Stoichiometry and Solubility

Mole Ratios and Chemical Formulas

FLINN SCIENTIFIC CHEM FAX!

Introduction

Double replacement reactions are generally considered to be irreversible. The formation of an insoluble precipitate provides a driving force that makes the reaction proceed in one direction only. The purpose of this demonstration is to find the optimum mole ratio for the formation of a precipitate in a double replacement reaction and use this information to predict the chemical formula of the precipitate.

Concepts

- Stoichiometry
- Double replacement reaction
- Mole ratio
- Solubility rules

Materials

Copper(II) chloride, $CuCl_2$, 0.05 *M*, 250 mL

Iron(III) nitrate, $Fe(NO_3)_3$, 0.1 *M*, 250 mL

Graduated cylinders, 50-mL, 2

Graduated cylinders, 100-mL, 7

Sodium hydroxide, NaOH, 0.1 *M*, 250 mL

Sodium phosphate, Na_3PO_4, 0.05 *M*, 250 mL

Stirring rods, large, 2

Safety Precautions

Copper(II) chloride, iron(III) nitrate, sodium hydroxide, and sodium phosphate solutions are skin and eye irritants and are slightly toxic by ingestion. Avoid contact with eyes and skin. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please consult current Material Safety Data Sheets for additional safety information.

Procedure

Part A. Reaction of Iron(III) Nitrate with Sodium Hydroxide

1. Label seven 100-mL graduated cylinders 1–7.
2. Using a clean, 50-mL graduated cylinder, add the appropriate volume of iron(III) nitrate solution to each graduated cylinder, as shown in Table 1.
3. Use a second 50-mL graduated cylinder to add the appropriate volume of sodium hydroxide solution to each graduated cylinder, as shown in Table 1.

Table 1.

Cylinder	**1**	**2**	**3**	**4**	**5**	**6**	**7**
$Fe(NO_3)_3$, 0.1 *M*, mL	10	15	20	30	40	45	50
NaOH, 0.1 *M*, mL	50	45	40	30	20	15	10
Fe^{3+}:OH^- Mole Ratio	1:5	1:3	1:2	1:1	2:1	3:1	5:1

4. Use a large stirring rod to thoroughly mix the reactants. Observe the signs of chemical reaction in each cylinder. *(Mixing the yellow-orange solution of iron(III) nitrate with the colorless sodium hydroxide solution gives a rust-colored precipitate and a pale yellow supernatant.)*
5. Let the reaction mixtures sit undisturbed for at least 10 minutes to allow the precipitates to settle. During this time, write the reactants on the board and identify the possible products.
6. After the precipitates have settled, record the volume of precipitate in each graduated cylinder.
7. What mole ratio gave the maximum amount of precipitate? Explain.

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Part B. Reaction of Copper(II) Chloride with Sodium Phosphate

8. Label seven 100-mL graduated cylinders 1–7.
9. Using a clean, 50-mL graduated cylinder, add the appropriate volume of copper(II) chloride solution to each graduated cylinder, as shown in Table 2.
10. Use a second 50-mL graduated cylinder to add the appropriate volume of sodium phosphate solution to each graduated cylinder, as shown in Table 2.

Table 2.

Cylinder	**1**	**2**	**3**	**4**	**5**	**6**	**7**
$CuCl_2$, 0.05 M, mL	10	20	25	30	35	40	50
Na_3PO_4, 0.05 M, mL	50	40	35	30	25	10	10
Cu^{2+}:PO_4^{3-} Mole Ratio	1:5	1:2	2:3	1:1	3:2	2:1	5:1

11. Use a large stirring rod to thoroughly mix the reactants. Observe the signs of chemical reaction in each cylinder. *(Mixing the blue solution of copper(II) chloride with the colorless sodium phosphate solution gives an aqua-colored precipitate and a colorless supernatant.)*
12. Let the reaction mixtures sit undisturbed for at least 10 minutes to allow the precipitates to settle. During this time, write the reactants on the board and identify the possible products.
13. After the precipitates have settled, record the volume of precipitate in each graduated cylinder.
14. What mole ratio gave the maximum amount of precipitate? Explain.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. Filter or decant the reaction mixtures from Parts A and B to collect the solid products. The solids may be disposed of in the solid waste disposal according to Flinn Suggested Disposal Method #26a. The waste solutions may be disposed of down the drain with excess water according to Flinn Suggested Disposal Method #26b.

