Key

Mixtures & Solutions Notes

Mixtures (2 types)- Heterogeneous - More than one phase
Homogeneous - 1 phase

Hetero → **Suspension-** When large particles seem to mix when stirred, but settle to the bottom when left to sit. Ex - Sand in water

Hetero → **Colloid-** Medium size particles do not mix in but do not settle down. Ex - Milk, Mayo

Tyndall Effect - The scattering of light due to the particles in a colloid not allowing light to pass through.

Solutions- Homogeneous mixtures of small particles mixing in with larger particles. Can be Solid, Liquid or gases.

2 parts of a solution
Solvent- the substance that does the dissolving (Ex. water)
Solute- the substance being dissolved (iced tea mix)

Aqueous Solution- Any solution with water as the solvent.

Alloy- A solid solution made up of 2 or more metals (Ex - Brass, Bronze, Sterling Silver, White Gold)

Saturated Solution- A solution that has the maximum amount of solute that the solvent can handle.

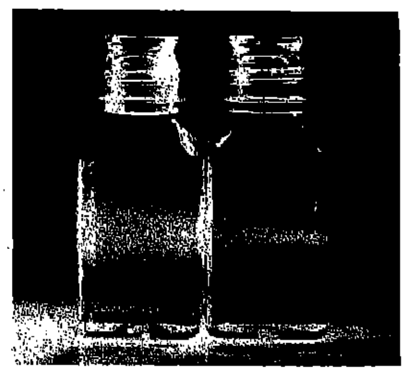
Supersaturated Solution- A solution that contains More than the maximum amount of solute. (Very unstable, needs to be heated!)

Unsaturated Solution-
- A solution that contains <u>Less</u> than the maximum amount of solute.

IV. DISTINGUISHING BETWEEN THE TYPES OF MIXTURES:

A. <u>3 types of MIXTURES:</u>

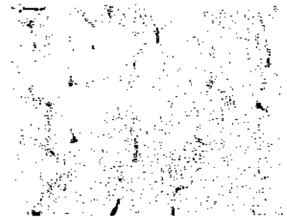
1) **<u>solution</u>** = a homogeneous mixture
2) **<u>suspension</u>** = a mixture in which the particles are so large that they settle out unless the mixture is constantly stirred or agitated
   - Ex: Sand and water
3) **<u>colloid</u>** = a mixture consisting of particles that are intermediate in size between those in solutions and those in suspensions
   - Ex: Milk
   - **<u>Tyndall effect</u>** = visible pattern caused by the reflection of light from suspended particles in a colloid (or from suspended particles in a suspension if the particles have not settled out)



     - Ex: visibility of a headlight beam on a foggy night
   - **<u>Brownian motion</u>** = the random continuous motions of colloidal particles
     - Demo: chalk erasers

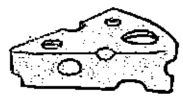
B. Classification of colloids based on the states of their dispersed and continuous phases:

a) **Aerosols** = Liquids and solids dispersed in gases (fog, smoke)



b) **Foams** = Gases dispersed in liquids (whipped cream) or in solids (marshmallows)

c) **Emulsions** = liquids are dispersed in other liquids (mayonnaise) or in solids (cheese)



d) **Gels/Sols** = solids dispersed in liquids (jelly, paint) or in solids (pearls, opals)

C. Properties of solution, colloids, and suspensions

Solutions	Colloids	Suspensions
Homogeneous	Heterogeneous	Heterogeneous
Particle size: 0.01-1 nm; can be atoms, ions, molecules	Particle size: 1-1000 nm, dispersed; can be aggregates or large molecules	Particle size: over 1000 nm, suspended; can be large particles or aggregates
Do not separate on standing	**Do not** separate on standing	Particles settle out
Cannot be separated by filtration	Cannot be separated by filtration	**Can** be separated by filtration
Do not scatter light	Scatter light (Tyndall effect)	**May** scatter light, but are not transparent

D. Determining if a mixture is a true solution, a colloid, or a suspension:

a) If particles settle or can be filtered out = **suspension**
b) If particles *DO NOT* settle or filter out shine a beam of light (Tyndall effect) through the mixture
   - If the Tyndall effect is observed = **colloid**
   - If the Tyndall effect is *NOT* observed = **solution**

II. THE NATURE OF SOLUTIONS:

1) **<u>Solvent</u>** = the substance that does the dissolving in a solution
   a) *Typically* present in the greatest amount
   b) *Typically* a liquid
   c) **<u>Water</u>** is the most common or "universal" solvent

2) **<u>Solute</u>** = substance being dissolved in a solution
   a) *Typically* present in the least amount
   b) *Typically* a solid

A. 9 Possible Solution Combinations:

Solvent	Solute	Common Example
Gas	Gas	**Diver's tank**
Gas	Liquid	**Humidity**
Gas	Solid	**Moth ball**
Liquid	Gas	**Carbonation**
Liquid	Liquid	**Vinegar**
Liquid	Solid	**Seawater**
Solid	Gas	**Gas stove lighter**
Solid	Liquid	**Dental fillings**
Solid	Solid	**Sterling Silver (Ag + Cu)**

- ***NOT all solutions are liquids/solids!***
- ***Solutions are formed in ALL 3 states!***

B. 3 Steps in Solution Formation:

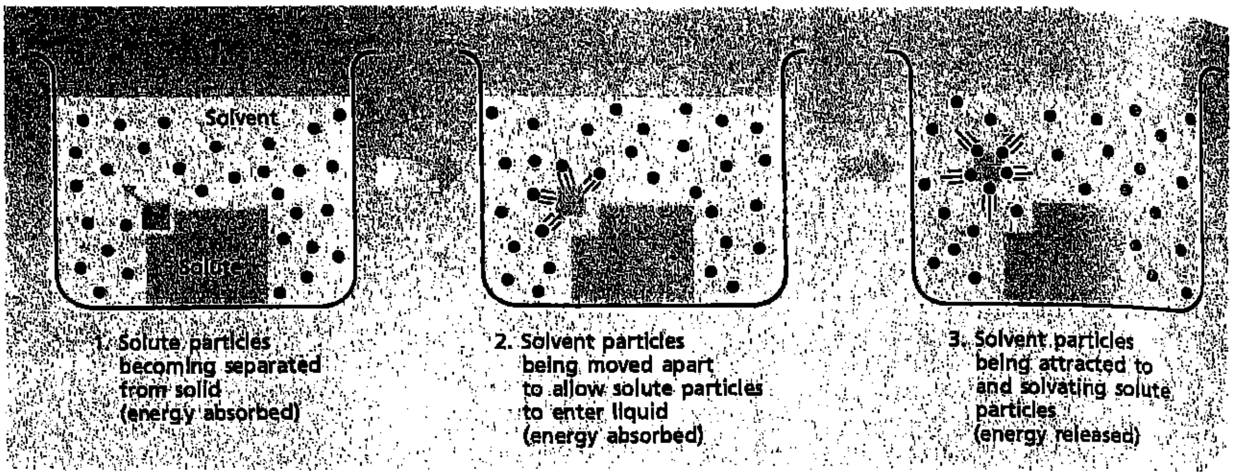
1) **<u>Solute-solute attraction is broken up</u>**; requiring energy
   - **<u>Dissociation</u>** = separation of ions from each other in a solution

     Ex: NaCl + H_2O – the Na ion and Cl ion become hydrated and gradually move away from the crystal into solution.

