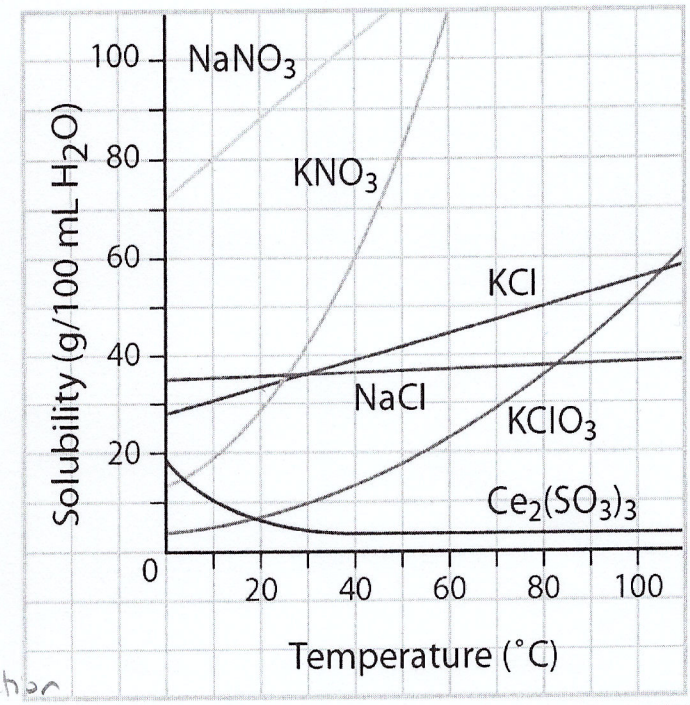
Solubility

- The **solubility** of a solute is the amount of a solute that can dissolve in a given quantity/amount of solvent at a given temperature
- An **unsaturated solution** is a solution that does not have the maximum amount of solute dissolved in it
- A **saturated solution** is a solution that contains the maximum amount of dissolved solute at a given temperature
  - The *solubility value* of a solute is actually the concentration of a saturated solution. A concentration value indicates how much solute (usually in moles) is dissolved in a certain amount of solvent (usually in liters).
- A **supersaturated solution** contains more dissolved solute than its solubility value at a given temperature
- Recall the solubility chart in the data book which is used to determine if an compound can dissolve in water (soluble) or not (insoluble)

EXAMPLES: Use the following graph to answer the following questions.



1. Indicate if the following solutions will be unsaturated, saturated, or superstatured.
   a. 10 g $KClO_3$ at 60 °C
   unsaturated
   b. 80 g $NaNO_3$ at 10 °C
   saturated
   c. 50 g KCl at 20 °C
   supersaturated

* 1m = 1g of water
∴ 100mL = 100g

2. How many grams of $Ce_2(SO_3)_3$ must be added to 100g of water to form a saturated solution at 10°C?
   ↳ solubility concentration
   ∴ 10g in 100g of water
3. Which solution is more concentrated; a saturated solution of KNO_3 at 10°C or a saturated solution of $NaNO_3$ at 10°C?
   $NaNO_3$ ↓ 80g/100mL
   KNO_3 ↓ ~ 20g/100mL
   ∴ $NaNO_3$ is more concentrated

4. If 115 g KNO_3 are added to 100 g of water at 35 °C, how many grams do not dissolve? ↳ solubility value = 50g/100mL

$115g - 50g = \boxed{65g}$

5. What mass of KCl would be needed to form a saturated solution if the KCl was dissolved in 200 g of water at 80 °C?

$\frac{50g}{100mL} = \frac{?}{200mL}$ $\boxed{? = 100g}$

*****Now try Practice Problems #1-2*****

- Consider what is happening at the molecular level when $CuSO_{4(s)}$ is dissolved in water
  - $CuSO_{4(s)}$ is added to water to form an unsaturated solution

