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CONCEPT: SOLUTIONS AND INTERMOLECULAR FORCES

Molarity **(M)** can serve as the connection between the interconversion of ____________ to ____________ and vice versa.

For example, a **5.8 M NaCl** solution really means __________________________ per __________________________.

$$\text{Molarity} = \frac{\text{Moles of Solute}}{\text{Liters of Solution}}$$

A typical mixture consists of a smaller amount of one substance, the ________________, dissolved in a larger amount of another substance, the __________________. Together they form a __________________.

According to the theory of **"likes"** dissolves **"likes"** compounds with the same __________________________ or _________________ will dissolve into each other.

EXAMPLE: Butane, a nonpolar organic compound, is most likely to dissolve in

a. HCl

b. C_6H_5OH

c. C_8H_{18}

d. $AlCl_3$

e. What the heck is butane?

CONCEPT: SOLUBILITY AS AN EQUILIBRIUM PROCESS

When an ionic solid dissolves, ions leave the solid and become dispersed in the solvent.

In a(n) _________________ solution the maximum amount of dissolved solute is present in the solvent.

In a(n) _________________ solution additional amounts of solute can be further dissolved in the solvent.

In a(n) _________________ solution more than the equilibrium concentration of solute has been dissolved.

EXAMPLE C1: Caffeine is about 10 times as soluble in warm water as in cold water. A student puts a hot-water extract caffeine into an ice bath, and some caffeine crystallizes. What is the identity of the solution before it's been placed in an ice bath?

a) Saturated

b) Super saturated

c) Unsaturated

d) Not enough information to answer the question.

_________________ law explains the relationship between gas pressure and solubility: the solubility of a gas (S_{gas}) is directly proportional to the partial pressure of the gas (P_{gas}) above the solution:

$$S_{Gas} = k_H \bullet P_{Gas}$$

PRACTICE: SOLUTIBILITY AS AN EQUILIBRIUM PROCESS

EXAMPLE: Henry's Law Constant for nitrogen in water is 1.67 x 10^{-4} M • atm^{-1}. If a closed canister contains 113 ppb nitrogen, what would be its pressure in atm?

PRACTICE 1: In general, as the temperature increases, the solubility of gas in a given liquid ________________, and the solubility of most solids in a given liquid ________________.

- **a.** Increases, increases
- **b.** Increases, decreases
- **c.** Decreases, increases
- **d.** Decreaes, decreases

PRACTICE 2: At a partial pressure of acetylene 1.35 atm, 1.21 moles of it dissolves in 1.05 L of acetonitrile. If the partial pressure of acetylene in acetone is increased to 12.0 atm, then what is its solubility?

CONCEPT: CALCULATE MOLARITY

Molarity is the concentration of a solution represented as moles of solute per liter of solution:

$$\text{Molarity (M)} = \frac{\text{Moles of solute}}{\text{Liters of solution}}$$

Understanding this explanation for molarity allows you to further expand it. For example, if we are given 0.20 M NaOH this means:

$$0.20\ \text{M NaOH} = \frac{0.20\ \text{mole NaOH}}{1\ \text{Liter of solution}}$$

Osmolarity

Ionic molarity or osmolarity represents the molarity of dissolved ions in a solution.

Dissolution of Ionic Compound

0.10 M $KNO_3 \longrightarrow K^+ + NO_3^-$

2 Ions

Osmolarity

Osmolarity = (# of ions) x (M of Compound)

Dilutions

Another common idea related to molarity deals with the dilution of stock solutions. In a dilution a concentrated solution is made more diluted by adding water.

$$M_1V_1 = M_2V_2$$

M_1 = Molarity before diltution

V_1 = Volume before dilution

M_2 = Molarity after dilution

V_2 = Volume after dilution

M_1 is larger than M_2

V_2 is larger than V_1

$V_2 = V_1 + V_{\text{Water Added}}$

PRACTICE: CALCULATE MOLARITY CALCULATIONS 1

EXAMPLE 1: Stock hydrochloric acid solution is 21.0% by mass HCl and has a specific gravity of 1.75. What is the molarity of the solution?

