Teacher Guide: Solubility and Temperature

Learning Objectives

Students will …

- Measure the solubility of a substance.
- Compare the solubility of two substances, potassium nitrate and sodium chloride.
- Explore how temperature affects solubility.
- Explain why the effect of temperature on solubility is much greater for potassium nitrate than for sodium chloride.

Vocabulary

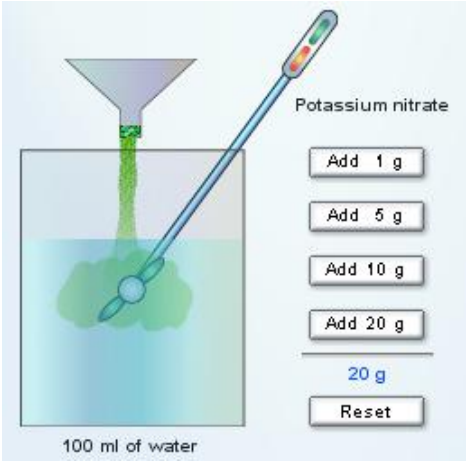
concentration, dissolve, homogeneous mixture, solubility, solubility curve, solute, solution, solvent

Lesson Overview

If you have ever tried to add sugar to your iced tea, you may have noticed that sugar does not dissolve very well in cold water. The *Solubility and Temperature* Gizmo™ allows students to explore how much of a substance can be dissolved in water at various temperatures. The solubility of potassium nitrate and sodium chloride can be investigated.

The Student Exploration sheet contains two activities:

- Activity A – Students compare the solubility of potassium nitrate and sodium chloride at 20 °C.
- Activity B – Students investigate how temperature affects the solubility of each substance.



Dissolving potassium nitrate in water

Suggested Lesson Sequence

1. **Pre-Gizmo activity: Dissolving sugar** (5 – 10 minutes)
   Give each student (or group of students) a beaker of hot water (hot tap water is fine), a beaker of ice water, a teaspoon, a stirring rod, and a supply of sugar. Instruct students to add several spoonfuls of sugar to each beaker and stir. Students will notice that while all of the sugar dissolves into the hot water, a small pile of sugar crystals will be visible at the bottom of the cold-water beaker. Ask students how the temperature of the water affected how much of the sugar could dissolve. Ask them why they think hot water could dissolve more sugar than cold water.

2. **Prior to using the Gizmo** (10 – 15 minutes)
   Before students are at the computers, pass out the Student Exploration sheets and ask students to complete the Prior Knowledge Questions. Discuss student answers as a class, but do not provide correct answers at this point. Afterwards, if possible, use a projector to introduce the Gizmo and demonstrate its basic operations. Demonstrate how to take a screenshot and paste the image into a blank document.

3. **Gizmo activities** (15 – 20 minutes per activity)
   Assign students to computers. Students can work individually or in small groups. Ask students to work through the activities in the Student Exploration using the Gizmo. Alternatively, you can use a projector and do the Exploration as a teacher-led activity.

4. **Discussion questions** (15 – 30 minutes)
   As students are working or just after they are done, discuss the following questions:
   - Why does solubility tend to increase as temperature increases?
   - At what temperature range is sodium chloride more soluble than potassium nitrate? At what temperature range is potassium nitrate more soluble? At what temperature is their solubility exactly the same?
   - The *Solubility and Temperature* Gizmo shows a solid being dissolved in a liquid. Gases also can be dissolved in liquids. What do you think is the general relationship between the temperature and solubility of a gas? [Gases become less soluble as temperature rises, see the **Scientific Background** below.]

5. **Follow-up activity: Measuring solubility** (30 – 45 minutes)
   The activities shown in the *Solubility and Temperature* Gizmo can be reproduced in the classroom. You can find the solubility of various solutes in water including sugar and sodium chloride, or other salts such as potassium nitrate or potassium chloride.

   The basic procedure for measuring solubility is to add a fixed amount of solute to a beaker of water, and then stir the solution to dissolve the solute. When the water is saturated, any additional solute will begin to pile up at the bottom of the beaker. At this point the solubility of the solution can be estimated. Have students find the solubility of the solution at several different temperatures and graph the resulting solubility curve. Experimental solubility curves then can be compared to published solubility curves. See the **Selected Web Resources** on the next page of this document for detailed instructions and sample solubility curves.

Scientific Background

A solution consists of a solute that is dissolved in a solvent. In most cases, the solvent is a liquid, although in some cases the solvent can be a gas or solid. When a solid is dissolved into a liquid, the molecules or crystal lattices break down into simpler particles. For example, sugar crystals consist of small sucrose molecules that are held together by relatively weak intermolecular bonds. When sugar is dissolved in water, these bonds are broken and the individual sucrose molecules spread throughout the liquid. To the naked eye, the sugar seems to “disappear” into the liquid, although it does retain its chemical properties. For example, the sugar-water solution tastes sweet.

