Solutions

Objective #1: Know the parts of a solution

A solution is a _____ mixture of substances in the same physical state. The most common type of solution is one in which a solid or liquid is dissolved in a liquid. This is seen anytime a solid or liquid substance is dissolved in water, which we label as _____ or ( ).

There are two main parts of a solution.

Solute: substance or substances that _____ _____

Example: the *salt* in *salt*water

- solute is usually a GAS or SOLID and is the LESSER quantity of the two

Solvent: the substance that _____ _____ _____

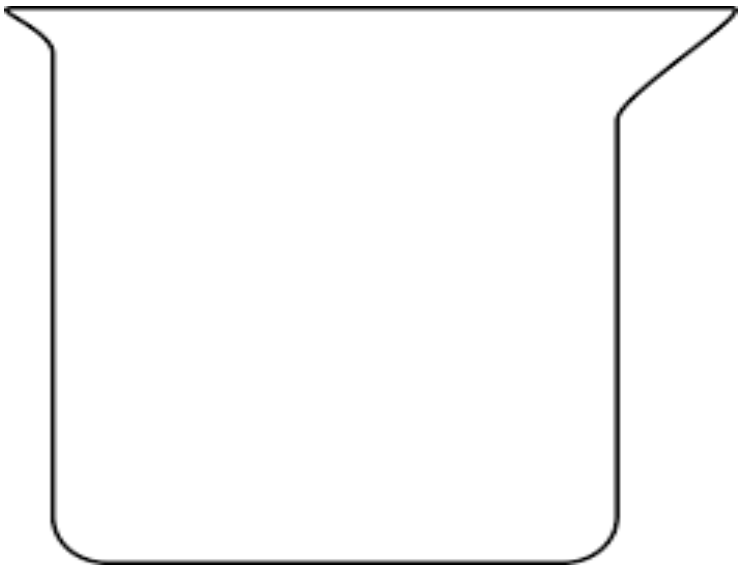
Example: the *water* in salt*water*

- solvent is usually a LIQUID and is the GREATER quantity of the two

Objective #2: Illustrate the Dissolving Process

Also known as the solvation process, this shows how the solutes break apart into charged ions and are kept apart in an aqueous solution. This process is described as a "Molecule - Ion Attraction".

Example: $LiCl(s) \xrightarrow{H_2O} Li^{+1}(aq) + Cl^{-1}(aq)$



Solution Questions

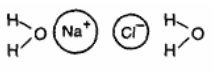
1. In an aqueous solution of potassium chloride, the solute is

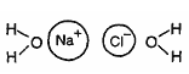
1) Cl^{-1} only 2) K^{+1} only 3) K^{+1} Cl^{-1} 4) H_2O

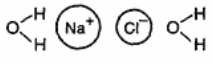
2) The attraction between water molecules and a Na^+ ion or a Cl^- ion occurs because water molecules are

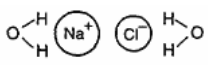
1) linear 2) symmetrical 3) polar 4) nonpolar

3. Which diagram best illustrates the ion-molecule attractions that occur when the ions of NaCl are added to water?

1) 

3) 

2) 

4) 

Objective #3: Identify Solubility Factors

Solubility: the ability of a given solute to _____ in a given solvent (at a set temperature and pressure)

- Soluble: When a given solute _____ dissolve in a solvent
- Insoluble: When a given solute _____ _____dissolve in a solvent

A. Factors that affect solubility

1. Nature of solute and solvent: " _____"

   For a given solute to dissolve in a solvent, the two substances must have the _____ type of polarity

   ** Remember: Polar molecule = _____

   Nonpolar molecule = _____

	Polar solvent	**Non-polar solvent**	**Ionic solvent**
Polar solute			
Non-polar solute			
Ionic solute			

2) Temperature

For solid and liquid solutes: as temperature increases, solubility _____

- the greater the temperature, the greater the number of _____ between solute and solvent, so the more that can be dissolved

For gas solutes: as temperature increases, solubility _____

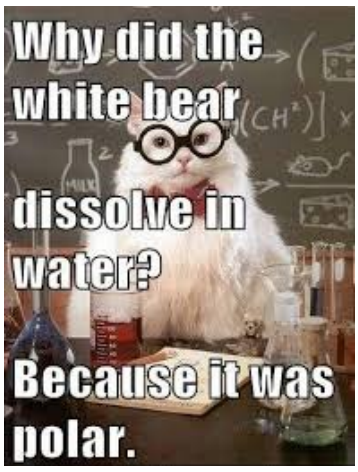
- when gas solutes increase in temperature, they are more likely to _____ and spread out and NOT stay in solution