- Each ion in the solution acts as though it were present **alone**: So there is only a solution containing Na^+ and Cl^- ions uniformly mixed with H_2O particles

2) **Solvent-solvent attraction is broken up**; requiring energy

3) **Solute-solvent attraction is *formed***, releasing energy
   - **Solvation** = surrounding of solute particles by solvent particles

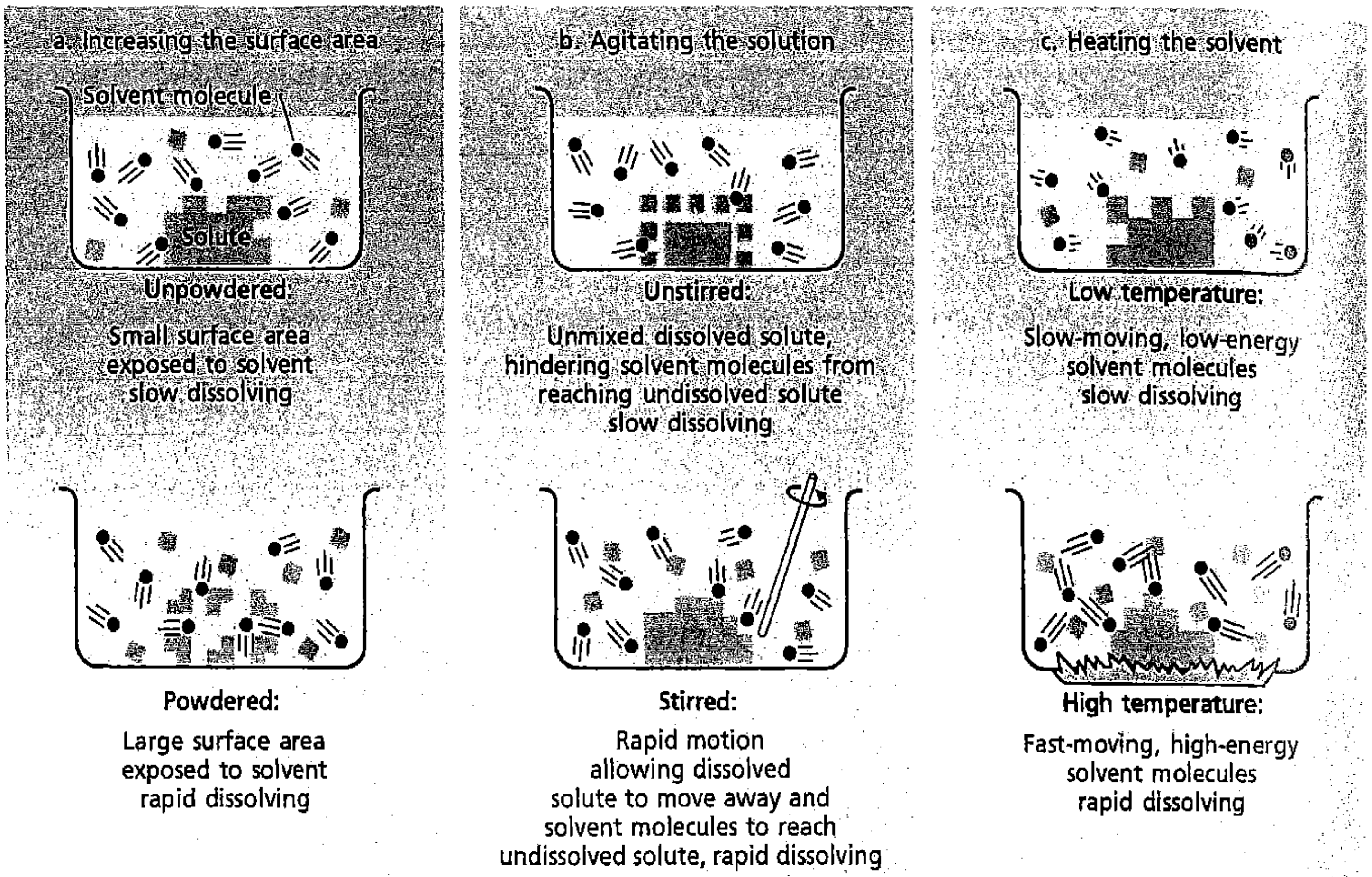


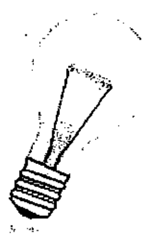
C. Factors Affecting the Rate of Dissolving (Increase Solution Rate):

1) **Grinding**: increases surface area

2) **Stirring**: allows solvent continual contact with solute

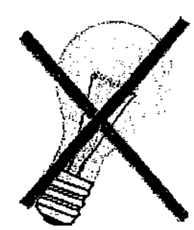
3) **Heating**: increases kinetic energy; increases mixing





D. Electrolytes and Nonelectrolytes

1) **electrolyte** = a substance that dissolves in water to give a solution that conducts electric current



2) **nonelectrolyte** = a substance that dissolves in water to give a solution that does NOT conduct an electric current

3) **Solutions** of electrolytes can conduct electric current:

a) The positive ions and the negative ions **disassociate** (separate) in solution. The **mobile** ions can move a charge from one point in the solution to another point

4) Solutions of **nonelectrolytes** CANNOT conduct electric current:

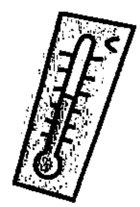
a) When a nonelectrolyte dissolves in water there are NO **charged particles** in solution.

5) *Solid* **ionic** compounds CANNOT conduct electric current:

a) Ions are present but they are NOT **mobile**.

