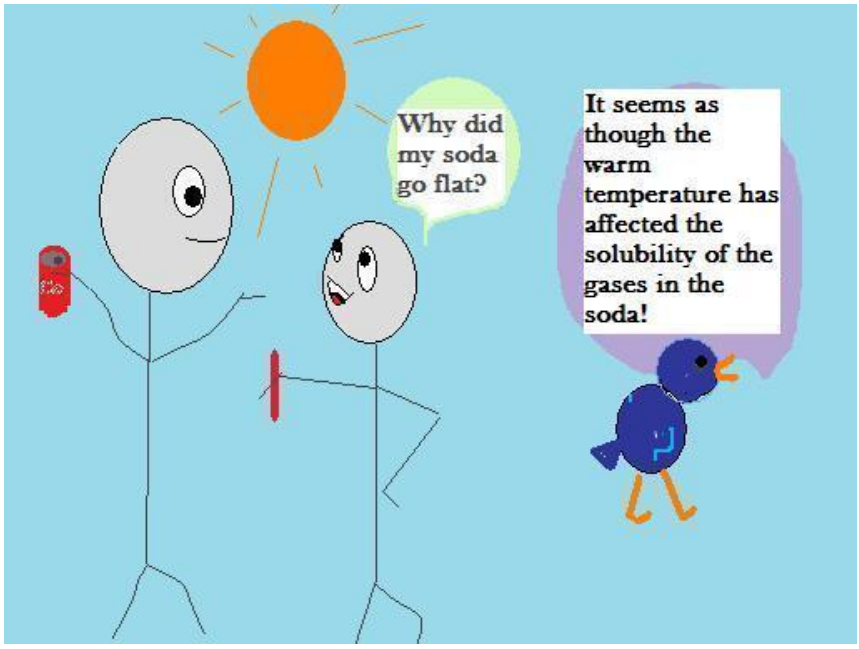
4.4 - Solubility Curves and Tables

pg 457-461 in Matter and Change



Click here for Solubility of Salts

Parameters Affecting Solubility

Solubility: the max amount of solute that will dissolve in a given amount of solvent at a specific temperature and pressure (usually expressed in g solute/100g of solvent or g solute/100cm^3 solvent)

Temperature:

- generally solid solubility increases as solubility increases (there are exceptions such as NH_3)
- gas solubility decreases as temperature increases
- if temperature decreases, excess solute will precipitate out
- a supersaturated solution is capable of retaining the solute in its dissolved form; these solutions are very unstable

Pressure and Gas:

- solubility of a gas in any solvent increases as the external pressure increases
- the mass of a gaseous solute dissolved within a liquid is proportional to the pressure upon the system **(Henry's Law)**

$$\frac{S_1}{P_1} = \frac{S_2}{P_2}$$

- **as pressure increases, the gas solubility increases proportionally.**

- ex: If 0.85 g of a gas at 4.0 atm of pressure dissolves in 1.0L of water, how much will dissolve in 1.0L of water at 1.0 atm at the same temperature?

Solubility Curves *(Table 11 and 12 in package)*

A **solubility curve** is a graph that shows us what mass of a solute will make a **saturated** solution in 100 g (or 100 mL) of water over a range of temperatures.

A solubility graph can be used to answer a variety of questions:

1. To determine the solubility of specific compounds at given temperatures.
Ex) How much $KClO_3$ will dissolve in water at 30˚ C? What about at 80˚ C?

2. To identify a substance when you are given the solubility
Ex) What substance has a solubility of 102 g/100 mL of water at 60˚ C?

3. To determine what temperature a substance has for a given solubility
Ex) At what temperature will sodium nitrate have a solubility of 95g/ 100mL?

*These types of situations only work if the amount of water is 100mL...otherwise you need to set up a proportion:

Ex) What is the solubility of sodium chloride at 25 ^{o}C in 150mL of water?

4. To determine amount of moles in a solution

Ex) How many moles of $NaNO_3$ are in 1.00 L of water if the solution is saturated at 25.0˚ C?

5. To determine if a solution is saturated, unsaturated or supersaturated

Values that are below the curve means the solution is unsaturate (more solute can be dissolved). Likewise, values above the curve represent supersaturation

Ex) Describe the solution in terms of saturation for the following:

a) 70 g of $NaNO_3$ per 100 mL of H_2O at 30˚ C.

b) 60 g of KCl per 100 mL of H_2O at 80˚ C.

c) 80 g of KNO_3 per 100 mL of H_2O at 50˚ C.