3) Pressure

For gases only: as pressure over the system of gases increases, solubility of a given gas _____

- increased pressure over the system FORCES a gas into a solution

** think carbonation in soda: CO_2 (g) dissolved "under pressure"**



B. Factors that affect the *rate* of solubility

1) Particle size
   - _____ particles will dissolve faster and quicker than _____ particles
     - decreasing the size increases the _____
2) Stirring
   - stirring will _____ the rate of solubility because it will cause more _____ between solute & solvent particles
3) Amount of solute already dissolved
   - the more solute dissolved, the less space available for future solute to dissolve, so the solubility rate _____ & will eventually stop

Solubility Factors

1. The amount of KCl(s) that can dissolve in water depends most on the
   1) pressure on the solution
   2) rate of stirring
   3) size of the KCl sample
   4) temperature of the water

2. Under which conditions of temperature and pressure is a gas most soluble in water?
   1) high temperature and low pressure
   2) high temperature and high pressure
   3) low temperature and low pressure
   4) low temperature and high pressure

3. At room temperature, the solubility of which solute in water would be most affected by a change in pressure?
   1) ethanol 2) sugar 3) carbon dioxide 4) sodium chloride

4. A change in pressure would have the greatest effect on the solubility of a
   1) solid in a liquid 2) gas in a liquid 3) liquid in a liquid 4) liquid in a solid

5. The solubility of $KClO_3$(s) in water increases as the
   1) temperature of the solution increases
   2) temperature of the solution decreases
   3) pressure on the solution increases
   4) pressure on the solution decreases

6. Which of the following two substances will be able to dissolve?
   1) polar solute and non-polar solvent
   2) polar solute and polar solvent
   3) non-polar solute and polar solvent
   4) ionic solute and non-polar solve

7. Which substance would most readily dissolve in water?
   1) N_2 2) CH_4 3) NH_3 4) Ne

Objective #4: Solubility and Solubility Curves

A) Types of Solutions

There are 3 types of solutions that exist. Each is at a different moment in the dissolving process.

1) Unsaturated solution: Contains _____ amount of solute that can be dissolved in a given amount of solvent
    - More solute can still be added (and will still readily dissolve
2) Saturated solution: Contains the _____amount of solute that can be dissolved in the given amount of solvent.
    - NO more solute can be dissolved; any excess solute settles to the bottom and will not dissolve
    - This state is in "*solution equilibrium*" between the solute and solvent particles.
3) Supersaturated solution**:** A very *rare situation* where the solution contains _____amount of solute than can theoretically be possible
    - Very unstable solution where the excess dissolved will precipitate out if the solution is disturbed.

B) Solubility Curves

Reference Table G shows the solubility of 10 different solutes in 100. grams of water. The curves provided on the graph are called solubility curves. Each curve represents one solute. The solubility of each substance (how _____ can be dissolved in 100. grams of water) mainly depends on the _____of the water.

- For 7 of the 10 solutes, their solubility _____ as the temperature increases.
    - These solutes are _____.
- For 3 of the 10 solutes, their solubility _____ as the temperature increases.
    - These solutes are _____..
        - They are _____, _____ and _____.

When using REFERENCE TABLE G, you are comparing TEMPERATURE of 100. grams of water vs. GRAMS of solute that can be dissolved.

