

## 9

**CHEMICAL NAMES AND FORMULAS****SECTION 9.1 NAMING IONS (pages 253–258)**

*This section explains the use of the periodic table to determine the charge of an ion. It also defines polyatomic ion and gives the names and formulas for the most common polyatomic ions.*

**► Monatomic Ions (pages 253–256)**

1. What are monatomic ions?

Monatomic ions are ions consisting of only one atom.

2. How is the ionic charge of a Group 1A, 2A, or 3A ion determined?

The ionic charge is numerically equal to the group number.

3. How is the ionic charge of a Group 5A, 6A, or 7A ion determined?

The charge of an ion in Groups 5A, 6A, or 7A is determined by subtracting 8 from the group number.

4. Circle the letter of the type of element that often has more than one common ionic charge.

- a. alkali metal
- b. alkaline earth metal
- c. transition metal
- d. nonmetal

5. The Stock system of naming transition metal cations uses a Roman numeral in parentheses to indicate the numeric value of the ionic charge.

6. An older naming system uses the suffix *-ous* to name the cation with the lesser charge, and the suffix *-ic* to name the cation with the greater charge.

7. What is a major advantage of the Stock system over the old naming system?

The Stock system gives the actual charge of the ion.

**CHAPTER 9, Chemical Names and Formulas** (continued)

8. Use the periodic table to write the name and formula (including charge) for each ion in the table below.

Element	Name	Formula
Fluorine	fluoride ion	F <sup>-</sup>
Calcium	calcium ion	Ca <sup>2+</sup>
Oxygen	oxide ion	O <sup>2-</sup>

► **Polyatomic Ions** (pages 257–258)

9. What is a polyatomic ion?

A polyatomic ion is a tightly bound group of atoms that behaves as a unit and carries a charge.

10. Is the following sentence true or false? The names of polyatomic anions always end in *-ide*. false

11. What is the difference between the anions sulfite and sulfate?

The sulfite ion has one less oxygen atom than the sulfate ion.

12. Look at Table 9.3 on page 257. Circle the letter of a polyatomic ion that is a cation.

**a.** ammonium

b. acetate

c. oxalate

d. phosphate

13. How many atoms make up the oxalate ion and what is its charge?

It is made up of 6 atoms (2 carbon atoms and 4 oxygen atoms) and it has a charge of 2-.

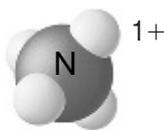
14. What three hydrogen-containing polyatomic anions are essential components of living systems?

a. hydrogen carbonate ion

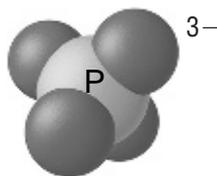
b. hydrogen phosphate ion

c. dihydrogen phosphate ion

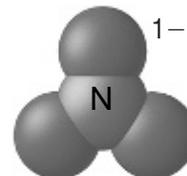
15. Look at Figure 9.5 on page 257. Identify each of the ions shown below.



a. ammonium ion



b. phosphate ion



c. nitrate ion

## SECTION 9.2 NAMING AND WRITING FORMULAS FOR IONIC COMPOUNDS (pages 260–266)

*This section explains the rules for naming and writing formulas for binary ionic compounds and compounds containing a polyatomic ion.*

### ► Binary Ionic Compounds (pages 260–263)

- Traditionally, common names were based on some property of a compound or its source.
- What is the general name for compounds composed of two elements?  
They are binary compounds.
- When writing the formula for any ionic compound, the charges of the ions must balance.
- What are two methods for writing a balanced formula?
  - finding the least common multiple of the charges
  - using the crisscross method
- What are the formulas for the compounds formed by the following pairs of ions?
  - $\text{Fe}^{2+}$ ,  $\text{Cl}^-$   $\text{FeCl}_2$
  - $\text{Cr}^{3+}$ ,  $\text{O}^{2-}$   $\text{Cr}_2\text{O}_3$
  - $\text{Na}^+$ ,  $\text{S}^{2-}$   $\text{Na}_2\text{S}$
- What are the formulas for these compounds?
  - lithium bromide  $\text{LiBr}$
  - cupric nitride  $\text{Cu}_3\text{N}_2$
  - magnesium chloride  $\text{MgCl}_2$
- The name of a binary ionic compound is written with the name of the cation first followed by the name of the anion.

**CHAPTER 9, Chemical Names and Formulas** (continued)

8. How can you tell that cobalt(II) iodide is a binary ionic compound formed by a transition metal with more than one ionic charge?

