Part 1 – Notes: Introduction to Solutions

Heterogeneous: mixture in which the components are not uniformly distributed and segregate upon

Homogeneous: mixture that demonstrates uniform mixing of components

Solution: homogeneous mixture

Solvent:

Solute:

Solvent	Solid – solute	Liquid – solute	Gaseous – solute
Solid			
Liquid			
Gas			

Aqueous Solution:

Saturated solution: a solution in which the maximum number of solute particles been dissolved in a certain amount of solvent at the specified temperature

Unsaturated solution: a solution in which additional solvent particles may be added

Supersaturated solution: a solution that may hold more solute than usually allowed at a specified temperature

How do you make a saturated solution?

Testing for saturation levels –

Solubility: the measure of the amount of solute able to be dissolved in a given amount of solvent at a given temperature

Influence of temperature on solubility –

Solid solute –

Gaseous solute –

Equilibrium of a saturated solution with excess solute

Solvation: a chemical reaction between the solute and solvent whereby a solution is formed

Dissociation: the separation of a crystal into component ions through the breakdown of the crystal lattice

Solvation causes dissociation.

Solubility Rules:

Miscible: unlimited ability to mix in solution

Immiscible: substances that are insoluble in one another

Like dissolves like!!!

Part 1 – Assignment: Introduction to Solutions

Answer the following questions completely.

1. Give an example of a solution where water is a solvent. . . .water is a solvent.

2. Why does increasing the temperature of a solution allow for more solid solute to be added?

3. Why does increasing the temperature of a solution allow for less gaseous solute to be added?

4. How do you make a supersaturated solution?

5. Explain the dynamic equilibrium that is occurring in a saturated solution where excess solute is present.

6. What is solvation? How does it help form a solution?

7. How would you test if a solution is saturated?

8. Write the dissociation reaction for:
   a. calcium chloride in water

   b. tin (II) fluoride in water

   c. aluminum sulfide in water

9. Identify the following as heterogeneous (HETERO) or homogeneous (HOMO).

a.	coffee with milk	b.	chocolate fudge
c.	chocolate chip ice cream	d.	lemonade and ice and fresh lemon slices
e.	fudge with chopped walnuts	f.	air
g.	tap water	h.	chocolate chip cookies
i.	tomato salsa	j.	Italian salad dressing
k.	ketchup	l.	sterling silver
m.	whole milk	n.	chocolate chip peanut butter cup cookie cups

10. What's the solute? What's the solvent?

a.	Coca-Cola®	b.	air
c.	14 kt gold	d.	steel

Part 2 – Notes: Solubility Rules

Solubility rules are helpful to determine if a substance is soluble in a given solvent. The solubility rules below indicate if a compound is soluble in water.

Negative Ion **(Anion)**	***Plus*** **(+)**	***Positive Ion*** **(Cation)**	Cmpd is. . .	
Any anion	+	Alkali metal ions	cmpd is	Soluble
Any anion	+	Ammonium ion	cmpd is	Soluble
Nitrate (NO_3^{-1})	+	Any cation	cmpd is	Soluble
Acetate ($C_2H_3O_2^{-1}$)	+	Any cation *except* Ag^{+1}	cmpd is	Soluble
Chloride (Cl^{-1}), or Bromide (Br^{-1}), or Iodide (I^{-1})	+ +	Ag^{+1}, Pb^{+2}, Hg_2^{+2}, or Cu^{+1} Any other cation	cmpd is	Not soluble Soluble
Sulfate (SO_4^{-2})	+ +	Ca^{+2}, Sr^{+2}, Ba^{+2}, Ra^{+2}, Ag^{+1}, or Pb^{+2} Any other cation	cmpd is	Not soluble Soluble
Sulfide (S^{-2})	+ + +	Alkali ions or NH_4^+ Be^{+2}, Mg^{+2}, Ca^{+2}, Sr^{+2}, Ba^{+2}, Ra^{+2} Any other cation	cmpd is	Soluble Soluble Not soluble
Hydroxide (OH^{-1})	+ + +	Alkali ions of NH_4^+ Sr^{+2}, Ba^{+2}, or Ra^{+2} Any other cation	cmpd is	Soluble Slightly soluble Not soluble
Phosphate (PO_4^{-3}), or Carbonate (CO_3^{-2}), or Sulfite (SO_3^{-2})	+ +	Alkali ions or NH_4^+ Any other cation	cmpd is	Soluble Not soluble

If a compound is soluble in water, solvation occurs and dissociation occurs.