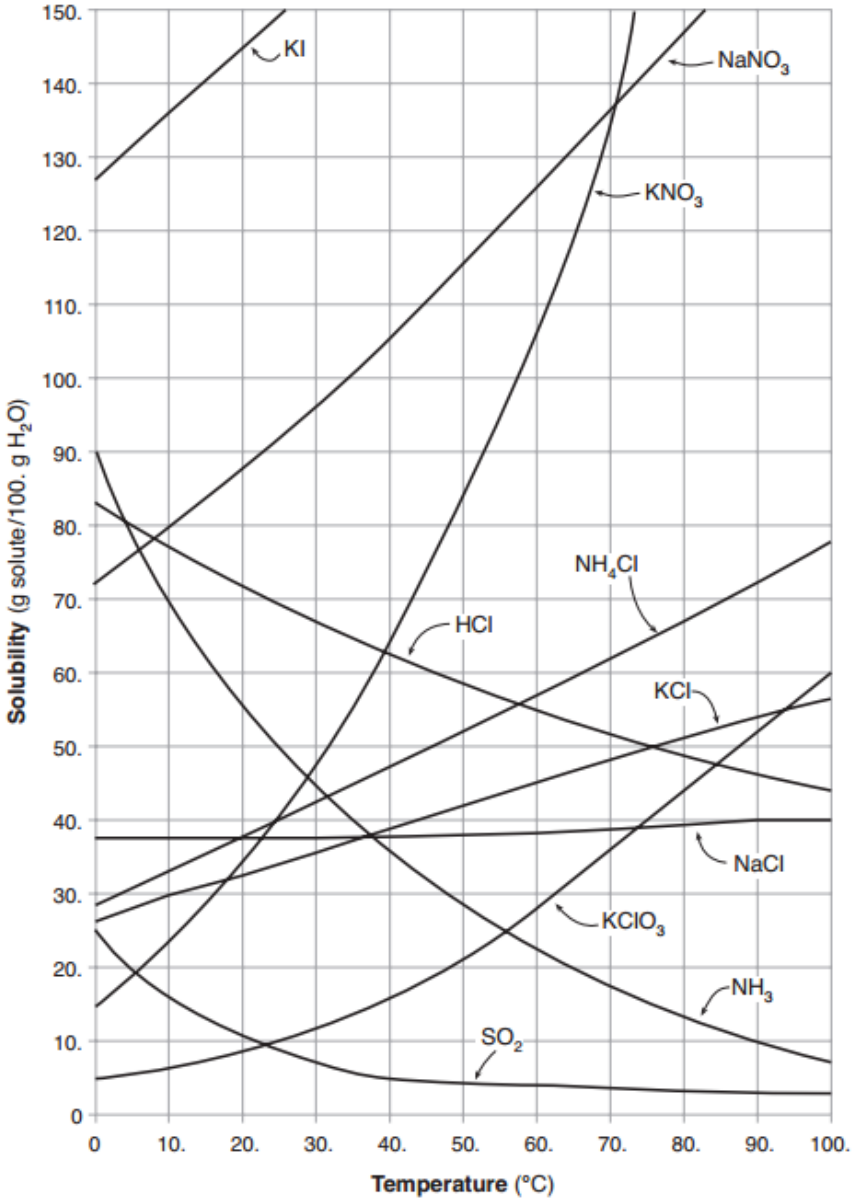
For each given solute:

- If the data point falls <u>below the solubility curve in question</u>, then the solution is <u>unsaturated</u>
- If the data point falls <u>on the line of the solubility curve in question</u>, the solution is <u>saturated</u>
- If the data point falls <u>above the line of the solubility curve in question</u>, the solution is <u>supersaturated</u>

If the amount of solvent (water) given is not 100.0g, the solubility value will need to be adjusted.

- *Note: this WILL NOT change the solubility temperature!!!*

Table G
Solubility Curves at Standard Pressure



** If <u>50.0 grams</u> of water is used (half the amount of what the graph is in), the solubility value (grams dissolved) will have to be doubled before using the graph

If <u>200.0 grams</u> of water is used (double the amount of what the graph is in), the solubility value (grams dissolved) will have to be halved before using the graph

1. State whether each of the following solutions is *saturated, unsaturated, or supersaturated*.

(a) 80 g $NaNO_3$ in 100 g H_2O at 10ºC _____

(b) 75 g $NaNO_3$ in 100 g H_2O at 10ºC _____

(c) 90 g $NaNO_3$ in 100 g H_2O at 10ºC _____

(d) 90 g KNO_3 in 100 g H_2O at 50ºC _____

(e) 90 g KI in 100 g H_2O at 50ºC _____

(f) 30 g KCl in 100 g H_2O at 10ºC _____

(g) 40 g KCl in <u>50 g H_2O</u> at 60ºC _____

(h) 35 g $NaNO_3$ in <u>50 g H_2O</u> at 10ºC _____

(i) 5 g $KClO_3$ in <u>50 g H_2O</u> at 5ºC _____

(j) 5 g $KClO_3$ in <u>200 g H_2O</u> at 5ºC _____

(k) 30 g NH_4Cl in <u>200 g H_2O</u> at 10ºC _____

(l) 40 g SO_2 in <u>200 g H_2O</u> at 5ºC _____

2. Tell how many MORE grams of each solute must be added to 100.0 g of water to form a saturated solution at that temperature.

- If a solution is unsaturated, you can add more solute at the given temperature until the solubility point falls exactly on the line of saturation

Grams Solute per 100 g H_2O	Solute Added to make Saturated		Grams Solute per 100 g H_2O	Solute Added to make Saturated		Grams Solute per 100 g H_2O	Solute Added to make Saturated
a. 35 g KNO_3 at 40ºC			c. 35 g NaCl at 90ºC			e. 25 g NH_3 at 5ºC	
b. 50 g NH_3 at 10ºC			d. 5 g NH_3 at 90ºC			f. 30 g $NaNO_3$ at 50ºC	

3. Tell how many grams of each solute will <u>crystallize/precipitate/settle.</u> Assume all solutions are saturated and in 100.0 grams of H_2O.