The name includes a Roman numeral representing the ionic charge of the transition metal cation.

9. Write the names for these binary ionic compounds.

a. PbS lead(II) sulfide

b. MgCl<sub>2</sub> magnesium chloride

c. Al<sub>2</sub>Se<sub>3</sub> aluminum selenide

► **Compounds with Polyatomic Ions** (pages 264–266)

10. What is a polyatomic ion?

A polyatomic ion contains more than one element.

11. How do you write the formula for a compound containing a polyatomic ion?

Write the symbol for the cation followed by the formula for the polyatomic ion and balance the charges.

12. Why are parentheses used to write the formula Al(OH)<sub>3</sub>?

The parentheses indicate how many polyatomic ions are needed in the formula.

13. Complete the table for these ionic compounds containing polyatomic ions.

Cation	Anion	Name	Formula
NH <sub>4</sub> <sup>+</sup>	S <sup>2-</sup>	ammonium sulfide	(NH <sub>4</sub> ) <sub>2</sub> S
Fe <sup>3+</sup>	CO <sub>3</sub> <sup>2-</sup>	iron(III) carbonate	Fe <sub>2</sub> (CO <sub>3</sub> ) <sub>3</sub>
Ag <sup>+</sup>	NO <sub>3</sub> <sup>-</sup>	silver nitrate	AgNO <sub>3</sub>
K <sup>+</sup>	CN <sup>-</sup>	potassium cyanide	KCN

## SECTION 9.3 NAMING AND WRITING FORMULAS FOR MOLECULAR COMPOUNDS (pages 268–270)

This section explains the rules for naming and writing formulas for binary molecular compounds.

### ► Naming Binary Molecular Compounds (pages 268–269)

1. Circle the letter of the type(s) of elements that form binary molecular compounds.

- a.** two nonmetallic elements
- b.** a metal and a nonmetal
- c.** two metals

2. Is the following sentence true or false? Two nonmetallic elements can combine in only one way. false

3. What method is used to distinguish between different molecular compounds that contain the same elements? Prefixes are used.

Match the prefix with the number it indicates.

c 4. *octa-*      **a.** 4

a 5. *tetra-*      **b.** 7

b 6. *hepta-*      **c.** 8

d 7. *nona-*      **d.** 9

8. What are the names of the following compounds?

- a.**  $\text{BF}_3$  boron trifluoride
- b.**  $\text{N}_2\text{O}_4$  dinitrogen tetroxide
- c.**  $\text{P}_4\text{S}_7$  tetraphosphorus heptasulfide

### ► Writing Formulas for Binary Molecular Compounds (page 270)

9. What are the formulas for the following compounds?

- a.** carbon tetrabromide  $\text{CBr}_4$
- b.** nitrogen triiodide  $\text{NI}_3$
- c.** iodine monochloride  $\text{ICl}$
- d.** tetraiodine nonaoxide  $\text{I}_4\text{O}_9$

**CHAPTER 9, Chemical Names and Formulas** (continued)**Reading Skill Practice**

Writing a summary can help you remember the information you have read. When you write a summary, include only the most important points. Write a summary of the information in Section 9.3 on pages 268–269. Your summary should be shorter than the text on which it is based. Do your work on a separate sheet of paper.

Students' summaries should focus on the main points of each subsection and include the information given in Table 9.4.

**SECTION 9.4 NAMING AND WRITING FORMULAS FOR ACIDS AND BASES** (pages 271–273)

*This section explains the three rules for naming acids and shows how these rules can also be used to write the formulas for acids. Names and formulas for bases are also explained.*

**► Naming Common Acids** (pages 271–272)

- Acids produce \_\_\_\_\_ **hydrogen** \_\_\_\_\_ ions when dissolved in water.
- When naming acids, you can consider them to be combinations of \_\_\_\_\_ **anions** \_\_\_\_\_ connected to as many \_\_\_\_\_ **hydrogen** \_\_\_\_\_ ions as are necessary to create an electrically neutral compound.
- What is the formula for hydrobromic acid? \_\_\_\_\_ **HBr** \_\_\_\_\_
- What are the components of phosphorous acid? What is its formula?  
\_\_\_\_\_ **hydrogen ion and phosphite ion; H<sub>3</sub>PO<sub>3</sub>** \_\_\_\_\_

**► Writing Formulas for Acids** (page 272)

- Use Table 9.5 on page 272 to help you complete the table about acids.

