Solubility Curve of Potassium Nitrate in Water

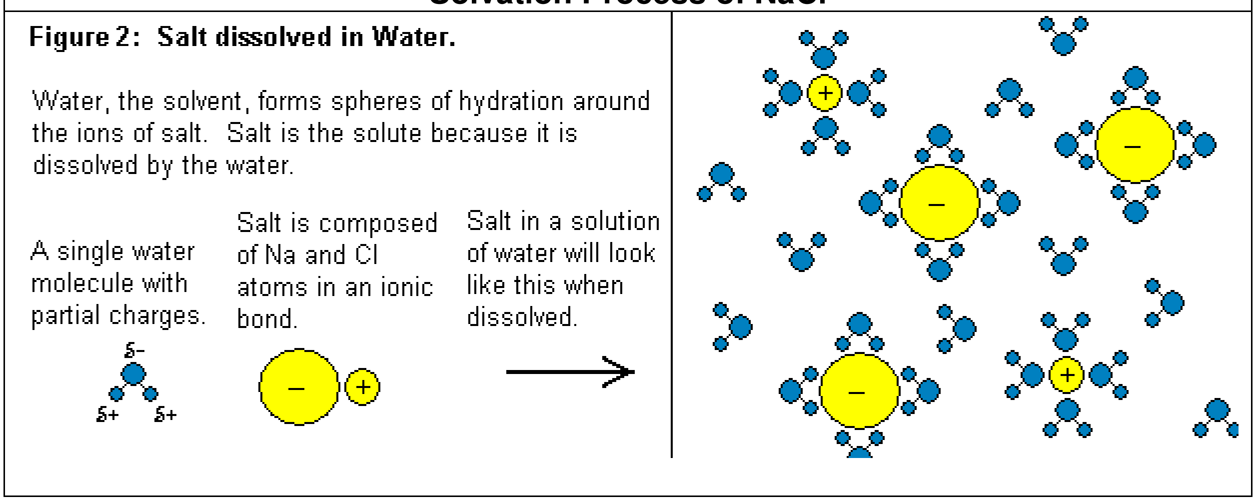
Introduction

Background

Solutions are homogeneous mixtures of **solvents** (the larger volume of the mixture) and **solutes** (the smaller volume of the mixture). For example, a hot chocolate is a solution, in which the solute (the chocolate powder) is dissolved in the solvent (the milk or water). The solute and solvent can be either a solid, liquid or a gas. A solution forms when the attractive forces between the solute and the solvent are similar. For example, the ionic or polar solute, NaCl, dissolves in water, a polar solvent. The phase "like dissolves like" has often been used to explain this.

As the water molecules collide with the ionic compound (NaCl), the charged ends of the water molecule become attracted to the positive sodium ions and negative chloride ions. The water molecules surround the ions and the ions move into solution. This process of attraction between the water molecules (the solvent) and the ionic compound (NaCl, the solute) is called **solvation**. Solvation continues until the entire crystal has dissolved and all ions are distributed throughout the solvent.

Solvation Process of NaCl



Some solutions form quickly and others form slowly. The rate depends upon several factors, such as, the size of solute, stirring, or heating. When making hot chocolate, we stir chocolate powder into hot milk or water. When a solution holds a maximum amount of solute at a certain temperature, it is said to be **saturated**. If we add too much chocolate powder to the hot milk, the excess solute will settle on the bottom of the container. Generally, the chocolate powder dissolves better in hot milk than cold milk. Thus, heating the solution can increase the amount of solute that dissolves. Most solids are more soluble in water (solvents) at higher temperatures.

Solubility is the quantity of solute that dissolves in a given amount of solvent. The solubility of a solute depends on the nature of the solute and solvent, the amount of solute, the temperature and pressure (for a gas) of the solvent. **Solubility** is expressed as the quantity of solute per 100 g of solvent at a specific temperature.