- If a saturated solution is cooled, the excess that will crystalize/precipitate/settle out is the difference in the area between where the data point is (at the given temperature) versus where the data point will fall at the new given temperature

Amount cooled	Amount Precipitated	Amount cooled	Amount Precipitated
a. KNO_3 (aq) is cooled from 70ºC to 40ºC		d. NaCl (aq) is cooled from 100ºC to 40ºC	
b. NH_4Cl (aq) is cooled from 90ºC to 20ºC		e. $NaNO_3$(aq) is cooled from 65ºC to 25ºC	
c. KCl (aq) is cooled from 55ºC to 30ºC		f. $KClO_3$ (aq) is cooled from 100ºC to 40ºC	

Solubility Graph Practice Questions

____ 1) According to Table *G*, which substance forms an unsaturated solution when 80. grams of the substance are stirred into 100. grams of H_2O at 10.°C?

1) KNO_3 3) NH_3
2) KI 4) NaCl

____ 2) Which quantity of salt will form a saturated solution in 100 grams of water at 45ºC?

1) 30 g of KCl 3) 60 g of KNO_3
2) 35 g of NH_4Cl 4) 110 g of $NaNO_3$

____ 3) A solution contains 100 grams of a nitrate salt dissolved in 100 grams of water at 50ºC. The solution could be a

1) supersaturated solution of $NaNO_3$
2) saturated solution of $NaNO_3$
3) supersaturated solution of KNO_3
4) saturated solution of KNO_3

____ 4) A student tested the solubility of a salt at different temperatures and then used Reference Table *g* to identify the salt. The student's data table appears below.

Temperature (°C)	g of salt per 10 g of water
30	1.2
50	2.2
62	3.0
76	4.0

What is the identity of the salt?

1) potassium nitrate
2) sodium chloride
3) potassium chlorate
4) ammonium chloride

Objective #5: Solution Concentration

Concentration is a measurement of how much solute is dissolved in a given amount of solvent. For solutions, there are several expressions of concentration. Depending on the circumstances, one expression may be favored over the others.

Use Reference Table T to obtain the formulas for each of the following:

Molarity:

To determine the molarity of a solution:

1) Determine the number of moles of solute (1 mole = G.F.M. g)
2) Determine the volume of solution you have in liters (1000 mL = 1 L)
3) Divide moles by liters.

- Unit is " _____"

Parts per Million:

To determine the ppm of a solution:

1) Determine the mass (g) of solute only
2) Determine the mass (g) of solution
   - This is the solute + solvent together
3) Divide the two numbers, then multiply by 10^6.

- Unit is " _____"

Percent Composition:

This formula is used for both percent mass and volume problems.

1) Determine the mass (g) or volume (mL) of solute only
2) Determine the mass (g) or volume (mL) of solution
   - This is the solute + solvent together
3) Divide the two numbers, then multiply by 100.

- Unit is "_____"

Sample Regents Questions:

1) Determine the molarity when 2.75 moles of sodium chloride is dissolved in water to make 750. mL of solution.

2) Determine the molarity when 10.5 grams of NaCl is dissolved to make 1.5 L of solution.

3) What is the concentration in ppm of selenium if 1.3 grams are found in 250,000. grams of soil?

4) Calculate the concentration of salt in a solution of water in parts per million if 45.0 grams is dissolved in 120,000. grams of water.

5) Calculate the mass of solute used for an 8.0% salt solution if the mass of the solution is 350. grams.

6) What mass of solution would be needed to deliver 3.00 mg of a drug if the concentration of the drug in the solution was 3.50%.

Objective #6: Colligative Properties of a Solution

Properties of a solution that depend upon the _____ _____

of dissolved solute particles, but not upon the _____ of the solute

- colligative properties include:

a) _____ _____ _____

b) _____ _____ _____

Remember:
"Normal" freezing point of pure water = 0°C
"Normal" boiling point of pure water = 100°C

A. How does dissolving a solute in water change the normal freezing point and boiling point of water?

When any solute is added to water and dissolved to make an aqueous (aq) solution:

- the freezing point of the solution will be _____ than the normal freezing point of water