Example 1: Write the dissociation reaction for copper (II) sulfate in water.

Example 2: Determine if the following compounds are soluble in water or not.

Tin (II) phosphate

Ammonium oxalate

Copper (II) bromide

Ammonium acteate

Can you think of any generalities you should know by heart???

Part 2 – Assignment: Solubility Rules and Dissociation

Use the solubility rules to answer the following questions.

1. Use the solubility rules to determine if the following compounds are soluble in water. If they will dissolve in water, write the dissociation reaction. If they will not dissolve, write NOT SOLUBLE.

    a. silver nitrate

    b. silver acetate

    c. sodium sulfate

    d. calcium hydroxide

    e. ammonium phosphate

    f. sodium sulfite

    g. calcium carbonate

    h. calcium acetae

    i. aluminum sulfide

    j. aluminum nitrate

    k. rubidium sulfide

    l. calcium sulfate

2. Determine if the following will dissolve in water. Write YES or NO. (Recall – things of like polarity will dissolve and water is polar.)

    a. CCl_4

    b. NH_3

    c. Br_2

    d. $CaBr_2$

    e. ethanol

    f. octane

    g. propanol

Part 3 – Notes: Solubility Curves

Recall:

What happens to the solubility of a solid solute as the temperature of the solution increases?

What happens to the solubility of a gaseous solute as the temperature of the solution increases?

The solubility graph provided, shows the quantity of various solutes that dissolve in 100 g of water over the temperature range from 0ºC to 100ºC.

Examine the unit on the vertical axis. It states that the quantity of solvent in this situation is 100 g of water. Other graphs may have different quantities of water as the quantity of solvent.

Examine the lines on the graph.

What does the line represent?

What do the points on the line of a specified solute represent?

What do the points below the line of a specified solute represent?

What do the points above the line of a specified solute represent?

Use the graph and answer the following questions. Be able to explain your answers.

1. Find the temperature at which $KClO_3$ has the same solubility as NH_3.
2. Which substance(s) show(s) a decrease in solubility with increasing temperature?
3. Which substance shows the greatest increase in solubility with increasing temperature? How did you choose?
4. Which substance shows the least increase in solubility with increasing temperature?
5. How much KNO_3 can dissolve in 100 g of water at 70ºC?
6. What mass of KNO_3 will crystallize from a solution if it is saturated at 70ºC and then cooled to 50ºC?
7. A saturated solution of NH_4Cl at 50ºC is warmed to 70ºC. How much more solid solute may be dissolved?
8. Which substance is most soluble in water at 10ºC?
9. Which substance is least soluble in water at 30ºC?
10. What mass of NH_4Cl can dissolve in 1 L of water at 90ºC? (Recall: 1 L of water has a mass of 1000 g.)
11. What mass of $NaNO_3$ would be required to make 250 mL of a saturated solution at 40ºC? (Note: For our purposes, 1 mL = 1 g.)
12. If 100 g KNO_3 is dissolved in 100 g of water at 50ºC, is the solution saturated, unsaturated, or supersaturated? How do you know?

Part 3 – Assignment: Solubility Curves

Use the solubility curve provided to answer the following questions.