Acid Name	Formula	Anion Name
acetic acid	<b>HC<sub>2</sub>H<sub>3</sub>O<sub>2</sub></b>	<b>acetate</b>
carbonic acid	<b>H<sub>2</sub>CO<sub>3</sub></b>	<b>carbonate</b>
hydrochloric acid	<b>HCl</b>	<b>chloride</b>
nitric acid	<b>HNO<sub>3</sub></b>	<b>nitrate</b>
phosphoric acid	<b>H<sub>3</sub>PO<sub>4</sub></b>	<b>phosphate</b>
sulfuric acid	<b>H<sub>2</sub>SO<sub>4</sub></b>	<b>sulfate</b>

► **Names and Formulas for Bases (page 273)**

6. A base is a compound that produces hydroxide ions when dissolved in water.

7. How are bases named?

Name the cation first followed by the anion (hydroxide ion).

**SECTION 9.5 THE LAWS GOVERNING FORMULAS AND NAMES (pages 274–279)**

*This section uses data to demonstrate that a compound obeys the law of definite proportions. It also explains how to use flow charts to write the name and formula of a compound.*

► **The Laws of Definite and Multiple Proportions (pages 274–275)**

1. What is the law of definite proportions?

In different samples of the same chemical compound, the masses of the elements are always present in the same proportions.

2. Circle the whole-number mass ratio of Li to Cl in LiCl. The atomic mass of Li is 6.9; the atomic mass of Cl is 35.5.

a. 42 : 1

b. 5 : 1

**c.** 1 : 5

3. Circle the whole-number mass ratio of carbon to hydrogen in C<sub>2</sub>H<sub>4</sub>. The atomic mass of C is 12.0; the atomic mass of H is 1.0.

a. 1 : 6

c. 1 : 12

**b.** 6 : 1

d. 12 : 1

4. In the compound sulfur dioxide, a food preservative, the mass ratio of sulfur to oxygen is 1 : 1. An 80-g sample of a compound composed of sulfur and oxygen contains 48 g of oxygen. Is the sample sulfur dioxide? Explain.

No; If the sample contains 48 g of oxygen, it contains 32 g of sulfur. The ratio 32 : 48 is equivalent to 2 : 3, not 1 : 1.

5. What is the law of multiple proportions?

When two elements form more than one compound, the different masses of one element that combine with the same mass of the other element are in a ratio of small whole numbers.

**CHAPTER 9, Chemical Names and Formulas** (continued)

6. Complete the table using the law of multiple proportions.

	Mass of Cu	Mass of Cl	Mass Ratio Cl : Cu	Whole-number Ratio of Cl
Compound A	8.3 g	4.6 g	0.55	1
Compound B	3.3 g	3.6 g	1.1	2

**► Practicing Skills: Naming Chemical Compounds** (pages 276–277)

7. How can a flowchart help you to name chemical compounds?

It gives step-by-step directions for naming a compound.

8. Use the flowchart in Figure 9.20 on page 277 to write the names of the following compounds:

a. CsCl \_\_\_\_\_ cesium chloride \_\_\_\_\_

b. SnSe<sub>2</sub> \_\_\_\_\_ tin(IV) selenide \_\_\_\_\_c. NH<sub>4</sub>OH \_\_\_\_\_ ammonium hydroxide \_\_\_\_\_

d. HF \_\_\_\_\_ hydrofluoric acid \_\_\_\_\_

e. Si<sub>3</sub>N<sub>4</sub> \_\_\_\_\_ trisilicon tetranitride \_\_\_\_\_

9. Complete the following five rules for writing a chemical formula from a chemical name.

a. In an ionic compound, the net ionic charge is \_\_\_\_\_ zero \_\_\_\_\_.