EXAMPLE 2: What is the concentration of nitrate ions in a solution that contains 83.3 g lead (IV) nitrate, $Pb(NO_3)_4$, dissolved in 700 mL solution? MW of $Pb(NO_3)_4$ is 455.24 g/mol.

EXAMPLE 3: How many micrograms of K_2CO_3 are required to prepare 120 mL of 0.325 M K_2CO_3? MW of K_2CO_3 is 138.21 g/mol.

PRACTICE: CALCULATE MOLARITY CALCULATIONS 2

EXAMPLE 1: If 50.0 mL of water is added to 80.0 mL of a 6.00 M solution, what will be the new concentration of the solution?

EXAMPLE 2: To what volume should you dilute 72.93 mL of a 7.505 M LiCl solution so that 23.25 mL contains 2.25 g LiCl? MW of LiCl is 42.392 g/mol.

EXAMPLE 3: 870.0 g of water contains 0.990 g of sodium phosphate, Na_3PO_4. Determine the concentration of Na_3PO_4 if the density of the solution is 1.10 g/mL. MW of Na_3PO_4 is 163.94 g/mol.

CONCEPT: MASS PERCENT

Mass or **weight percent** is the percentage of a given element or compound within a solution.

$$\text{Mass Percent} = \frac{\text{Mass Component}}{\text{Total Mass}} \times 100$$

For example, if we are given 23.0% NaOH this means:

$$23.0\ \%\ \text{NaOH} = \frac{23.0\ \text{grams NaOH}}{100\ \text{grams Solution}}$$

EXAMPLE 1: Calculate the amount of water (in kilograms) that must be added to 12.0 g of urea, $(NH_2)_2CO$, in the preparation of a 18.3 percent by mass solution. The molar mass of urea, $(NH_2)_2CO$, is 60.055 g/mol.

EXAMPLE 2: A solution was prepared by dissolving 51.0 g of KBr in 310 mL of water. Calculate the mass percent of KBr in the solution.

PRACTICE: At 298 K, a solution is prepared by dissolving 12.7 g NaCl in 95.5 mL of water. What is the ppm of NaCl if the density of water at this temperature is 0.9983 g/mL.

CONCEPT: MOLALITY

Molality is depicted as moles of solute per kilograms of solvent:

$$\text{Molality (m)} = \frac{\text{Moles of solute}}{\text{kg of solvent}}$$

In the same way we can expand molarity the same approach can be applied to molality:

$$0.30\ \text{m NaCl} = \frac{0.30\ \text{mole NaCl}}{1\ \text{kg of solvent}}$$

Osmolality

Ionic molality or osmolality represents the molality of dissolved ions in a solution.

Dissolution of Ionic Compound

$$\textbf{0.30 m}\ \text{NaCl} \longrightarrow \underbrace{Na^{+} + Cl^{-}}_{\text{2 Ions}}$$

Osmolality

Osmolality = (# of ions) x (m of Compound)

EXAMPLE: A solution is prepared by dissolving 43.0 g potassium chlorate, $KClO_3$, in enough water to make 100.0 mL of solution. If the density of the solution is 1.760 g/mL, what is the molality of $KClO_3$ in the solution? MW of $KClO_3$ is 122.55 g/mol.

PRACTICE: MOLALITY CALCULATIONS

EXAMPLE 1: If the molality of glucose, $C_6H_{12}O_6$, in an aqueous solution is 2.56 what is the molarity? Density of the solution is 1.530 g/mL.

EXAMPLE 2: What is the ionic molality of nitrate ions in 0.305 m lead (IV) nitrate, $Pb(NO_3)_4$?.

PRACTICE: What is the mass percent of NH_3 of a 1.25 m aqueous solution of NH_3?