1. What mass of NH_3 is dissolved in 100 g of Water to make a saturated solution at 90°C?

2. What mass of NH_3 is dissolved in 425 g H_2O to make a saturated solution at 90°C?

3. What temperature is required to dissolve 95 g $NaNO_3$ in 100 g H_2O?

4. What mass of KCl may be dissolved in 318 g H_2O at 80°C so it is saturated?

5. What mass of NH_4Cl is needed to form a saturated solution at 50°C?

6. A solution of $NaNO_3$ is saturated at 10°C. How much additional solute is required to maintain a saturated solution is the temperature is raised to 80°C?

7. How many grams of KNO_3 will crystallize from 250 g of water solvent that had been saturated at 70°C then cooled to 40°C?

8. A saturated solution of KNO_3 in 100 g of water is cooled from 70°C to 60°C. If all of the KNO_3 solute remains in solution, the solution is ___???___.

9. The amount of a solid solute that will dissolve in a liquid solvent _____ with increasing temperature.

   The amount of a gaseous solute that will dissolve in a liquid solvent _____ with increasing temperature.

10. What mass of KCl can dissolve in 1 L of water at 80°C?

11. What mass of KNO_3 dissolve in 375 mL of water at 40°C?

12. A solution of $NaNO_3$ in water is saturated at 20°C. How much additional solute would need to be added to maintain a saturation if the temperature is raised to 60°C?

13. A saturated solution of $KClO_3$ and 387 g of water is at 70°C. The solution is cooled to 40°C. How much crystallizes out from the solution?

For 14 through 16, consider the solubility of NaCl and $KClO_3$.

14. At what temperature are the solubilities equal?

15. Which substance has a lower solubility at 50°C?

16. Which substance has a greater increase in solubility with increasing temperature?

Part 4 – Notes: Solubility and Units of Concentration

Review:

Saturated solution – solution in which no more solute is able to be dissolved
Unsaturated solution – solution in which more solute is able to be dissolved
Solubility – the amount of a solute that is able to be dissolved in a given amount of solute at a given temperature
Concentration – in a solution – how much of a solute is present in a solution relative to a set quantity

Solubility may be measured in terms of parts per million (ppm), parts per billion (ppb), grams of solute per 100 g of solvent, MOLARITY, and MOLALITY.

Molarity: the number of ***moles*** of solute per ***liter of solution***. It is important to note that the solution is equal to the solute plus the solvent. Unless otherwise noted, the solvent used for our work will be water.

MOLARITY =

Example 1: What is the molarity of a solution made with 126.32 g of sodium hydroxide dissolved to make 874.2 mL of a solution? (Remember to show all the required work, units, etc.)

Example 2: How many grams of zinc acetate are present in 568.1 mL of a 1.53 M solution?

Molality: the number of ***moles*** of solute per ***kg of solvent***. It is important to remember that the solution is equal to the mass of the mass of the solute plus the mass of the solvent. In molality, the mass of interest is that of the solvent alone.

MOLALITY =

Example 3: What is the concentration, in molality, of a solution made with 145.8 g ammonium carbonate dissolved in 845.6 g of water?

Example 4: What is the mass, in grams, of copper (II) chloride present in 741.2 g of water to make a 2.56 m solution?

Example 5: What is the mass of the ***solution*** made from 125.0 g of sodium nitrate with enough solvent to make a 1.75 m solution? Recall: solution = solute + solvent.

Parts per million and Parts per billion

ppm =

ppb =

Example 6: What is the concentration, in ppm and ppb, of a solution made with 18.5 g of salt in 12 500.0 g of water?

Part 4 – Assignment: Units of Concentration

Solve the following problems. Be sure to show all required work, units, formulas, etc.

1. How many molecules (actually formula units) of calcium chloride are in 3.57 L of a 4.25 M solution of calcium chloride?

