Solubility Curve of Potassium Nitrate in Water

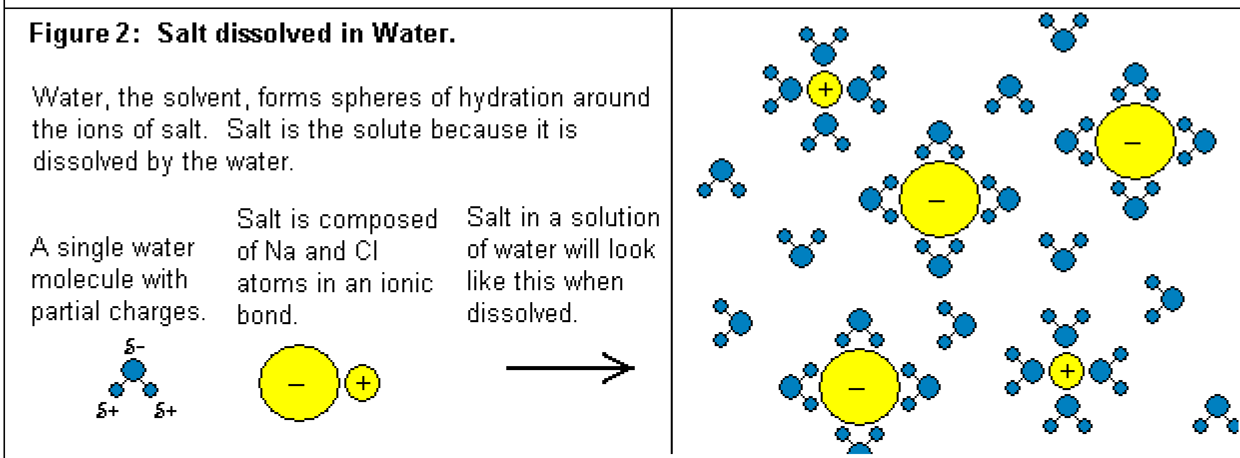
Introduction

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 phrase "***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



http://homepages.ius.edu/GKIRCHNE/Water.htm

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.

Aim

To construct a solubility curve for KNO_3 in distilled water.

Materials List

- Balance
- Burner
- Spatula
- Test tubes
- Test tube holders and rack
- 400 ml beaker
- Thermometer
- 10 ml graduated cylinder
- Stirring rod
- Tripod
- Wire gauze
- Marking pencil

Pre-Lab Questions

1. Why does an oil and vinegar salad dressing have two separate layers?

2. When making hot chocolate, how does stirring affect the rate of solvation?

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

4. What does the phrase "like dissolves like" mean?

5. How is solubility expressed?

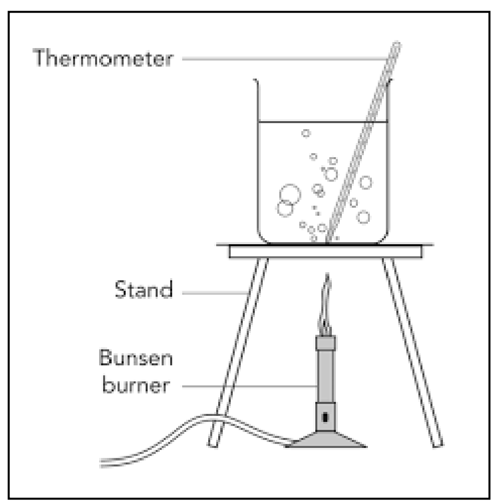
6. What is the difference between a saturated and an unsaturated solution?

Procedures

1. Using a marking pencil, number four test tubes and place them into a test tube rack.
2. Using a balance to measure the KNO_3, prepare the test tubes as indicated below:

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

3. Fill a 400 ml beaker about ¾ full of tap water. This will be used as a hot water bath. Place the test tubes in the water bath and heat them over a Bunsen burner. Heat the water to 90 ºC and adjust the flame to maintain this temperature.
4. Stir the KNO_3-water mixture in test tube number one with a glass stirring rod until the KNO_3 is completely dissolved. Using a test tube holder, remove the tube. Place the thermometer in the test tube and cool the contents by running cold tap water down the outside of the test tube. Record the temperature when crystal start to appear.
5. Repeat step 4 for test tube 2, 3 and 4.



Data Table

Test tube #	grams of KNO_3 + ml of H_2O	grams of KNO_3 per 100 g of H_2O	Crystallization temp. (ºC)
1	2g/5ml		

2	4g/5ml		
3	6g/5ml		
4	8g/5ml		

Calculations

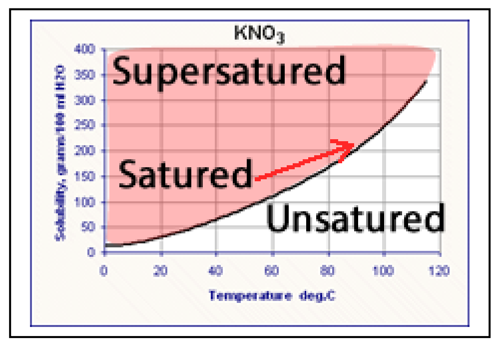
1. Convert mass/**5.0 ml** ratios to mass/**100 ml** ratios.
2. Plot your data. Note: Plot the mass of solute per 100 ml of water on the y-axis and the temperature of crystallization on the x-axis.
3. Construct a solubility curve by connecting the plotted points on your graph.