CONCEPT: MOLE FRACTION

Mole Fraction is depicted as moles of solute per moles of solution:

$$\text{Mole Fraction}\,(X) = \frac{\text{Mole of Solute}}{\text{Mole of Solution}} =$$

For example, if we are given a mole fraction of 0.160 for NaOH this means:

$$0.160 = \frac{0.160\text{ mole NaOH}}{1.0\text{ mole Solution}} =$$

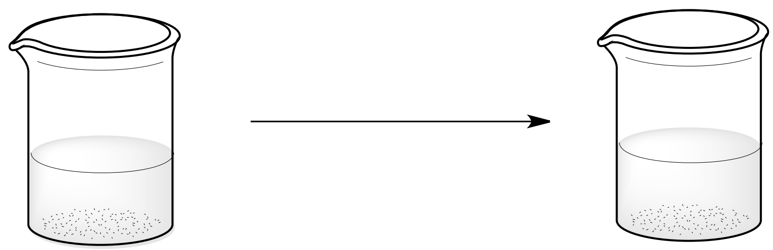
EXAMPLE 1: If the mole fraction of glucose, $C_6H_{12}O_6$, in an aqueous solution is 0.320 what is the molarity? Density of the solution is 1.530 g/mL.

EXAMPLE 2: If the mole fraction of methanol, CH_3OH, in an aqueous solution is 0.060 what is the molality? Density of the solution is 1.39 g/mL.

EXAMPLE 3: Calculate the mole fraction of acetic acid, $HC_2H_3O_2$, in a 27.13 mass % aqueous solution (d = 0.9883 g/mL). MW of $HC_2H_3O_2$ is 60.054 g/mol

CONCEPT: PROPERTIES OF SOLUTIONS

The 4 ______________________ properties help to explain what happens to a pure solvent as we add solute to it.



EXAMPLE: Explain what happens to each of the following properties as solute is added to a pure solvent.

a. Boiling Point $\Delta T_b = i \bullet k_b \bullet m$

b. Freezing Point $\Delta T_f = i \bullet k_f \bullet m$

c. Osmotic Pressure $\Pi = i \bullet MRT$

d. Vapor Pressure $P_{Solution} = X_{Solvent} \bullet P^o_{Solvent}$

EXAMPLE: Which of the following compounds will have the **highest** boiling point?

a) 0.10 m sucrose

b) 0.10 m $CsBrO_3$

c) 0.35 m CH_3OH

d) 0.15 m $SrBr_2$

PRACTICE: PROPERTIES OF SOLUTIONS

EXAMPLE 1: Pure water boils at 100^{o}C. What is the expected boiling point of water after the addition of 13.12 g calcium bromide, $CaBr_2$, to 325 g water. K_b = 0.512 ^{o}C/m. **(MW of $CaBr_2$ is 199.88 g/mol)**.

EXAMPLE 2: The vapor pressure of water at 100.0^{o}C is 0.630 atm. Determine the amount (in grams) of aluminum fluoride, AlF_3, (in grams) needed to reduce its vapor pressure to 0.550 atm. **(MW of AlF_3 is 83.98 g/mol)**.

PRACTICE 1: Beta-carotene is the most important of the A vitamins. Calculate the molar mass of Beta-carotene if 25.0 mL of a solution containing 9.88 mg of Beta-carotene has an osmotic pressure of 56.16 mmHg at 30^{o}C.

CONCEPT: THE LIQUID STATE

VAPOR PRESSURE is defined as the partial pressure of vapor molecules above the surface of the liquid under the dynamic equilibrium condition of condensation and evaporation.

EXAMPLE: The vapor pressure of pure liquid A is 550 torr and the vapor pressure of pure liquid B is 320 torr at room temperature. If the vapor pressure of a solution containing A and B is 465 torr, what is the mole fraction of A in the solution?

CONCEPT: THE LIQUID STATE (CALCULATIONS)

EXAMPLE: Determine the vapor pressure lowering associated with 1.32 m $C_6H_{12}O_6$ solution (MW: 180.156 g/mol) at 25°C.

PRACTICE: The following boiling points belong to one of the following compounds: 117°C , 78°C, 34.5°C & 23°C

CH_3-O-CH_3 CH_3CH_2OH CH_3CH_2-O-CH_2CH_3 $CH_3CH_2CH_2CH_2OH$

a) Which boiling point goes with what compound?

b) If each of the following substances were placed in separate sealed clear bottles at room temperature, could you identify one of the substances right away?