to a 1:9 ratio of $CuCl_2$:Na_3PO_4.
7. After the precipitates have settled, observe the appearance of the products (*both the solid and the supernatant solution above the precipitate*). Record your observations in the data table in the space provided. Be as detailed as possible.
8. Use a metric ruler to measure the height of the precipitate of millimeters in each test tube. Read from the top of the solid material to the bottom center of the test tube. Record each height in mm in the data table.
9. Dispose of the contents of the test tubes as directed by your instructor.

Data Table

Color of $CuCl_2$ solution		**Color of Na_3PO_4 Solution**					
Appearance of Products							
Precipitation Reactions							
Test tube	1	2	3	4	5	6	7
Volume Ratio * (Drops of $CuCl_2$:Drops Na_3PO_4							
Height of Precipitate (mm)							

*Reduce the volume ratio to the simplest whole-number ratio

Complete the following bar graph to show the height of the precipitate in each test tube.



Analyze and Apply Answer these questions in complete sentences.

1. Which test tube had the greatest amount of precipitate?

2. What was the total number of drops of solution in each test tube? Why was it necessary to keep the total volume of reactant constant in each test tube?

3. Determine the experimental lowest whole-number ratio of copper(II) ions and phosphate ions. Does this result agree with the prediction made in the hypothesis concerning the empirical formula of the product? Why or why not? Explain.

4. Name the precipitate formed in the reaction of copper(II) ion with phosphate ion.

5. Does the *height* of precipitate in each test tube accurately reflect the *amount* of precipitate in each case? *Hint:* Compare the shape of a test tube to that of a graduated cylinder. What effect does this error have on the conclusions reached in this experiment?

Conclusion: Answer each of the following questions in *meaningful* complete sentences.

- What did you enjoy about the lab?
- What did you learn from the lab?
- How could you improve the lab or your results, if you were to repeat it?