    $CuSO_{4(aq)} \longrightarrow Cu^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$
  - $CuSO_{4(s)}$ is continually added until no more solid can dissolve and the solid crystals start to accumulate on the bottom of the container
  - At this point, saturated solution is established
  - At a macroscopic level (ie. what we observe with our eyes), the system in the beaker appears to remain unchanged
  - However, at a molecular level, the $CuSO_{4(s)}$ at the bottom of the beaker continues to dissolve at the same rate as that the ions in solution crystallize

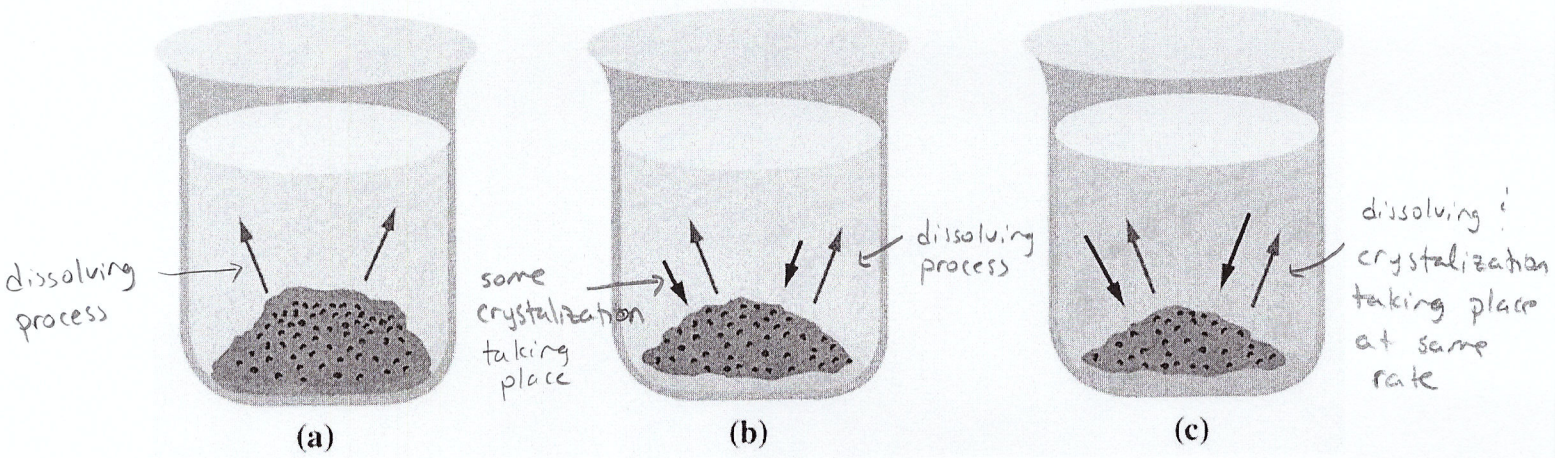
dissolving : $CuSO_{4(aq)} \longrightarrow Cu^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$

crystalization : $Cu^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)} \longrightarrow CuSO_{4(aq)}$

  - Since the rate of dissolving is taking place at the same rate as the crystallization, the saturated solution is said to be at *equilibrium*

$CuSO_{4(aq)} \rightleftharpoons Cu^{2+}_{(aq)} + SO_4^{2-}{}_{(aq)}$

- **Equilibrium** occurs when a process (such as dissolving) and the reverse process (such as crystallization) take place at the *same rate*
- This explains why we cannot see any changes to the amount of $CuSO_{4(s)}$ at the bottom of the container when a solution is saturated