E. SOLUBILITY:

1) **Solubility** = quantity of solute that will dissolve in specific amount of solvent *at a certain temperature.* (pressure must also be specified for gases).

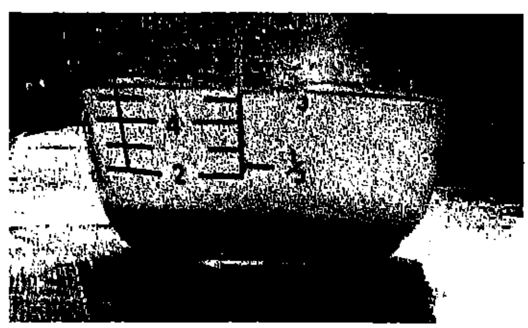


a) Ex: 204 g of sugar will dissolve in 100 g of water at 20°C

b) *soluble* and *insoluble* are relative terms

c) solubility should NOT be confused with the rate at which a substance dissolves

2) **saturated solution** = a stable solution in which the maximum amount of solute has been dissolved.



a) Visual evidence: a quantity of undissolved solute remains in contact with the solution

3) **<u>solution equilibrium</u>** = state where the solute is dissolving at the same rate that the solute is coming out of solution (crystallizing).

a) Opposing processes of the dissolving and crystallizing of a solute occur at equal rates.

b) solute + solvent $\rightleftharpoons$ solution

4) **<u>unsaturated solution</u>** = a solution that contains less solute than a saturated solution under existing conditions

5) **<u>supersaturated solution</u>** = a solution that temporarily contains more than the saturation amount of solute than the solvent can hold (unstable)

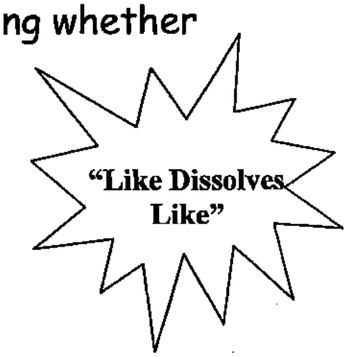
F. <u>3 FACTORS EFFECTING SOLUBILITY:</u>

⇨ The extent to which a given solute dissolves in a solvent depends on the identity of the solute and solvent and also on the existing conditions of pressure & temperature

1) Nature of solute and solvent

a) **<u>"Like dissolves like"</u>** = rule of thumb for predicting whether or not one substance dissolves in another

- "Alikeness" depends on:
  - Intermolecular forces
  - Type of bonding



- Polarity or nonpolarity of molecules:
    - ❖ ionic solutes tend to dissolve in polar solvents but not in nonpolar solvents

<u>Solvent-Solute Combinations</u>:

<u>Solvent Type</u>	<u>Solute Type</u>	<u>Is Solution Likely?</u>
Polar	Polar	Yes
Polar	Nonpolar	No
Nonpolar	Polar	No
Nonpolar	Nonpolar	Yes

2) **<u>Pressure:</u>**

a) Pressure has **<u>little effect</u>** on the solubility of liquids or solids in liquid solvents.

b) The solubility of a **<u>gas</u>** in a **<u>liquid solvent</u>** INCREASES when pressure **<u>increases</u>**. It is a direct relationship.

3) **<u>Temperature:</u>**

a) The solubility of a gas in a liquid solvent DECREASES with an **<u>increase</u>** in temperature.

b) The solubility of a solid in a liquid solvent MOST OFTEN increases with an increase in temperature. However, solubility changes vary widely with temperature changes sometimes decreasing with temperature increases.

Name: Period: Date:

Concentration of Solution- Molarity

Molarity is commonly used to express the concentration of a solute in a solvent. The molarity (M) of a solution can be expressed as the number of moles of solute per liter (L) of solution:

$$\text{Molarity} = \frac{\text{moles of solute}}{\text{Liters of solution}}$$

When working with this type of problem, it is necessary to express the volume in **liters**. *The problems often express the volume in mL; therefore it is necessary to convert the volume to liters:*

$$\#\text{ of L} = \#\text{ of mL} \div 1000$$

Example: *What is the molarity of a solution that contains 64.8 grams of $NaNO_3$ dissolved in 950 mL of solution? (MM of Na = 23; MM of N = 14; MM of O = 16)*

Step 1: *In order to use the molarity relationship, it is necessary to convert grams to moles and mL to L.*

$$\text{Moles } NaNO_3 = 64.8\text{ g} \div 85.0\text{ g} = 0.762\text{ moles}$$
$$\text{L of solution} = 950\text{ mL} \div 1000 = 0.950\text{ L}$$

Step 2: *Substitute and solve.*

$$\text{Molarity} = \frac{\text{moles of } NaNO_3}{\text{L of solution}}$$

$$= \frac{0.762\text{ moles of } NaNO_3}{0.950\text{ L}} = 0.802\text{ mol/L} = 0.802\text{ M}$$

Exercises: *Solve the following problems, showing all work. Express your answer with the correct units.*

1. Calculate the molarity of a solution that contains 2.0 moles of a solute dissolved in 6.0 L of solution.

$M = \frac{\text{moles}}{L} = \frac{2\text{ moles}}{6L} = .333\frac{\text{mol}}{L} = \underline{.333M}$

2. Calculate the molarity of a solution if there are 1.8 moles of solute dissolved in 600 mL of solution.

.6L

$M = \frac{\text{moles}}{L} = \frac{1.8\text{ mol}}{.6L} = \underline{3M}$

3. How many moles of solvent are present in 3.00 L of 2.00 M HCl?

$\text{mols} = M \times L = 2\frac{\text{mol}}{\cancel{L}} \times 3\cancel{L} = \underline{6\text{ mol HCl}}$

4. How many moles of solvent are present in 15 mL of a 0.50 M solution?

.015L

$\text{moles} = M \times L =$

$.5\frac{\text{mol}}{\cancel{L}} \times .015\cancel{L} = \underline{.0075\text{ moles}}$

5. What volume of 0.80 M sodium hydroxide solution will contain 4.8 moles of solute?

$L = \frac{moles}{M} = \frac{4.8 \text{ mol}}{.8 \frac{mol}{L}} = \underline{6 \text{ L}}$

6. A chemist wishes to obtain 1.2 moles of $CaCl_2$ by evaporating a 0.50 M solution of the salt. What volume of the solution should be used? Express your answer in mL.