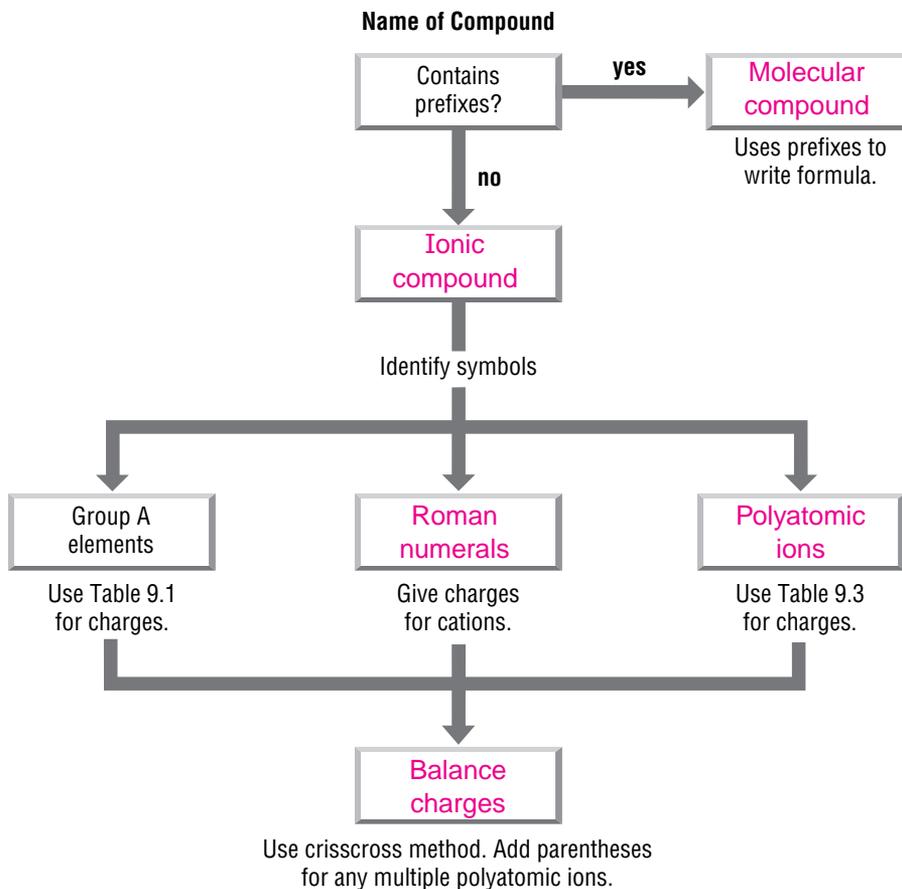
b. An *-ide* ending generally indicates a \_\_\_\_\_ binary \_\_\_\_\_ compound.c. An *-ite* or *-ate* ending means there is a \_\_\_\_\_ polyatomic \_\_\_\_\_ ion that includes oxygen in the formula.

d. \_\_\_\_\_ Prefixes \_\_\_\_\_ in a name generally indicate that the compound is molecular and show the number of each kind of atom in the molecule.

e. A \_\_\_\_\_ Roman numeral \_\_\_\_\_ after the name of a cation shows the ionic charge of the cation.

► **Practicing Skills: Writing Chemical Formulas (page 278)**

10. Fill in the missing labels from Figure 9.22 on page 278.



11. Use the flowchart in Figure 9.22 to write the formulas of the following compounds:

- a. potassium silicate            $K_2SiO_3$
- b. phosphorus pentachloride            $PCl_5$
- c. manganese(II) chromate            $MnCrO_4$
- d. lithium hydride            $LiH$
- e. diiodine pentoxide            $I_2O_5$

**CHAPTER 9, Chemical Names and Formulas** (continued)

**GUIDED PRACTICE PROBLEMS**

**GUIDED PRACTICE PROBLEM 2 (page 256)**

2. How many electrons were lost or gained to form these ions?

- a.  $\text{Fe}^{3+}$       b.  $\text{O}^{2-}$       c.  $\text{Cu}^+$

**Step 1.** Determine the number of electrons based on the size of the charge.

**Step 2.** Determine whether the electrons were lost or gained based on the sign of the charge.

- a.  $\text{Fe}^{3+}$  lost 3 electrons. \_\_\_\_\_  
 b.  $\text{O}^{2-}$  gained 2 electrons. \_\_\_\_\_  
 c.  $\text{Cu}^+$  lost 1 electron. \_\_\_\_\_

**GUIDED PRACTICE PROBLEMS 10B AND 10C (page 263)**

10. Write formulas for compounds formed from these pairs of ions.

- b.  $\text{Li}^+$ ,  $\text{O}^{2-}$

**Analyze**

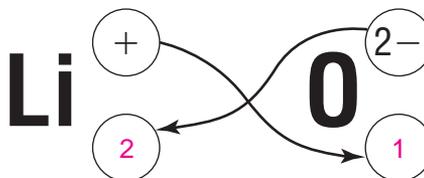
**Step 1.** Do the ions combine in a 1:1 ratio?