Objectives

In this experiment, you will be:

- Measuring the solubility of different quantities of KNO_3 at various temperatures of crystallization. The start of **crystallization** indicates that the solution has become saturated at this temperature.
- Constructing a solubility curve for KNO_3 in water.
- Able to identify and understand the key terms: solubility, solute, solvent, saturated, unsaturated and supersaturated solutions.
- Able to use the solubility curve graph to solve various problems and determine trends in the curve.

Materials and Equipment List

- Balance
- Hot plate
- Spatula
- Test tubes
- Test tube holders and rack
- 400 ml beaker
- Thermometer
- 10 ml graduated cylinder
- Stirring rod
- Potassium nitrate, $KN0_3$
- Distilled water

General Safety

- Test tube holders should always be used to remove test tubes from the hot water bath. Hot glass does not look hot!
- Be careful with the hot plates and cords. Ensure that the cords are not touching the surface of the hot plate.

Hot-water Bath Safety

- Make sure to either hold on to the thermometer or have it hanging from a clamp. Do not let it touch the bottom of the beaker for accurate measurements.
- Make sure to pick up the hot-water bath with tongs when moving it, or let it cool down first before moving it.

Pre-Lab Questions

1. How is the solubility of sugar in water affected by increasing the temperature?

2. How is solubility expressed?

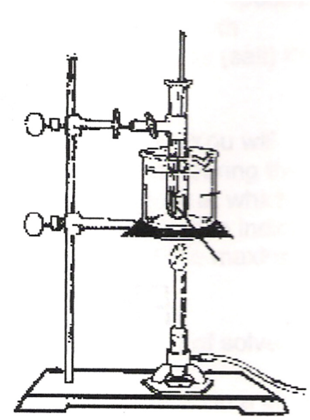
3. What is the difference between a saturated and an unsaturated solution?

Procedures

1. Divide the lab up so that one lab partner completes steps 2-3, while another partner begins on step 4.
2. Using a marking pencil, number five test tubes and place them into a test tube rack.
3. You will be given 5 masses of KNO_3, prepare the test tubes as indicated below:

Test tube #	grams of KNO_3	ml of distilled H_2O
1	2.0	5
2	4.0	5
3	6.0	5
4	8.0	5
5	10.0	5

4. Fill a 400-600 ml beaker about ¾ full of tap water. This will be used as a hot water bath. Place the water bath and test tube #1 on the stand (already set up), firmly attached. Heat the water to 90 ºC and adjust the hot plate to maintain this temperature.
5. Stir the KNO_3-water mixture with a glass stirring rod until the KNO_3 is completely dissolved. Loosen the clamp and, using a test tube holder, remove the tube.
6. One lab partner repeats step 5 for test tube #2. The other lab partner holds a warm thermometer into the solution in the test tube # 1. Hold the test tube up to the light and watch for the first signs of **crystallization** in the solution. Record the temperature immediately as crystallization begins in the data table.
7. Repeat steps 5 and 6 for all four test tubes. One partner should do step 5 and the other step 6. Record all temperatures in the data table.



Data Table

Test tube #	grams of KNO_3 + ml of H_2O	Crystallization temp. (ºC)
1	2g/5ml	
2	4g/5ml	
3	6g/5ml	
4	8g/5ml	
5	10g/5ml	

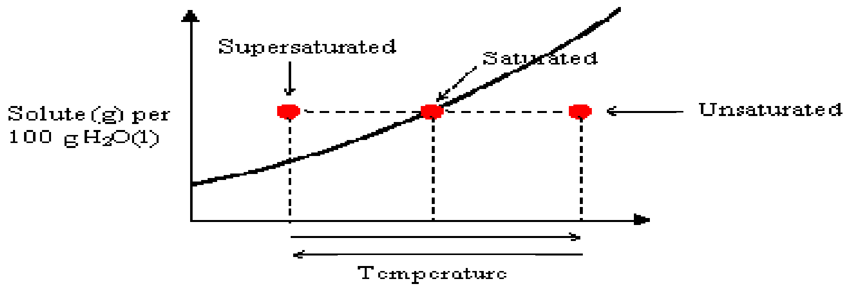
Calculations

1. Convert mass/**5.0 ml** ratios to mass/**100 ml** ratios.
2. Plot your data. Note: Plot the mass of solute per 100 ml of water on the y-axis and the temperature of crystallization on the x-axis.
3. Construct a solubility curve by connecting the plotted points on your graph.