$L = \frac{moles}{M} = \frac{1.2 \text{ moles}}{.5 \frac{mol}{L}} = 2.4 \text{ L} = \boxed{2{,}400 \text{ mL}}$

7. What is the molarity of a solution that contains 32.0 g of $NaNO_3$ dissolved in 1.80 L of solution? (MM of Na = 23 g/mole; MM of N = 14 g/mole; MM of O = 16 g/mole)

$M = \frac{moles}{L} = \frac{.376 \text{ moles}}{1.8 \text{ L}} = \boxed{.209 \text{ M}}$

$32 \text{ g } NaNO_3 \div 85 \text{ g/mole} = .376 \text{ moles}$

8. Calculate the molarity of a solution if 4.0 g of NaOH are dissolved in 60.0 mL of solution. (MM of Na = 23 g/mole; MM of O = 16 g/mole; MM of H = 1 g/mole)

$M = \frac{moles}{L} = \frac{.1 \text{ mol}}{.06 \text{ L}} = \boxed{1.67 \text{ M NaOH}}$

$4.0 \text{ g NaOH} \div 40 \text{ g/mole} = .1 \text{ mol } NaNO_3$

$60 \text{ mL} \div 1000 = .060 \text{ L}$

Name: Period: Date:

Worksheet- Molarity

Use the following formulas to answer the following Molarity problems.

Molarity (M) = moles/liters **liters = moles/Molarity** **moles = Molarity x liters**
To convert grams to moles: divide the mass by the molar mass
To convert moles to grams: multiply the moles by the molar mass

1. What is the molarity of a solution of 2.43 grams of hydrogen bromide in 1.0 liters of solution? (MM of HBr = 80.9 g/mole)

2.43 g HBr ÷ 80.9 g/mole = .0300 mol

$M = \frac{moles}{L} = \frac{.0300\ mol}{1\ L} = .0300\ M\ HBr$

2. What is the molarity of a solution of 1.14 grams of $Al_2(SO_4)_3$ in 100 mL of solution? (MM = 342 g/mole)

moles = 1.14 g ÷ 342 g/mole = .00333 mole

100 mL ÷ 1000 = .1 L

$M = \frac{moles}{L} = \frac{.00333\ mol}{.1\ L} = .0333\ M\ Al_2(SO_4)_3$

3. What is the molarity of a solution of 2.1 grams of manganese (II) chloride in 150 mL of solution? (MM of $MnCl_2$ = 125.7 g/mole)

2.1 g ÷ 125.7 g/mole = .0167 mol

150 mL = .15 L

$M = \frac{moles}{L} = \frac{.0167\ mol}{.15\ L} = \boxed{.111\ M\ MnCl_2}$

4. How many moles of iron (II) sulfate ($Fe_2(SO_4)_3$) are in 125 mL of 0.015-M solution?

.125 L

$moles = M \times L = .015\ \frac{mol}{\cancel{L}} \times .125\ \cancel{L} = .001875\ mol\ Fe_2(SO_4)_3$

5. How many moles of potassium phosphate (K_3PO_4) are in 0.25 L of 0.325-M solution?

$moles = M \times L = .325\ M \times .25\ L = .08125\ mol\ K_3PO_4$

6. How many grams of aluminum sulfate ($Al_2(SO_4)_3$) are in 0.40 L of 0.9-M solution? (MM of aluminum sulfate = 342 g/mole)

$moles = M \times L = (.9\ M) \times (.4\ L) = .36\ mol\ Al_2(SO_4)_3 \times 342\ g/mole =$

$\boxed{123.12\ g\ Al_2(SO_4)_3}$

7. How many liters of solution would be required to make a 0.20-M solution with 6.84 grams of aluminum sulfate? (MM of aluminum sulfate = 342 g/mole)

6.84 g ÷ 342 = .02 moles

$L = \frac{moles}{M} = \frac{.02\ moles}{.2\ M} = \boxed{.1\ L}$

8. How many milliliters of solution would be required to make a 0.10-M solution with 10.4 grams of barium nitrate ($Ba(NO_3)_2$)? (MM = 261.33 g/mole)

10.4 ÷ 261.33 = .0398 moles

$L = \frac{moles}{M} = \frac{.0398\ moles}{.1\ M} = .398\ L =$

$\boxed{398\ mL}$

Dilution: Definition & Calculations

To dilute a substance means to add more solvent without the addition of more solute. Of course, the resulting solution is thoroughly mixed so as to ensure that all parts of the solution are identical. The fact that the solute amount stays constant allows us to develop calculation techniques.

First, we write: moles before dilution = moles after dilution

From the definition of molarity, we know that the moles of solute equals the molarity times the volume. So we can substitute MV (molarity times volume) into the above equation, like this:

$$M_1V_1 = M_2V_2$$

The "sub one" refers to the situation before dilution and the "sub two" refers to after dilution.

This equation does not have an official name like Boyle's Law, so we just call it the dilution equation.

Example #1- 53.4 mL of a 1.50 M solution of NaCl is on hand, but you need some 0.800 M solution. How many mL of 0.800 M can you make?

Answer- From the dilution equation, we write: (1.50 mol/L)(53.4 mL) = (0.800 mol/L)(x)
Solving the equation gives an answer of 100 mL.

Notice that volumes need not be converted to liters. Any old volume measurement is fine, just so long as the same one is used on each side.

Example #2- 100.0 mL of 2.500 M KBr solution is on hand. You need 0.550 M. What is the final volume of solution that can be made?

Answer- Placing the proper values into the dilution equation gives:

(2.500 mol/L)(100.0 mL) = (0.550 mol/L)(x)

x = 454.5454545 mL (oops, my fingers got stuck typing.) (Bad attempt at humor, I know!)

Sometimes the problem might ask how much more water must be added. In this last case, the answer is 454.5 mL – 100.0 mL = 345.5 mL water.

