Dilution Effect on Solubility

Solubility Equilibria

Introduction

Show students how even a highly soluble compound such as potassium chloride can be forced out of solution when it is diluted with the right solution containing a common ion.

Concepts

- Common ion effect
- Solubility product constant (K_{sp})

Materials

Potassium chloride solution, KCl, saturated, 20 mL
Hydrochloric acid solution, HCl, 6 M, 10 mL
Hydrochloric acid solution, HCl, 12 M, 10 mL
Test tubes, 18 × 150 mm, 4
Test tube rack

Safety Precautions

Hydrochloric acid solution is toxic and corrosive to eyes and skin tissue. Wear chemical splash goggles, chemical-resistant gloves, and a chemical-resistant apron. Please review current Material Safety Data Sheets for additional safety, handling, and disposal information.

Preparation

1. To prepare the saturated KCl solution: Add 40 g of KCl to 100 mL of distilled or deionized water in a 250-mL storage bottle. Cap and mix. Allow the undissolved potassium chloride to settle to the bottom of the bottle.
2. On the board, write the equation for the dissociation of potassium chloride in water. $KCl(s) \longleftrightarrow K^+(aq) + Cl^-(aq)$
3. Below this equation write the expression and value for the K_{sp} of potassium chloride. $K_{sp} = [K^+][Cl^-] = 14.2$

Procedure

1. Show the students the equilibrium expressions for the solubility of potassium chloride. Explain to the students that they will use these expressions to make predictions as to whether or not certain combinations of solutions will form precipitates.
2. Add approximately 10 mL of saturated potassium chloride to a test tube. Add the same amount of 6 M hydrochloric acid to a second test tube.
3. Tell the students to calculate the final concentrations of potassium ions and chloride ions if these two solutions are mixed and predict whether a precipitation of KCl will occur.
4. After the students have had sufficient time to make their predictions, add the 6 M HCl solution to the saturated KCl solution. Were the students correct?
5. Repeat steps 2 to 4 with the 12 M solution of HCl. Were the students correct?

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Background

When an ionic compound is placed in water, an equilibrium occurs between the undissolved solid compound and dissolved aqueous cations and anions. The *solubility equilibrium* that results is described quantitatively in terms of the equilibrium constant for this reversible reaction. Since the reaction involves solubility, the equilibrium constant is called the *solubility product constant* (K_{sp}). Consider the following equilibrium that results when potassium chloride, a highly soluble ionic compound, dissolves in water (Equation 1). The solubility product expression for this equilibrium reaction is shown in Equation 2.

$$KCl(s) \longleftrightarrow K^+(aq) + Cl^-(aq) \qquad \textit{Equation 1}$$

$$K_{sp} = [K^+][Cl^-] \qquad \textit{Equation 2}$$

The solubility, in grams per liter, of potassium chloride at 0ºC is 281g/L. This translates to a concentration of 3.77 M for each ion in solution. K_{sp} at 0 ºC equals:

$$K_{sp} = [K^+][Cl^-] = (3.77)(3.77) = 14.2 \qquad \textit{Equation 3}$$

The purpose of this demonstration is to show that the addition of a common ion can cause the precipitation of a salt that has a high solubility in water. All salts, even highly soluble ones, have a limit to the quantity of salt that can be dissolved in a given volume of water, at a specific temperature. This constitutes a saturated solution.

K_{sp} is a measure of this limit. For any solution containing potassium ions and chloride ions, the quotient, Q ($[K^+][Cl^-]$), can be calculated.

If $Q < 14.2$, no precipitation forms

If $Q > 14.2$, a precipitate of KCl forms

For this demonstration, the first combination creates the following ion concentrations:

$$[K^+] = (6 + 3.7)/2 \text{ M} = 4.8 \text{ M}$$

$$[Cl^-] = (0 + 3.7)/2 \text{ M} = 1.85 \text{ M}$$

$Q = (4.8)(1.85) = 8.80$, therefore no precipitation occurs.

For the second combination:

$$[K^+] = (12 + 3.7)/2 \text{ M} = 7.8\text{M}$$

$$[Cl^-] = (0 + 3.7)/2 \text{ M} = 1.85 \text{ M}$$

$Q = (7.8)(1.85) = 14.4$, this is greater than 14.2 and precipitation occurs.

Disposal

Please consult your current *Flinn Scientific Catalog/Reference Manual* for general guidelines and specific procedures governing the disposal of laboratory waste. The remaining acidic potassium chloride solution may be disposed of according to Flinn Suggested Disposal Method #24b.

Tips

- Preparation of the saturated potassium chloride solution requires about 45 minutes of teacher prep time prior to class. This may be done 1–2 days before lab if the resulting solution is stored in a stoppered bottle or flask.
- Several Flinn student laboratory kits have been developed to allow students to further their understanding of the solubility of ionic compounds. *Precipitation Reactions and Solubility Rules* (Catalog No. AP4862) allows students to analyze solubility patterns and to formulate the rules of solubility. *Factors Affecting Solubility* (Catalog No. AP4865) provides an inquiry-based activity to investigate the factors that affect the rate at which substances dissolve in solution.

Connecting to the National Standards

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

Unifying Concepts and Processes: Grades K–12
Systems, order, and organization
Content Standards: Grades 5–8
Content Standard B: Physical Science, properties and changes of properties in matter
Content Standards: Grades 9–12
Content Standard B: Physical Science, structure of atoms, structure and properties of matter, chemical reactions

Flinn Scientific—Teaching Chemistry™ eLearning Video Series

A video of the *Dilution Effect on Solubility* activity, presented by Annis Hapkiewicz, is available in *Solubility Equilibria*, part of the Flinn Scientific—Teaching Chemistry eLearning Video Series.

Materials for *Dilution Effect on Solubility* are available from Flinn Scientific, Inc.

Catalog No.	Description
P0183	Potassium Chloride, 100 g
H0031	Hydrochloric Acid, 12 M, 100 mL
H0033	Hydrochloric Acid, 6 M, 500 mL
AP4862	Precipitation Reactions and Solubility Rules Kit
AP4865	Factors Affecting Solubility Kit

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