No, the charges on the ions are not equal. \_\_\_\_\_

**Solve**

**Step 2.** Use the crisscross method to balance the formula.

Write the formula.  $\text{Li}_2\text{O}$  \_\_\_\_\_



**Evaluate**

**Step 3.** How do you know your formula is reasonable?

The positive and negative charges are equal. \_\_\_\_\_  
 \_\_\_\_\_

c.  $\text{Ca}^{2+}$ ,  $\text{N}^{3-}$

### Analyze

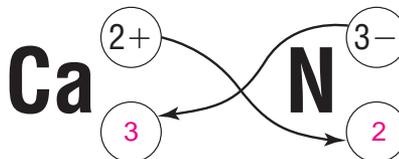
**Step 1.** Will the calcium ( $\text{Ca}^{2+}$ ) and nitride ( $\text{N}^{3-}$ ) ions combine in a 1 : 1 ratio?  
How do you know?

No, because then the total charge would be negative, instead of neutral.

### Solve

**Step 2.** Use the crisscross method to balance the formula.

Write the formula.  $\text{Ca}_3\text{N}_2$



### Evaluate

**Step 3.** How do you know this formula is reasonable?

The positive and negative charges are equal.

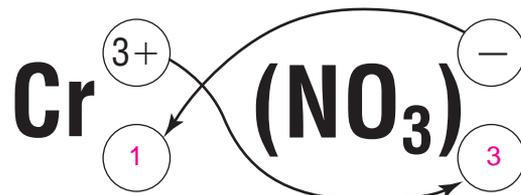
## GUIDED PRACTICE PROBLEM 13B (page 265)

**13b.** Write the formula for chromium(III) nitrate.

- Is the compound ionic or molecular? Explain.

It is ionic because it has no prefixes and it contains a metal.

- Use Table 9.3 on page 257 to write the formula for the nitrate ion.  $\text{NO}_3^-$
- Use the crisscross method to balance the formula.
- Write the formula.  $\text{Cr}(\text{NO}_3)_3$



**CHAPTER 9, Chemical Names and Formulas** (continued)

**GUIDED PRACTICE PROBLEM 34** (page 275)

34. Lead forms two compounds with oxygen. One compound contains 2.98 g of lead and 0.461 g of oxygen. The other contains 9.89 g of lead and 0.763 g of oxygen. For a given mass of oxygen, what is the lowest whole-number mass ratio of lead in the two compounds?

Complete the following steps to solve the problem.

	First compound	Second compound
<b>Step 1.</b> Write the ratio of lead to oxygen for each compound.	$\frac{\boxed{2.98} \text{ g lead}}{0.461 \text{ g oxygen}}$	$\frac{9.89 \text{ g lead}}{\boxed{0.763} \text{ g oxygen}}$

<b>Step 2.</b> Divide the numerator by the denominator in each ratio.	$\frac{6.46 \text{ g lead}}{\text{g oxygen}}$	$\frac{\boxed{13.0} \text{ g lead}}{\text{g oxygen}}$
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<b>Step 3.</b> Write a ratio comparing the first compound to the second.	$\frac{\boxed{6.46} \text{ g lead/g oxygen}}{13.0 \text{ g lead/g oxygen}}$	
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<b>Step 4.</b> Simplify. Note that this ratio has no units.	$\frac{0.497}{1} = \text{roughly } \frac{1}{\boxed{2}}$	
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The mass ratio of lead per gram of oxygen in the two compounds is 1 : 2 .

## Formula of an Ionic Compound - Balancing Charges on Ions

### Introduction:

Atoms of different elements combine with one another to form compounds. The formula of an ionic compound indicates the kinds of atoms that are present in the compound as well as the relative number (ratio) of each kind of atom. This lab investigates how the formula of an ionic compound can be determined experimentally.

### Background:

Some ions consist of a charged group of covalently bonded atoms. Such ions are called *polyatomic ions*. An example is the nitrate ion ( $\text{NO}_3^-$ ), which contains one nitrogen atom and three oxygen atoms and has an overall charge of -1. In calcium nitrate, calcium ( $\text{Ca}^{2+}$ ) ions combine with nitrate ions in a 1:2 ratio in order to balance the positive and negative charges. The formula for calcium nitrate is  $\text{Ca}(\text{NO}_3)_2$ . Parentheses are used around the nitrate ion to show that the subscript "2" pertains to the nitrate ion as a whole. The overall charge on ionic compounds is always zero.