Go ahead and answer the question, if your teacher asks it, but it is bad technique in the lab to just measure out the "proper" amount of water and then add it. The volumes are not necessarily additive. The only volume of importance is the final solution's volume. You add enough water to get that volume without caring how much the actual volume is.

$$M_1V_1 = M_2V_2$$

Practice Problems

1. A stock solution of 1.00 M NaCl is available. How many milliliters are needed to make 100.0 mL of 0.750 M?

   M_1 $V_1 = ?$ V_2 M_2

   $$M_1V_1 = M_2V_2$$
   $$(1M)(V_1) = (.750M)(100mL)$$
   $$\boxed{V_1 = 75 mL}$$

2. What volume of 0.250 M KCl is needed to make 100.0 mL of 0.100 M solution?

   $V_1 = ?$ M_1 V_2 M_2

   $$M_1V_1 = M_2V_2$$
   $$(.250M)(V_1) = (.1M)(100 mL)$$
   $$\boxed{V_1 = 40 mL}$$

3. Concentrated H_2SO_4 is 18.0 M. What volume is needed to make 2.00 L of 1.00 M solution?

   M_1 V_1 V_2 M_2

   $$M_1V_1 = M_2V_2$$
   $$(18M)(V_1) = (1M)(2L)$$
   $$\boxed{V_1 = .111 L}$$

4. Concentrated HCl is 12.0 M. What volume is needed to make 2.00 L of 1.00 M solution?

   M_1 V_1 V_2 M_2

   $$M_1V_1 = M_2V_2$$
   $$(12M)(V_1) = (1)(2)$$
   $$\boxed{V_1 = .167 M}$$

5. A 0.500 M solution is to be diluted to 500.0 mL of a 0.150 M solution. How many mL of the 0.500 M solution are required?

   M_1 V_2 M_2 $V_1 = ?$

   $$M_1V_1 = M_2V_2$$
   $$(.5)(V_1) = (.150)(500)$$
   $$\boxed{V_1 = 150 mL}$$

6. A stock solution of 10.0 M NaOH is prepared. From this solution, you need to make 250.0 mL of 0.375 M solution. How many mL will be required?

   M_1 V_2 M_2 V_1

   $$M_1V_1 = M_2V_2$$
   $$(10M)(V_1) = (.375)(250)$$
   $$\boxed{V_1 = 9.375 mL}$$

7. 2.00 L of 0.800 M $NaNO_3$ must be prepared from a solution known to be 1.50 M in concentration. How many mL are required?

   V_1 M_1 M_2 V_2

   $$M_1V_1 = M_2V_2$$
   $$(.8)(2L) = (1.5M)(V_2)$$
   $$V_2 = 1.07 L = \boxed{1067 mL}$$

Concentration Measurement Formulas

There are various ways to measure the concentration of a solution: Molarity, % by mass, % by volume, Molality, and Mole Fraction.

Here are the formulas to calculate each.

Molarity (M) = $\dfrac{\textbf{moles of solute}}{\textbf{Liters of solution}}$

Dilution: $M_1V_1 = M_2V_2$
(moles 1 = moles 2)

% by mass = $\dfrac{\textbf{mass of solute}}{\textbf{Mass of solution}}$ **x 100**

% by volume = $\dfrac{\textbf{volume of solute}}{\textbf{volume of solution}}$ **x 100**

Molality (*m*) = $\dfrac{\textbf{moles of solute}}{\textbf{kg of solvent}}$

Mole Fraction (X) = $\dfrac{\textbf{moles of A}}{\textbf{Total moles}}$

If you need to have some extra practice with any of these concentration measurements, refer to your book in the following pages.
p. 481 # 10, 12
p. 482 # 13, 15
p. 483 # 17, 19
p. 484 # 21, 23
p. 487 # 27, 28
p. 488 # 29. 30

Concentration Practice Worksheet

1) If I make a solution by adding water to 75 mL of ethanol until the total volume of the solution is 375 mL, what's the percent by volume of ethanol in the solution?

$$\% \text{Volume} = \frac{\text{Vol ethanol}}{\text{total V}} = \frac{75\text{ mL}}{(75+375)} \times 100 = \boxed{16.7\% \text{ ethanol}}$$

2) If I add 1.65 L of water to 112 grams of sodium acetate...

a) What is the molality of $NaC_2H_3O_2$ in this solution?

$112\text{g } NaC_2H_3O_2 \div 82 = 1.366 \text{ moles}$

$$m = \frac{\text{moles solute}}{\text{Kg solvent}} = \frac{1.366 \text{ moles } NaC_2H_3O_2}{1.65\text{ Kg}}$$

$1.65\text{ L } H_2O = 1.65\text{ kg } H_2O$

$$\boxed{m = .828\ m}$$

b) What is the percent by mass of sodium acetate in this solution?

$$\% \text{ mass} = \frac{\text{mass } NaC_2H_3O_2}{\text{total mass}} \times 100$$

$1{,}650\text{g} + 112 = 1762\text{ g}$

$$\frac{112\text{g}}{1762\text{g}} \times 100 = \boxed{6.36\%}$$

c) What is the mole fraction of water in this solution?

$$\text{mole fraction} = \frac{\text{moles } H_2O}{\text{total moles}} = \frac{91.7}{(91.7+1.366)} = \boxed{.985}$$

$1650\text{g} \div 18 = 91.7 \text{ moles } H_2O$

1.366 moles Sod. Acetate

Colligative properties are properties that depend only upon the number of solute atoms, ions, or molecules in a solution and not on the nature of those atoms, ions or molecules. Freezing point depression and boiling point elevation are examples of colligative properties. Raoult discovered that the addition of solute particles causes the boiling point of a solution to be elevated and the freezing point to be depressed. It has been found that 1 mole of nonvolatile, nonionizing solute particles will raise the boiling point of 1.0 kg of water by 0.52 °C, to 100.52°C at 1 atm of pressure. The same concentration will lower the freezing point of 1.0 kg of water by 1.86°C, to -1.86°C. These two numbers apply only to water and are called the molal boiling point and freezing point constants for water. Other solvents have different constants.

PROPERTY	BOILING POINT ELEVATION	FREEZING POINT DEPRESSION
EQUATION	Boiling Point Elevation: A solution wil boil at a higher temperature than the pur solvent. $\Delta T_b = i\ K_b\ m$ ΔT_b = change in boiling temp. in (°C) i = a unitless constant (called the van't Hoff factor) associated with the degree of dissociation of the solute in a solvent. K_b = molal boiling point elevation constant (°C/m) **For H_2O: K_b = .52°C/m** m = molality of the solution	Freezing Point Depression: A solution will freeze at a lower temperature than the pure solvent. $\Delta T_f = i\ K_f\ m$ ΔT_f = change in freezing temp. in (°C) i = a unitless constant (called the van't Hoff factor)associated with the degree of dissociation of the solute in a solvent. K_f = molal freezing point lowering constant (°C/m) **For H_2O: K_f = 1.86°C/m** m = molality of the solution
GUIDLINES	i = 1 for substances that do not ionize 2 for substances which ionize into two ions like LiCl 3 for substances which ionize into three ions like $CaCl_2$ ....etc. i may have to be calculated if a % of dissociation is given for a solute. If the solvent is not water you must find its K_b.	i = 1 for substances that do not ionize 2 for substances which ionize into two ions like LiCl 3 for substances which ionize into three ions like $CaCl_2$ ....etc. i may have to be calculated if a % of dissociation is given for a solute. If the solvent is not water you must find its K_f.