2. If 162.35 g aluminum hydroxide are dissolved in 6.75 L of solution, what is the molarity of the solution?

3. Calculate the molality of a solution containing 0.0762 mol of iodine (molecule) in 450.0 g of carbon tetrachloride.

4. What mass of solvent is required to make 1.725 m solution with 75.45 g lithium phosphate?

5. What volume of a 0.856 M solution may be made by using 118.02 g iron (II) acetate?

6. How many grams of water are required to prepare a 0.375 m solution of C_2H_5OH using 2.50 g ethanol?

7. You have 125 g of potassium sulfate and 385 g water. You mix them together to make a solution.
   a. What is the molality of the solution you make.

   b. What is the molarity of the solution you make? (Recall: solution = solute + solvent. For this problem: 1 g = 1 mL.)

Part 5 – Notes: Boiling Point Elevation and Freezing Point Depression

When a solute is dissolved in a solvent, the freezing point of the solution is generally lower than the freezing point of the pure solvent. The boiling point of the solution is generally higher than the boiling point of the pure solvent.

The size and type of the molecules or ions that compose the solute **do NOT** determine how it will affect the boiling point or freezing point of a solution, but rather it is the **number of dissolved ions or molecules** that affect the boiling point and freezing point of a solution.

Generally, the greater the **number** of dissolved particles, the higher the boiling point of a solution compared to the boiling point of the solvent alone.
Likewise, the greater the **number** of dissolved particles, the lower the freezing point of a solution compared to the freezing point of the solvent alone.

Example 1: What is the concentration of the sucrose particles in water, in molality, if 1 mole of sucrose ($C_{12}H_{22}O_{11}$) is dissolved in 1 kg of water?

Molality of sucrose:

Molality of dissolved particles:

Example 2: What is the concentration of the sodium chloride particles in water, in molality, if 1 mole of sodium chloride is dissolved in 1 kg of water?

Molality of sodium chloride:

Molality of dissolved particles:

Example 3: What is the concentration of the calcium chloride particles in water, in molality, if 1 mole of calcium chloride is dissolved in 1 kg of water?

Molality of calcium chloride:

Molality of dissolved particles:

Note: There are three times as many dissolved particles hydrated when calcium chloride is dissolved than when sucrose is dissolved. Therefore, the calcium chloride affects boiling and freezing points of the solution three times more than does the sucrose.

Calculations Involving Boiling Point and Freezing Point Changes

Boiling Point Elevation

ΔT_b if the difference between the boiling point of the pure solvent and that of the solution. For our purposes, there is always an increase in the boiling point; it is elevated.

$\Delta T_b =$ $\Delta T_b =$

k_b is the constant that relates change in temperature to the molality of the dissolved particles. ***Note: the k_b constant is different for every solvent.***

$k_{b\ (water)} =$ $k_{b\ (ethanol)} =$

$\mathbf{m_{dp}}$ is the molality of the dissolved particles. **Remember:** the molality of the ionic compounds is different from the molality of dissolved particles.

$\mathbf{m_{dp}}$ =

Freezing Point Depression

ΔT_f is the difference between the freezing point of the pure solvent and that of the solution. For our purposes, there is always a decrease in the freezing point; it is depressed.

ΔT_f = ΔT_f =

k_f is the constant that relates change in temperature to the molality of the dissolved particles. ***Note: the k_f constant is different for every solvent.***

$k_{f\,(water)}$ = $k_{f\,(ethanol)}$ =

$\mathbf{m_{dp}}$ is the molality of the dissolved particles. **Remember:** the molality of the ionic compounds is different from the molality of dissolved particles.

$\mathbf{m_{dp}}$ =

Examples: Calculate the boiling point for each of the solutions in examples 1, 2, and 3 above.

Part 5 – Assignment: Boiling Point Elevations and Freezing Point Depressions

Use the information in the data table to answer questions about BP and FP changes.