Solute is dissolving

More solute is dissolving, but some is crystallizing

Saturation equilibrium established

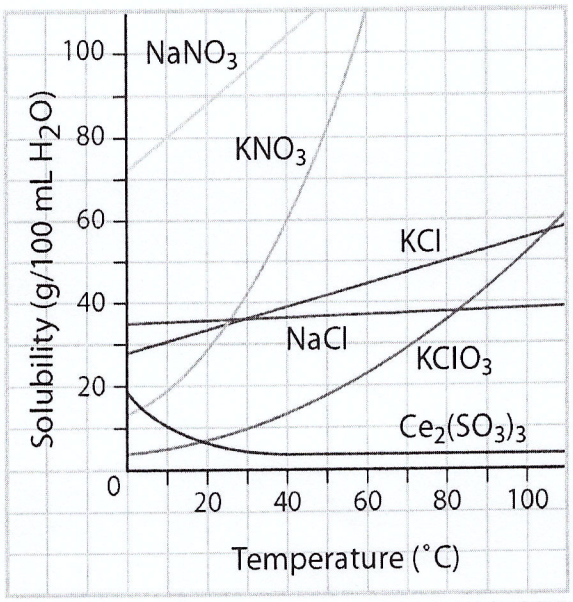
- The temperature can affect the solubility of a chemical
  - When a solid dissolves in a liquid, the solubility of the solid increases with increasing temperature
  - When a liquid dissolves in a liquid, the solubility of the liquid is not affected by a temperature
  - When a gas dissolves in a liquid, the gas particles need to lose kinetic energy so that they can slow down enough to allow them to dissolve in the liquid. Therefore, as temperature increases, the solubility of a gas decreases.
- The pressure can also affect the solubility of gases. Pressure does not affect the solubility of solids or liquids.
  - As the pressure increases, the solubility of a gas also increases
  - For example, when you open a pop bottle, the pressure is reduced which causes the dissolved gas to become less soluble and the gas is released from the liquid as "fizzing bubbles"

*****Now try Practice Problem #3-4*****

Practice Problems

1. The solubility of potassium carbonate, $K_2CO_{3(s)}$ is 94g/100mL of water at 20°C.
   a. How much of this solute is dissolved in 200mL of a saturated solution at 20°C?
   b. How would you describe 500mL of solution that contained 94g of potassium carbonate at 20°C? (Is it saturated or unsaturated?)
   c. A solution of potassium carbonate has a volume of 100mL and contains 50.0g of solute at 20°C. How much more potassium carbonate can dissolve?
   d. How much potassium carbonate, in total, is in a beaker containing 100mL of saturated solution and 10g of undissolved solid at 20°C?

2. The graph shows the solubility of various substances plotted against the temperature of the solution. Use the graph to answer the following questions.



   a. Which substance is the most soluble at 15°C?
   b. Which substance is the least soluble at 15°C?
   c. Which substance decreases in solubility as temperature increases?
   d. What mass of sodium chloride will dissolve in 100 mL of water at 10°C?
   e. At what temperature is the solubility of sodium nitrate equal to 80g/100mL H_2O?
   f. What minimum temperature is required to dissolve 30 g of potassium chlorate in 100 mL of water?
   g. What minimum temperature is required to dissolve 30 g of potassium nitrate in 50 mL of water?
   h. If 20 mL of a saturated solution of potassium nitrate at 50°C is cooled to 20°C, approximately what mass of solid would crystallize out of the solution?

3. Write the chemical equations representing the following processes.
    a. Calcium chloride, $CaCl_{2(s)}$, dissolves to form an unsaturated solution.
    b. Magnesium phosphate, $Mg_3(PO_4)_{2(s)}$, dissolves to form a saturated solution.

4. Would you expect to find more mineral deposits near a thermal spring or near a cool mountain spring? Explain.

Answers

1.
    a. 188 g
    b. Unsaturated
    c. 44 g
    d. 104 g

2.
    a. $NaNO_3$
    b. $KClO_3$
    c. $Ce_2(SO_3)_3$
    d. 35 g
    e. 10°C
    f. 70°C
    g. 40°C
    h. 10 g

3.
    a. $CaCl_{2(s)} \rightarrow Ca^{2+}_{(aq)} + 2Cl^{-}_{(aq)}$
    b. $Mg_3(PO_4)_{2(s)} \rightleftharpoons 3\ Mg^{2+}_{(aq)} + 2\ PO_4^{3-}{}_{(aq)}$

4. I would expect to find more mineral deposits at a cool mountain spring because the solubility of solids in liquids is less at lower temperatures.