EXAMPLE #1

If 90.0 g of nonionizing $C_6H_{12}O_6$, are dissolved in 255 g of H_2O, what will be the boiling point of the resulting solution?

First calculate the molality (m) of the solution:

$$m = \frac{92\text{g}}{(180\,\frac{\text{g}}{\text{mole}})(0.255\text{ kg of solvent})} = 2.0\text{ m}$$

Next apply the boiling point elevation equation:
[i = 1 for a nonionizing solute.]
$\Delta T_b = i\ K_b\ m$
$\Delta T_b = (1)(0.52°C/m)(2.0\ m)$
$\Delta T_b = 1.04\ °C$
BP = (ΔT_b + 100.00 °C)
BP =(1.04°C + 100.00 °C) = <u>101. 04°C</u>

EXAMPLE #2

If 152 g of sodium sulfate, Na_2SO_4, are dissolved in 875 g of H_2O, what will be the boiling point of the resulting solution? Assume 100% ionization.

First calculate the molality (m) of the solution:

$$m = \frac{152g}{(142\frac{g}{mole})(0.875 \text{ kg of solvent})} = 1.22 \text{ m}$$

Next apply the freezing point depression equation:

$\Delta T_f = i\, K_f\, m$

$i = 3$ since each unit of Na_2SO_4 yields 3 ions upon dissociation.

$\Delta T_f = (3)(1.86\ °C/m)(1.22\ m)$
$\Delta T_f = 6.8°C$

$FP = 0.0°C - \Delta T_f$
$FP = 0.0°C - 6.8°C$
$\underline{FP = -6.8°C}$

EXAMPLE #3

Determine the molality of a water solution if the boiling temperature is 104.42°C.

First solve the boiling point elevation equation for molality '"m".

$\Delta T_b = i\, K_b m$

$$m = \frac{\Delta T_b}{i\, K_b}$$

ΔT_b = 104.4°C - 100°C = 4.4 °C.
i = 1 (we can assume i is (1) for a problem of this type
K_b = 0.52 °C/m

$$m = \frac{4.4\ C}{(1)\,(0.52\frac{C}{m})} = 8.46\ m$$

Example #4

A solution of a nonelectrolyte contains 30 g of solute dissolved in 250 g of water. The boiling point of the water is observed to be 101.04°C. What is the GMM of this substance?

the molality of the solution can be calculated by using:
$m = (\Delta T_b)/(i)(K_b) = (1.04°C)/(1)(0.52°C/m) = 2.0$ m

Then use this equation grams = (m)(GMM)(kg of solvent)

(Solve for GMM) GMM = (grams)/(m)(kg of solvent) = (30 g)/(2 moles/kg)(0.250 kg) = <u>60g/mole</u>

Practice Problems:

A. Calculate the molality, freezing point, and boiling point for each of the following water solutions of nonionizing solutes:

1. 144 g of $C_6H_{12}O_6$ dissolved in 1000 g of H_2O

$m = \frac{\text{moles } C_6H_{12}O_6}{kg\ H_2O} = \frac{(144 \div 116)}{1kg} = 1.24\ m$