### Experiment Overview:

The purpose of this experiment is to determine the 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 total 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 formula of the product.

### Procedure:

1. Record the color of the 0.1 M copper (II) chloride solution in the data table.
2. Carefully add the appropriate number of drops of copper (II) chloride solution to each test tube #1-7, as shown in Table-1. **Note:** Exact volumes are very important.
3. Record the color of the 0.1 M sodium phosphate solution in the data table.
4. Carefully add the appropriate number of drops of sodium phosphate solution to each test tube, as shown in Table-1
5. Use a clean stirring rod to stir each reaction mixture in test tubes #1-7. Let the tubes sit undisturbed for 10-15 minutes to allow the precipitate 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  $\text{CuCl}_2$  and 27 drops of  $\text{Na}_3\text{PO}_4$  correspond to a 1:9 ratio of  $\text{CuCl}_2:\text{Na}_3\text{PO}_4$ .
7. After the precipitates have settled, observe the appearance of the products (both the solid and the solution). Record the 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 in 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.

Table 1.

Test Tube	1	2	3	4	5	6	7
$\text{CuCl}_2$ , 0.1 M (drops)	3	6	12	15	18	24	27
$\text{Na}_3\text{PO}_4$ , 0.1 M (drops)	27	24	18	15	12	6	3

## Formula of an Ionic Compound - Balancing Charges on Ions

### Introduction:

Atoms of different elements combine with one another to form compounds. The formula of an ionic compound indicates the kinds of atoms that are present in the compound as well as the relative number (ratio) of each kind of atom. This lab investigates how the formula of an ionic compound can be determined experimentally.

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### Experiment Overview:

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### Procedure:

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**Table 1.**

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$\text{Na}_3\text{PO}_4$ , 0.1 M (drops)	27	24	18	15	12	6	3

**Data Table:**

Color of copper (II) chloride solution: \_\_\_\_\_

Color of sodium phosphate solution: \_\_\_\_\_

Color of precipitate (solid): \_\_\_\_\_

Precipitation Reactions							
Test Tube	1	2	3	4	5	6	7
Volume Ratio* (drops $\text{CuCl}_2$ :drops $\text{Na}_3\text{PO}_4$ )	1:9						
Height of Precipitate (mm)							

\*reduce the volume ratio to the simplest whole-number ratio.

**Questions:**

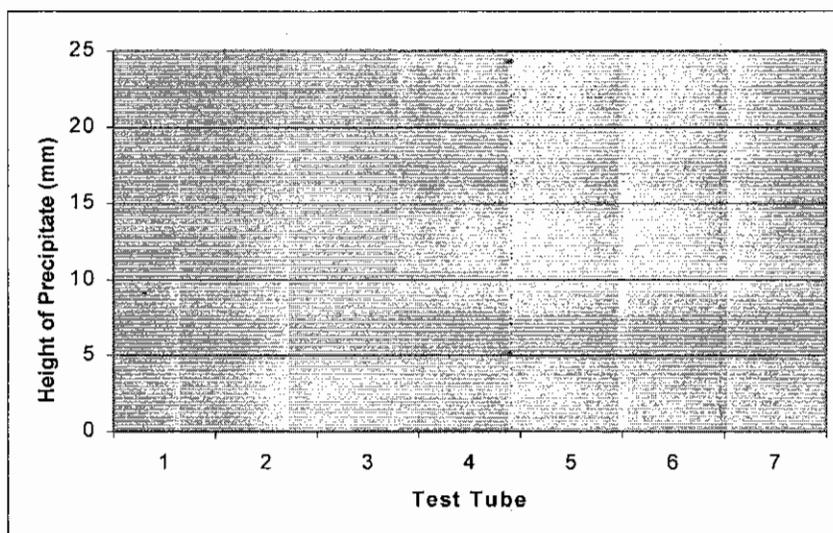
1. The two possible solids are copper (II) phosphate and sodium chloride. Write the formulas of the products. (hint: Use the charges on the ions to balance the compound.)

copper (II) phosphate: \_\_\_\_\_ sodium chloride: \_\_\_\_\_

2. a) Based on common knowledge, which product is likely to be soluble in water?

b) The other product must be insoluble in water and therefore precipitate from solution. Which product formed the precipitate?

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



4. Which test tube had the greatest amount of precipitate? Does this result agree with the prediction made in Question #1 concerning the formula of the product? **EXPLAIN.**