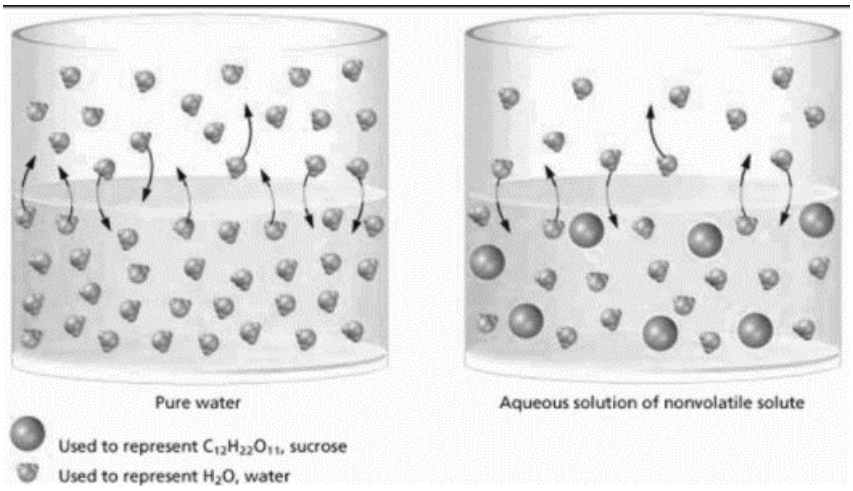
*Each mole of solute particle lowers the freezing point by 1.86 °C

- the boiling point of the solution will be _____ than the normal boiling point of water

*Each mole of solute particle raises the boiling point by 0.52°C

WHY ??!?!?!

The solute particles "*get in the way*" of the water molecules trying to move closer together or farther apart



B. How much lower is the freezing point of a solution and how much higher is the boiling point of a solution when a solute is dissolved in water?

It only depends on _____ _____ of dissolved particles!!!

- The _____ dissolved solute particles there are in a solution, the _____ the change in the freezing and boiling point of the solution.

Ionic (metal + nonmetal) solutes dissociate (break apart) completely into cations and anions

Solute	**Solution**	**Total # of moles (particles)**	**Rank of effect (1 = greatest; 3=least)**
NaCl(s)			
$MgCl_2$(s)			
Al_2O_3 (s)			

Covalent (nonmetals only) solutes will never break apart into ions, they simply become aqueous

Solute	**Solution**	**Total # of moles (particles)**	**Rank of effect (1 = greatest; 3=least)**
$C_6H_{12}O_6$(s)			
CH_4(s)			
CO_2 (g)			

Solutes with both Ionic and Covalent bonds break apart partially into ions

Solute	**Solution**	**Total # of moles (particles)**	**Rank of effect (1 = greatest; 3=least)**
Na_3PO_4(s)			
$Fe(NO_3)_2$(s)			
$Al_2(SO_4)_3$(s)			

Colligative Property Questions

1. Which solution has the highest boiling point?
   (1) 2.0 M NaCl
   (2) 2.0 M $CaCl_2$
   (3) 2.0 M $(NH_4)_3PO_4$
   (4) 2.0 M CH_3OH

2. Compared to pure water, a solution of $CaCl_2$ has a
   (1) higher boiling point and higher freezing point
   (2) higher boiling point and lower freezing point
   (3) lower boiling point and higher freezing point
   (4) lower boiling point and lower freezing point

3. Which solution has the highest boiling point?
   (1) 1.0 M KNO_3
   (2) 1.0 M KI
   (3) 1.0 M $Ca(NO_3)_2$
   (4) 1.0 M $Al(NO_3)_3$

4. Why is salt (NaCl) put on icy roads and sidewalks in the winter?
   (1) it is ionic and lowers the freezing point of water
   (2) it is ionic and raises the freezing point of water
   (3) it is covalent and lowers the freezing point of water
   (4) it is covalent and raises the freezing point of water

5. What occurs as a salt dissolves in water?
   (1) The number of ions in the solution decreases, and the freezing point decreases
   (2) The number of ions in the solution decreases, and the freezing point increases
   (3) The number of ions in the solution increases, and the freezing point decreases
   (4) The number of ions in the solution increases, and the freezing point increases

6. Which aqueous solution of KI freezes at the lowest temperature?
   (1) 1 mol of KI in 500. g of water
   (2) 2 mol of KI in 500. g of water
   (3) 1 mol of KI in 1000. g of water
   (4) 2 mol of KI in 1000. g of water

7. Compared to a 2.0 M aqueous solution of NaCl at 1 atmosphere, a 3.0 M aqueous solution of NaCl at 1 atmosphere has a
   (1) lower boiling point and a higher freezing point
   (2) lower boiling point and a lower freezing point
   (3) higher boiling point and a higher freezing point
   (4) higher boiling point and a lower freezing point

8. Based on Reference Table F, which of these solutes will have the lowest concentration of dissolved ions?
   (1) NaCl
   (2) $MgCl_2$
   (3) $NiCl_2$
   (4) AgCl