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. A 100 mL saturated solution at 30°C is to be heated to 60°C. Using your graph, how many more grams of KNO_3 can be dissolved in the same 100 ml solution so that it forms a saturated solution at 60^{0}C?
4. On your solubility curve, what is the change in solubility from 30ºC to 80ºC?
5. Using your graph, how much KNO_3 must be added to 20.0 grams of water to make a saturated solution at 55 ºC.

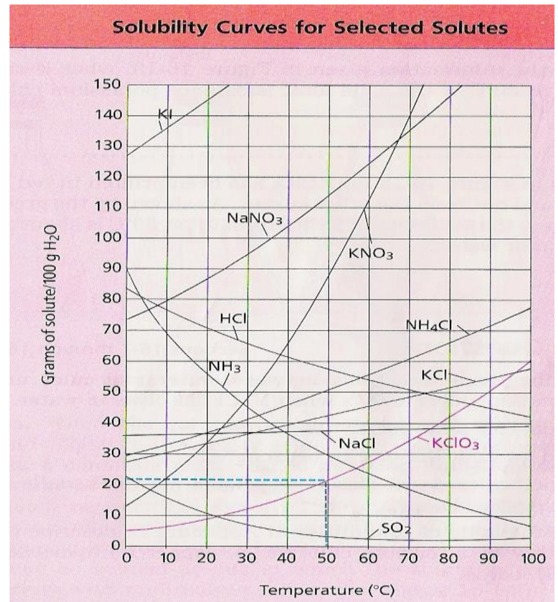
6. Define the terms saturated, unsaturated and supersaturated. Use the diagram on the right to explain the terms.

   Above the curve = supersaturated
   Below the curve = unsaturated
   On the line = saturated



Use the solubility curve provided below 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 *= 52g*
   b) $KClO_3$ at 90ºC *= 42g*
   c) $NaNO_3$ at 10ºC*= 146g*
   d) SO_2 at 20 ºC *= 2g*
   e) NH_4Cl at 70ºC*= 66g*



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 *(below the line =unsaturated)*
   b. 30 g of NH_3 at 30ºC*(below the line =unsaturated)*
   c. 70 g of HCl at 20ºC*(on the line =saturated)*
   d. 80 g of KNO_3 at 60ºC*(below the line =unsaturated)*
   e. 80 g of NH_4Cl at 80ºC*(above the line =supersaturated)*

9. How many grams of $KClO_3$ per 100 g of water would be crystallized from a saturated solution as the temperature drops from:
   a. 90ºC to 20ºC *50 - 8 = 42g*
   b. 60ºC to 40ºC *27 – 17 = 10g*
   c. 50ºC to 30ºC *22 – 12 = 10g*

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 *15g*
    b. 200 g of water with a temp change of 10ºC to 30ºC *30g*
    c. 100 g of water with a temp change of 40ºC to 70ºC *30g*
    d. 1000g of water with a temp change of 40ºC to 70ºC *10 30g = 300g*
    e. 100 ml of water with a temp change of 10ºC to 60ºC *45g*
    f. 1 L of water with a temp change of 10ºC to 60ºC *10 X 45 = 450g*

11. At what temperature are the following solutes equally soluble in 100 g of water?
    At the point of the two lines intersect.
    a. $NaNO_3$ and KNO_3 *67^{o}C*
    b. NH_4Cl and HCl *57^{o}C*
    c. NH_3 and KNO_3 *28^{o}C*
    d. $KClO_3$ and NaCl *39^{o}C*
    e. SO_2 and $KClO_3$ *23^{o}C*

12. Which solute is least affected by the temperature changes?
    NaCl curve is flat.
13. Which three solutes show a decrease in solubility with increasing temperature?
    SO_2, NH_3, HCl The three gasses.

14. How does the solubility of all "ionic solids" change with an increase in temperature? Explain.
Increases with temperature. It is clear from the solubility curves of ionic salts that the amount dissolved increases with increase in temperature.
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.
For all soluble solids dissolved in liquid water, solubility increases with increase in temperature. An increase in temperature is an increase in the average kinetic energy of all particles especially the solvent molecules. This has the result of breaking apart the ionic lattice more efficiently and overcoming the already strained intermolecular bonds holding the solute together. Gases, on the other hand, show an opposite trend, whereby the solubility increase with a decrease in temperature. Gas particles in a solvent, such as water, absorb heat readily and increase their average kinetic energy to a point where they can escape the liquid solvent.