Solvent	*Normal FP (°C)*	k_f *(°C/m)*	*Normal BP (°C)*	k_b *(°C/m)*	*Formula*
benzene	5.50	5.1	80.15	2.53	C_6H_6
naphthalene	80.20	6.9	218.0	5.65	$C_{10}H_8$
phenol	40.90	7.1	181.2	3.56	C_6H_5OH
water	0.00	1.86	100.0	0.52	H_2O

Note: Sucrose = $C_{12}H_{22}O_{11}$ = 342.34 g/mol Glucose = $C_6H_{12}O_6$ = 180.18 g/mol

1. A solution is prepared by dissolving 6.75 g glucose in 325 g water. What is the freezing point of the solution?

2. A 0.400 m solution of naphthalene in benzene is needed. 32.0 g naphthalene is available. How much benzene solvent is needed? What is the boiling point of this solution?

3. 65.43 g ammonium nitrate are dissolved in 654.3 g water. What is the freezing point of the solution?

4. A 5.250 g sample of a newly synthesized, non-dissociating compound is added to 250.0 g water and the freezing point of the solution was 0.62°C. What is the molar mass of the new compound?

5. A solution contains 98.76 g sodium carbonate dissolved in 765.4 g water. What is the boiling point of the solution?

Part 5B – Assignment: Boiling Point Elevations and Freezing Point Depressions

Solve the following problems. Show all required "stuff".

1. What is the molality of the solution of glucose in phenol that freezes at 37.20°?

2. At what temperature will a solution freeze if it is composed of 40.00 g $CaCl_2$ dissolved in 550.0 mL of water?

3. The boiling point of a solution is 101.0°C. How many moles of sucrose must be dissolved in 1.000 kg water to cause this to be the boiling point?

4. The freezing point of a $CaCl_2$ solution is –5.00°C. How many moles of $CaCl_2$ must be dissolved in 875.0 g water to cause this to be the freezing point?

5. The freezing point of water becomes –1.75°C when 37.5 g of a non-dissociating solute is added to 136 g water. What is the molar mass of the solute?

Part 6 – Notes: Net Ionic Equations

Precipitation Reactions: reactions characterized by the formation of an insoluble product

Precipitate: an insoluble solid that separates from the solution as a product

For example, an aqueous solution of lead (II) nitrate is added to sodium iodide, a yellow precipitate of lead (II) iodide is formed.

Write the complete and balanced equation for the reaction described above.

How can we predict whether a precipitate will form when two solutions are mixed or when a compound is added to a solution? We need to examine the solubility rules to determine if a substance is soluble or not.

The complete and balanced equation written above is an example of a **molecular equation**.

Molecular Equation: an equation where the formulas of all the compounds are written as though all species existed as whole molecules or whole units

Useful –

However –

(Complete) Ionic Equations: an equation that shows dissolved compounds in terms of their free ions

Spectator Ions: ions not involved in the overall reaction

Net Ionic Equation: equation that shows only the species that actually take part in the reaction

Steps for Writing Net Ionic Equations:

1. Write a balanced molecular equation for the reaction.
2. Use the solubility rules to check that reactants are soluble in water. Also check which products are soluble in water. It may be none, one, or two.
3. Write a complete ionic equation, showing all species present. Remember charges and (aq), etc.
4. Eliminate spectator ions. (Which ions are identical on both sides of the yield sign?)
5. Write the net ionic equation that shows just the species involved in the reaction. (Spectators are eliminated.)

Example 1: Write the net ionic equation: copper (II) nitrate and potassium chloride.

Example 2: Write the net ionic equation: copper (II) sulfate and iron (III) chloride.

Note: If a product compound is not soluble then a reaction has occurred. If all ions are eliminated because they are all spectators, then no reaction has occurred and all ions remain in solution without having reacted. You need to designate these products as → NR.

Part 6 – Assignment: Net Ionic Equations

Write the net ionic equations for each of the following reactants sets described below. Assume all reactions are taking place in an aqueous environment. Make sure to show all steps (1, 2, and 3) as shown in class. Remember the NR.

1. iron (II) sulfate and ammonium sulfide

2. potassium carbonate and strontium nitrate

3. sodium iodide and silver nitrate

4. aluminum sulfate and calcium chloride

5. sodium sulfate and calcium chloride

6. potassium sulfate and barium acetate