6. To determine amount of additional solute is needed to make a saturated solution

Ex) 30 g of potassium nitrate has been added to 100 cm^3 of water at 50^{o}C. How many additional grams must be added to make it saturated?

Solubility Tables

A **solubility table** tells us whether or not an ionic compound will DISSOCIATE in water at a specific temperature (usually 25.0° C).

To read the table (*Table 10 in package*), look at the left hand column. It gives you a list of anions.

- **soluble** - an ionic compound that will probably not form a precipitate in water
- **low solubility** - the ionic compound will probably form a precipitate in water

For example, in the first row, it tells you that essentially all anions matched up with an alkali cation (the first column in the periodic table) will be soluble in water.

- That is, NaCl and K_3PO_4 are two substances soluble in water.

In general, you need to find a specific ion from your formula on the chart and see if the ion it is paired up with will produce a soluble substance.

Ex) is $(NH_4)_2SO_4$ soluble in water?

Ex) is PbI_2 soluble in water?

Solubility of Common Compounds in Water

Rule	Negative Ions	Positive Ions	Solubility
1	essentially all	Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	soluble
2	essentially all	H^+	soluble
3	essentially all	NH_4^+	soluble
4	nitrate, NO_3^-	essentially all	soluble
5	acetate, CH_3COO^-	Ag^+	low solubility
		all others	soluble
6	bromide, Br^- chloride, Cl^- iodide, I^-	Ag^+, Pb^{2+}, Hg_2^{2+}, Cu^+, Tl^+	low solubility
		all others	soluble
7	sulfate, SO_4^{2-}	Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}, Pb^{2+}, Ag^+, Hg_2^{2+}	low solubility
		all others	soluble
8	sulfide, S^{2-}	Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Ra^{2+}	soluble
		all others	low solubility
9	hydroxide, OH^-	Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+, H^+, NH_4^+, Sr^{2+}, Ba^{2+}, Ra^{2+}, Tl^+	soluble
		all others	low solubility
10	carbonate, CO_3^{2-} phosphate, PO_4^{3-} sulfite, SO_3^{2-}	Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+, H^+, NH_4^+	soluble
		all others	low solubility

4.4 – Solubility Curves and Tables - Worksheet

1. Use a solubility curve to determine the solubility of the following compounds at the temperatures given.

compound	temperature	solubility
NH_3	10°C	
$Ce_2(SO_4)_3$	50°C	
KCl	90°C	

2. For each of the following solutions, classify the solution as unsaturated, saturated, or supersaturated.

compound	temperature	mass solute in 100 mL water	solution
NH_3	90°C	10g	
NH_4Cl	80°C	70g	
$NaNO_3$	30°C	80g	

3. What is the solubility of ammonium chloride, NH_4Cl, at 100°C? Express this both as g/100mL of water and as mol/L of water. Round your answer to the nearest molarity.

4. What mass of potassium chlorate, $KClO_3$ could be dissolved in 100mL of water at 70°C?

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5. A **saturated solution** of potassium chloride at 80.0 °C is cooled to 40.0 °C. Initially, no solid was present in the beaker. Once cooled, there appeared to be solid at the bottom of the beaker. Explain the difference in the presence of solid at the bottom of each solution assuming there is 100 g of water. How much solid (in grams) will there be once the solution has cooled.

6. Use a Table of Solubility of Common Compounds to predict whether or not the following compounds will be soluble in water at 25°C.

$Mg(NO_3)_2$		$CaSO_4$	
$CaCl_2$		K_2SO_4	
Al_2S_3		$Ba(OH)_2$	
$(NH_4)_3PO_4$		$Mg(OH)_2$	
$SrCO_3$		BeS	
$BaSO_4$		$CuCl_2$	
$Mg(CH_3COO)_2$		CuCl	
SrI_2		H_2CO_3	

7. A glass of cold cola is left to stand 5 minutes at room temperature. How does temperature affect the solubility of the $CO_2(g)$?

8. At room temperature, the solubility of which solute in water would most be affected by a change in pressure? Explain your answer.
a. methanol $_{(l)}$
b. sugar $_{(s)}$
c. carbon dioxide $_{(g)}$
d. sodium nitrate $_{(s)}$

9. Calculate the solubility of oxygen gas in water at 0 °C and a pressure of 3.00 atm. The solubility of oxygen is 0.348 g/100 mL water at 0 °C and 1.00 atm.