$\Delta t_f = i k_f m$

$= (1)(1.86)(1.24) = 2.31°C$

FP = -2.31°C

$\boxed{FP = -.0163°C}$

$\Delta t_b = i k_b m$

$\Delta t = (1)(.52)(1.24)$

$\Delta t_b = .645$

BP = 100.645

2. 48 g of CH_3OH dissolved in 200 g of H_2O

$m = \frac{\text{moles}}{kg\ H_2O} = \frac{(48 \div 32)}{.2kg} = 7.5\ m$

$\Delta t_f = k_f m = (1.86)(7.5)$

$\Delta t_f = 13.95°C$

$\boxed{\text{New FP} = -13.95°C}$

$\Delta t_b = k_b m = (.52)(7.5)$

$\Delta t_b = 3.9°C$

$\boxed{\text{New BP} = 103.9°C}$

3. 184 g of C_2H_5OH dissolved in 400 g of H_2O

$m = \frac{184g \div 46}{.4kg} = 10\ m$

$\Delta t_f = k_f m = (1.86)(10)$

$\Delta t_f = 18.6°C$

New FP = -18.6°C

$\Delta t_b = k_b m$

$(.52)(10)$

$\Delta t_b = 5.2°C$

New BP = 105.2°C

4. 600 g of C_3H_7OH dissolved in 600 g of H_2O

$m = \frac{600g \div 60 g/mol}{.6 kg} = 16.7\ m$

$\Delta t_f = k_f m = (1.86)(16.7)$

$\Delta t_f = 31°C$

New FP = -31°C

$\Delta t_b = k_b m$

$\Delta t_b = .52(16.7)$

$\Delta t_b = 8.67°C$

New BP = 108.67°C

5. 100 g of of $C_2H_6O_2$ dissolved in 200 g of H_2O

$m = \frac{100g \div 62}{.2kg} = 8.06\ m$

$\Delta t_f = k_f m = (1.86)(8.06)$

$\Delta t_f = 15°C$

New FP = -15°C

$\Delta t_b = k_b m = (.52)(8.06)$

$\Delta t_b = 4.19°C$

New BP = 104.2°C

B. Calculate the molality of a water solution if the freezing point is:

6. -9.3°C $\Delta t_f = 9.3°C$

$\Delta t_f = k_f m$

$m = \frac{\Delta t_f}{k_f} = \frac{9.3}{1.86} = 5\ m$

7. -27.9°C

$\Delta t_f = 27.9°C$

$m = \frac{\Delta t_f}{k_f} = \frac{27.9°C}{1.86°} = 15\ m$

8. -7.44°C

$\Delta t_f = 7.44°C$

$m = \frac{\Delta t_f}{k_f} = \frac{7.44°C}{1.86} = 4\ m$

C. Calculate the molality of a water solution if the boiling point is:

9. 103.12°C

$\Delta t_b = 3.12°C$

$m = \frac{\Delta t_b}{k_b} = \frac{3.12}{.52} = 6\ m$

10. 108. 32°C

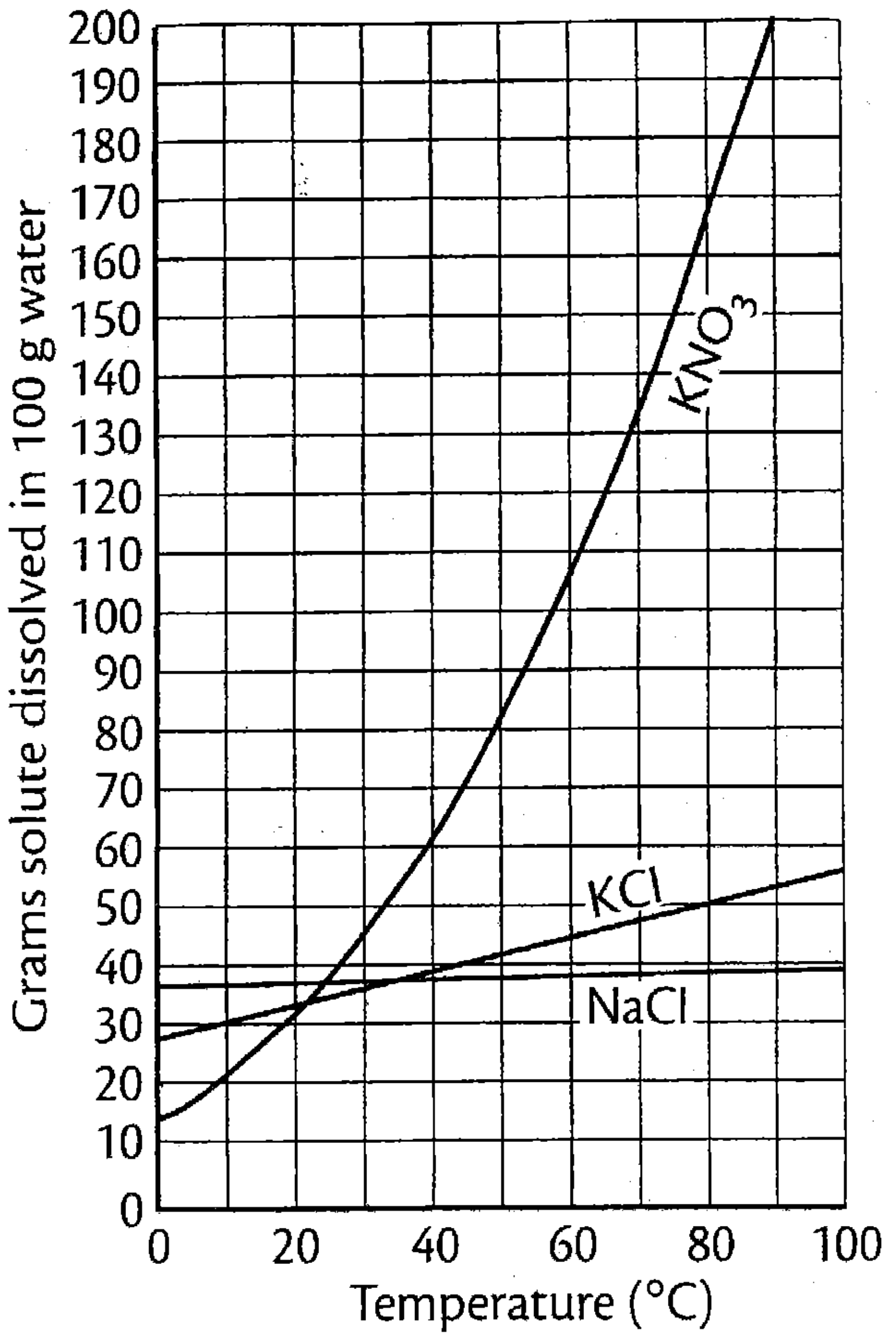
$\Delta t_b = 8.32°C$

$m = \frac{\Delta t_b}{k_b} = \frac{8.32}{.52} = 16\ m$

III. SOLUBILITY CURVE:

1) **Saturated** = any point on the line or ABOVE the line
    - Point on the line = **solution equilibrium**

2) **Unsaturated** = any point BELOW the line



1. What is the solubility of the following solutes in water?

   a) NaCl at 60°C = **<u>38g</u>**

   b) KCl at 40°C = **<u>39g</u>**

   c) KNO_3 at 20°C = **<u>31g</u>**

2. Are the following solutions saturated or unsaturated? Each solution contains 100 g of H_2O.

   a) 31.2 g of KCl at 30°C = **<u>Unsaturated</u>**

   b) 106 g KNO_3 at 60°C = **<u>Saturated (on the line)</u>**

   c) 40 g NaCl at 10°C = **<u>Saturated</u>**

   d) 150 g KNO_3 at 90°C = **<u>Unsaturated</u>**

3. For each of the following solutions, explain how much of the solute will dissolve and how much will remain undissolved at the bottom of the test tube?

   a) 180 g of KNO_3 in 100 g of water at 80°C

   <u>~11g undissolved; 169g dissolved</u>

   b) 180 g of KNO_3 in 100 g of water at 20°C

   <u>~149g undissolved; 31g dissolved</u>

   c) 60 g of NaCl in 100 g of water at 60°C

   <u>~21g undissolved; 39g dissolved</u>

4. A saturated solution of KNO_3 is formed from one hundred grams of water. If the saturated solution is cooled from 90°C to 30°C, how many grams of precipitate are formed?

   <u>(200g-45g) = 155g</u>

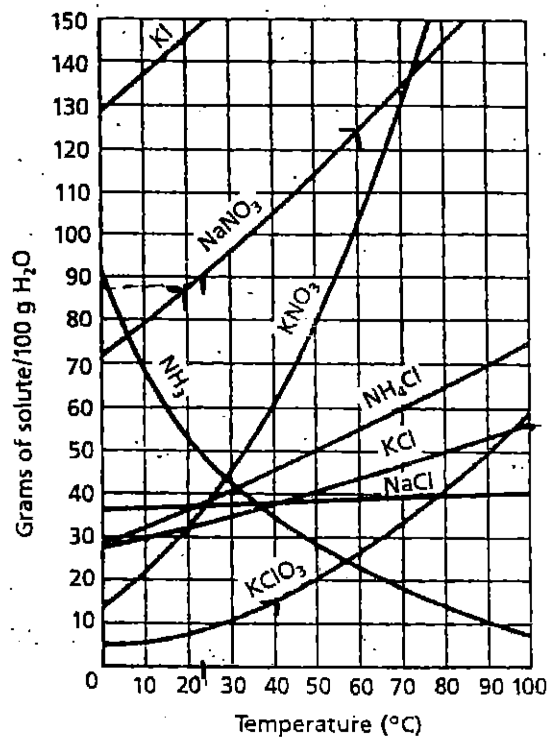
5. A saturated solution of KCl is formed from one hundred grams of water. If the saturated solution is cooled from 90°C to 40°C, how many grams of precipitate are formed?