When a salt such as sodium chloride or potassium nitrate dissolves in water, the crystal lattice breaks up, or *dissociates* into positive and negative ions. Sodium chloride (NaCl) dissociates into Na^+ and Cl^- ions, while potassium nitrate (KNO_3) dissociates into K^+ and $(NO_3)^-$ ions.

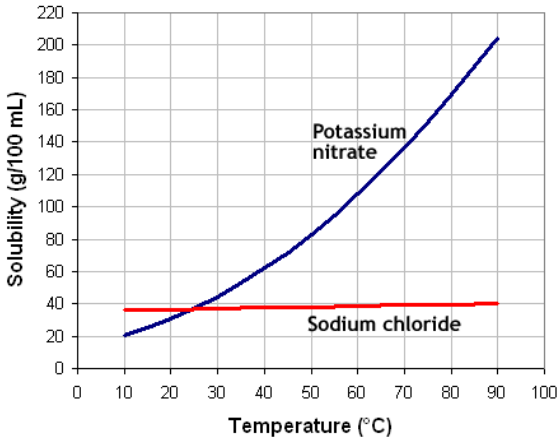
One of the reasons that so many materials can dissolve in water is that water molecules are *polar*. Each water molecule (H_2O) has a slight positive charge on the oxygen atom and a slight negative charge on each of the two hydrogen atoms. The charged water molecules interact with the positive and negative ions in the salt crystals, helping to pull them apart.

In any solution, larger molecules are constantly breaking up (*dissolving*) while smaller particles are constantly joining together to form larger molecules (*precipitating*). In an *unsaturated* solution, the rate of dissolution is greater than the rate of precipitation, so all of the solute remains dissolved. In an *oversaturated* solution, the rate of precipitation is higher than the rate of dissolution, so some of the solute precipitates out of the solution.

The *saturation point* of a solution is reached when the rate of dissolution is equal to the rate of precipitation. The concentration of solute at the saturation point is the *solubility* of the solution. Solubility is commonly measured in grams of solute per 100 milliliters of solvent, or g/100 mL (g/dL). To measure the solubility of a solution, gradually stir solute into the solvent until solute begins to accumulate at the bottom of the container. Solubility is often affected by temperature.

Heat must be absorbed to break apart the ions in a crystal lattice, and heat is released when the ions are *hydrated*, or joined to water molecules. The difference between heat absorbed and released during dissociation determines the effect of temperature on solubility.

Sodium chloride absorbs very little heat as it dissolves, so increasing temperature does not increase its solubility very much, as shown at right. Potassium nitrate absorbs more heat energy as it dissolves. Therefore, raising the temperature greatly increases the solubility of potassium nitrate.



The solubility of gases in liquids depends on temperature and pressure. Gas solubility increases as temperature declines and pressure increases. These relationships result in some interesting phenomena. For example, many fish are unable to survive in warm lakes or ponds because the water doesn't contain enough dissolved oxygen. The relationship between pressure and solubility is experienced by divers. Spending a long period of time at depth causes a large amount of nitrogen to be dissolved in the blood. Returning too quickly to the surface causes the dissolved nitrogen can bubble out suddenly, resulting in a dangerous condition called the bends.

Selected Web Resources

Solutions (basic): http://www.chem4kids.com/files/matter_solution.html
Solutions (advanced): http://www.chemtutor.com/solution.htm
Solubility labs:
http://umanitoba.ca/outreach/crystal/resources%20for%20teachers/Solubility%20Curve%20Lab%20C11-4-06.doc, http://www.sciencebyjones.com/kcl_solubility.htm,
http://schools.lwsd.org/kijh/t_palmer/documents/8th%20Grade/POM/Part%202/Solubility%20Lab.pdf, http://www.marshallschool.net/school/forsman/documents/SolubilityCurveofSugar.doc
Solubility curves: http://www.thesciencedesk.com/SolubilityGraph.html
Sucrose solubility: http://www.nzifst.org.nz/unitoperations/conteqseparation10.htm#solubility
Solubility and temperature: http://www.elmhurst.edu/~chm/vchembook/174temppres.html

Related Gizmos:
Freezing Point of Salt Water: http://www.explorelearning.com/gizmo/id?426
Colligative Properties: http://www.explorelearning.com/gizmo/id?511
Pond Ecosystem: http://www.explorelearning.com/gizmo/id?664