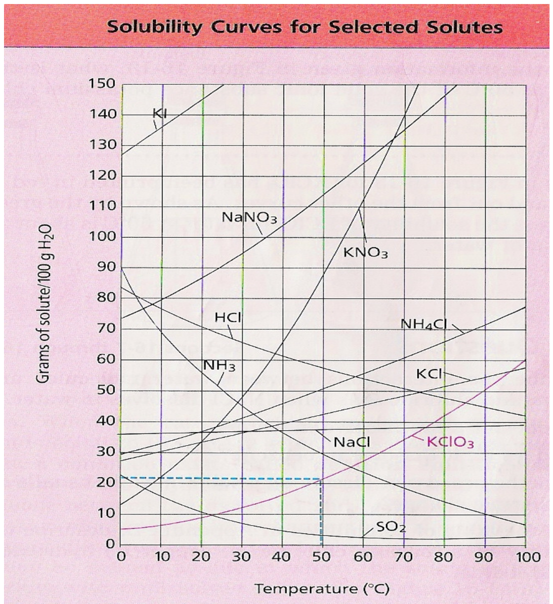
Conclusion and Questions

1. According to your graph, how does the solubility of KNO_3 change as the temperature rises?

2. Explain at the molecular level why this relationship exists between temperature and solubility.
3. Using your graph, how many grams of KNO_3 can be dissolved in 100 ml of water at the following temperatures: 40ºC, 50ºC, 60ºC
4. On your solubility curve, what is the change in solubility from 30ºC to 60ºC?
5. Using your graph, how much KNO_3 must be added to make a saturated solution at 55 ºC.
6. Define the terms saturated, unsaturated and supersaturated. Use the diagram below to explain the terms.



Use the solubility curve provided on the right to determine the answers to the following questions:



7. How many grams of solute are required to saturate 100 g of water in each of the following solutions?
   a) KCL at 80ºC
   b) $KClO_3$ at 90ºC
   c) $NaNO_3$ at 10ºC
   d) SO_2 at 20 ºC
   e) NH_4Cl at 70ºC

8. What is each of the solutions below: saturated, unsaturated or supersaturated? All of the solutes are mixed with 100 g of water.
   a. 40 g of NaCl at 50ºC
   b. 30 g of NH_3 at 30ºC
   c. 70 g of HCl at 20ºC
   d. 80 g of KNO_3 at 60ºC
   e. 80 g of NH_4Cl at 80ºC

9. How many grams of KNO_3 per 100 g of water would be crystallized from a saturated solution as the temperature drops from:
   a. 80ºC to 20ºC
   b. 60ºC to 40ºC
   c. 50ºC to 30ºC
   d. 80ºC to 0ºC
   e. 50ºC to 10ºC

10. How many additional grams of $NaNO_3$ are required to keep each of the following $NaNO_3$ solutions saturated during the temperature changes indicated?
    a. 100 g of water with a temp change of 10ºC to 30ºC
    b. 200 g of water with a temp change of 10ºC to 30ºC
    c. 100 g of water with a temp change of 40ºC to 90ºC
    d. 1000g of water with a temp change of 40ºC to 90ºC
    e. 100 ml of water with a temp change of 10ºC to 60ºC
    f. 1 L of water with a temp change of 10ºC to 60ºC

11. At what temperature are the following solutes equally soluble in 100 g of water?
    a. $NaNO_3$ and KNO_3
    b. NH_4Cl and HCl
    c. NH_3 and KNO_3
    d. $KClO_3$ and NaCl
    e. SO_2 and $KClO_3$

12. Which solute is least affected by the temperature changes?
13. Which three solutes show a decrease in solubility with increasing temperature?
14. How does the solubility of all "ionic solids" change with an increase in temperature? Explain.
15. How does the solubility of all "gases" (NH_3, SO_2 and HCl) change with increased temperatures? Explain at the particle level the cause of the change in solubility.