Connecting to the National Standards

This laboratory activity relates to the following National Science Education Standards (1996):

Unifying Concepts and Processes: Grades K–12
Evidence, models, and explanation
Constancy, change, and measurement

Content Standards: Grades 9–12
Content Standard A: Science as Inquiry
Content Standard B: Physical Science, structure and properties of matter, chemical reactions
Content Standard G: History and Nature of Science, nature of scientific knowledge

Tips

- Carrying out the reactions in graduated cylinders makes it easy to quickly measure the volume of precipitate and determine the optimum mole ratio. The reactions may also be carried out in large test tubes in a test tube rack. The quantities may be scaled down to any convenient test tube size.
- This demonstration illustrates the method of continuous variation. The best way to use this method is to graph the amount of product obtained in each reaction as a function of the mole ratio. Ideally, the amount of product should increase in a continuous manner, and then begin to decrease. To find the optimum mole ratio, draw two best-fit straight lines through the increasing and decreasing points on the graph. The optimum mole ratio should occur at the intersection of the two lines. Notice that if this graphical method is used, it is not necessary to use the optimum mole ratio in a single run—the ratio is determined by extrapolation.

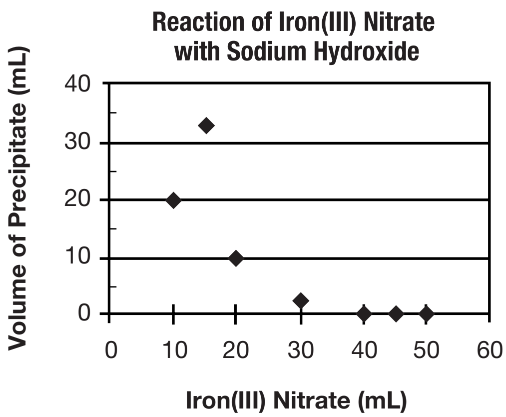
- The continuous variation method may be extended to determine the optimum mole ratio and the chemical formula of the precipitate for any double replacement reaction. Keep a solubility chart and a table of common ion charges handy to help students predict the formulas of the products obtained in double replacement reactions.
- It is not necessary to do all of the sample trials in Table 1. Cylinders 6 and 7 can be eliminated without compromising the purpose of the demonstration. To reduce the amount of chemicals used in Part B, consider eliminating cylinders 2 and 6

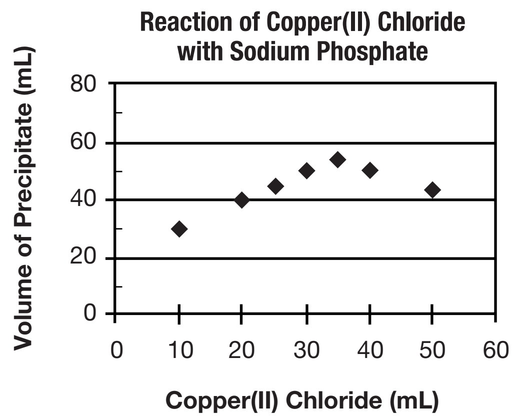
Discussion

Equations 1 and 2 summarize the chemical reactions occurring in Parts A and B, respectively. The results of the experiments are illustrated graphically below.

$$Fe(NO_3)_3(aq) + 3NaOH(aq) \rightarrow Fe(OH)_3(s) + 3NaNO_3(aq) \quad \textit{Equation 1}$$

$$3CuCl_2(aq) + 2Na_3PO_4(aq) \rightarrow Cu_3(PO_4)_2(s) + 6NaCl(aq) \quad \textit{Equation 2}$$





Reference

This activity was adapted from *Molar Relationships and Stoichiometry*, Volume 7 in the *Flinn ChemTopic*™ *Labs* series; Cesa, I., Editor; Flinn Scientific: Batavia, IL (2002).

Materials for *Stoichiometry and Solubility* are available from Flinn Scientific, Inc.

Catalog No.	Description
C0382	Copper(II) Chloride, 0.1 M
F0047	Iron(III) Nitrate, 0.1 M
S0149	Sodium Hydroxide, 0.1 M
S0250	Sodium Phosphate, 0.1 M

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.