   <u>(53g-39g) = 14g</u>

Name: Date: Period:

Solubility Curve Worksheet

Study the solubility curves in the figure, and then answer the questions.



1. What relationship exists between the solubility and temperature for most of the substances shown?

Temp ↑ solubility ↑

2. What is the exception?

NH_3

3. What general principle accounts for this exception?

NH_3 is a gas

4. Approximately how many grams of $NaNO_3$ will dissolve in 100 g of water at 20 °C?

≈87 g $NaNO_3$

5. How many grams of $NaNO_3$ will dissolve at 60 °C?

≈124 g $NaNO_3$

6. How many grams of NH_4Cl will dissolve in 1 liter of water at 50 °C?

@ 50°C $\frac{50\,g\,NH_4Cl}{100\,g\,H_2O} = \frac{x}{1000\,g\,H_2O}$ $x = 500\,g\,NH_4Cl$

7. Ninety grams of $NaNO_3$ is added to 100 grams of H_2O at 0 °C. With constant stirring, to what temperature must the solution be raised to produce a saturated solution with no solid $NaNO_3$ remaining?

≈22°C

8. A saturated solution of $KClO_3$ was made with 300 grams of water at 40 °C. How much $KClO_3$ could be recovered by evaporating the solution to dryness?

$\frac{x}{300\,g} = \frac{15\,g\,KClO_3}{100}$ @ 40° $x = 45\,g\,KClO_3$

9. Five hundred grams of water is used to make a saturated solution of KCl at 10 °C. How many more grams of KCl could by dissolved if the temperature were raised to 100 °C?

@ 10° $\frac{30\,g\,KCl}{100} = \frac{x}{500\,g}$ $x = 150\,g$ @ 100° $\frac{55\,g}{100} = \frac{x}{500}$ $x = 275\,g$ it can hold 125 g more

10. A saturated solution of KNO_3 is 200 grams of H_2O at 50 °C is cooled to 20 °C. How much KNO_3 will precipitate out of solution?

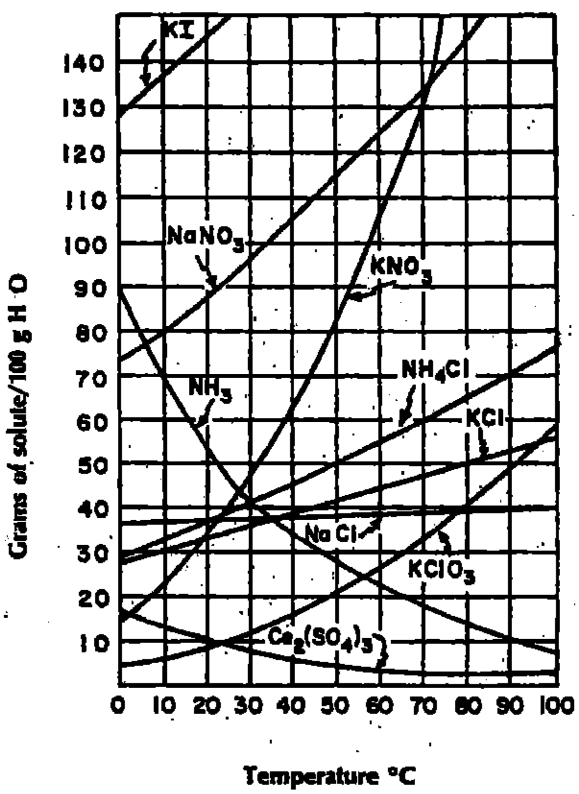
KNO_3 @ 50° $\frac{80\,g}{100\,g}$ KNO_3 @ 20° $\frac{31\,g}{100\,g}$ 80-31 = 49 g more $\frac{49\,g\,more}{100\,g\,H_2O} = \frac{x}{200}$ $x = 98$ 98 g more

Name ______________________ Class______ Date__________

Activity 5-5
Solubility Curves

Introduction

It is often convenient to describe solubility in the form of a graph. The graph below is a typical set of solubility curves. Note that the units on the *y*-axis express solubility in "grams of solute per 100 grams of water." (Other solubility curves may use different units.)



1. Most substances on this graph show increased solubility as temperature increases. What are the exceptions? NH_3 + $Ce_2(SO_4)_3$
2. Each curve shows how solubility for that substance changes as temp changes. The solubilities of substances whose curves show greater (steeper) slopes are more (*more/less*) affected by temperature changes than those that have more gradual slopes.

Using solubility curves

Practice using the solubility curves by answering each of the following.

3. If 50 grams of water saturated with potassium chlorate at 23°C is slowly evaporated to dryness, how many grams of the dry salt will be recovered?

$KClO_3$ @23° $\frac{10_g KClO_3}{100_g H_2O} = \frac{x}{50_g}$ $\boxed{x = 5g}$

3. 5g

4. What is the smallest mass of water required to dissolve completely 23 grams of NH_4Cl at 40°C?

@40°C $\frac{45_g NH_4Cl}{100_g H_2O} = \frac{23_g NH_4Cl}{x}$ $x = 51.1$

4. $51.1_g H_2O$

5. A saturated solution of $NaNO_3$ in 100 grams of water at 40°C is heated to 50°C. What is the rate of increase in solubility in grams per degree.

@40° $\frac{105_g NaNO_3}{100_g H_2O}$ @50° $\frac{115_g NaNO_3}{100_g H_2O}$

5. rate $= \frac{10g}{10°} = 1 g/°C$

6. Which salt has solubility values that are least affected by changes in temperature? (Flattest curve)

6. NaCl

7. If 30 grams of KCl is dissolved in 100 grams of water at 45°C, how many additional grams of KCl would be needed to make the solution saturated at 80°C?

KCl @80° $\frac{50_g}{100_g H_2O}$ it can hold 50_g it has 30_g 20_g

7. 20_g KCl

8. At what temperature do potassium chlorate and potassium chloride have the same solubility in water?

8. ≈95°C

9. At 50°C, 100 grams of water is saturated with cerium (III) sulfate. How many grams of cerium (III) sulfate must be added to saturate the solution at 0°C?

50°C $\frac{5_g Ce_2(SO_4)_3}{100_g H_2O}$ 0°C $\frac{18_g Ce_2(SO_4)_3}{100_g H_2O}$

18-5 = 13g

9. ≈13g

25