Name: SOLUTIONS
Hour: ______ Date: ______

Unit 9, Day 4-5: Concentration + Dilutions Packet

Percent concentrations

Percent by Volume (v/v) Exercises:

1. What is the percent by volume of ethanol (C_2H_6O) in the final solution when 85 mL of ethanol is diluted to a volume of 250 mL with water?

V_{solute} ; $V_{solution}$ (total amount)

$$\therefore \%(v/v)\ \text{ethanol} = \frac{85\ \text{mL ethanol}}{250\ \text{mL solution}} \times 100\% = 34\%$$

($\therefore$ 34% of solution is made of ethanol)

2. A bottle of hydrogen peroxide (H_2O_2) is labeled 3% (v/v). How many mL H_2O_2 are present in 400 mL of this solution?

%(v/v) ; V_{solute}? ; $V_{solution}$

$$\%(v/v)\ H_2O_2 = \frac{x}{400\ \text{mL}} \times 100\% = 3\%$$

$$V_{H_2O_2} = \frac{3\%}{100\%} \times 400\ \text{mL} = 12\ \text{mL}\ H_2O_2$$

Percent by Mass (m/m) Exercises:

1. A solution is made by dissolving 13.5 g of glucose in 0.100 kg of water. What is the mass percent (m/m) of solute in this solution?

mass solute ; mass solvent

$$\%(m/m)\ \text{glucose} = \frac{\text{Mass}_{glucose}}{\text{Mass}_{solution}} \times 100\% = \frac{13.5\ g\ \text{glucose}}{13.5\ g + 100\ g\ H_2O} \times 100\%$$

$$= 11.9\%\ \text{glucose solution}$$

2. Calculate the grams of solute required to make 250 g of 0.10% $MgSO_4$ (m/m).

Mass solute ; Mass solution

$$\%(m/m)\ MgSO_4 = \frac{x}{250\ g\ \text{solution}} \times 100\% = 0.10\%$$

$$x = \frac{0.10\%}{100\%} \times 250\ g\ \text{solution}$$

$$x = 0.25\ g\ MgSO_4$$

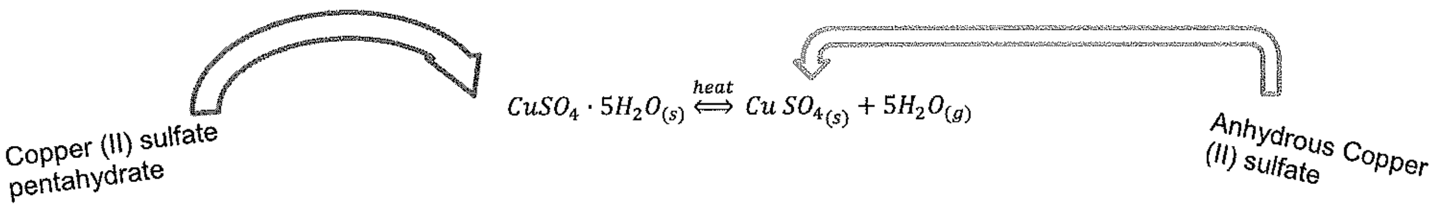
remember:

1 kg = 1000 g

1 g = 1000 mg

Hydrates: a specific example of percent by mass

Hydrates are created when compounds combine with water molecules to form a crystal which "traps" a fixed amount of water per formula unit. These forces which hold water molecules in **hydrates** *are not very strong, so the water contained in a formula unit of the hydrate is easily lost (through heating or desiccation). The substance that has lost its water molecules is called* **anhydrous.**



$$CuSO_4 \cdot 5H_2O_{(s)} \overset{heat}{\Longleftrightarrow} Cu\,SO_{4(s)} + 5H_2O_{(g)}$$

HYDRATE NOMENCLATURE: THINGS TO KEEP IN MIND:

To name a hydrate, you will use the name of the ionic compound and then add a word after the name to show that this compound grabs water from the air.

Additional steps to consider when naming a hydrate:

i. What is the correct prefix to use to indicate the number of moles of water present?

ii. How does the naming change when the water has been removed?

Nomenclature Rules:

1. Prefixes are used to denote the number of atoms

2. "Mono" is not used to name the first element

Note: When the addition of the Greek prefix places two vowels adjacent to one another, the "a" (or the "o") at the end of the Greek prefix is usually dropped; e.g., "nonaoxide" would be written as "nonoxide", and "monooxide" would be written as "monoxide". In contrast, the "i" at the end of the prefixes "di-" and "tri-" are never dropped.

Prefix	number indicated
mono-	1
di-	2
tri-	3
tetra-	4
penta-	5
hexa-	6
hepta-	7
octa-	8
nona-	9
deca-	10

I. Write the chemical name for the following hydrates:

a. $Na_2SO_4 \cdot 10\ H_2O$ Sodium sulfate decahydrate
b. Na_2SO_4 anhydrous sodium sulfate
c. $CaCl_2 \cdot 2\ H_2O$ Calcium chloride dihydrate
d. $CaCl_2$ anhydrous calcium chloride
e. $Ba(OH)_2 \cdot 8\ H_2O$ Barium hydroxide octahydrate
f. $Ba(OH)_2$ anhydrous barium hydroxide

II. Write the chemical formula for the following hydrates:

a. Tin (IV) chloride pentahydrate $SnCl_4 \cdot 5H_2O$
b. Iron (II) sulfate heptahydrate $FeSO_4 \cdot 7H_2O$
c. Barium bromide tetrahydrate $BaBr_2 \cdot 4H_2O$
d. Iron (III) phosphate tetrahydrate $FePO_4 \cdot 4H_2O$

CALCULATING THE PERCENT BY MASS OF WATER PRESENT IN HYDRATES:

What is the percent by mass of water present in $CuSO_4 \cdot 5H_2O$?

- *Assume that you are working with 1 mole of the hydrate unless the problem states otherwise.*
- *Calculate the number of grams of water present in 1 mole of the hydrate.*

$$5\ mol\ H_2O \times \frac{18.0152\ g\ H_2O}{1\ mol\ H_2O} = 90.076\ g\ H_2O$$

- *Determine the molar mass of the hydrate*

$$Molar\ mas\ of\ CuSO4 \cdot 5H2O = 249.69\ g\ CuSO4 \cdot 5H2O$$

- *Percent by mass is the mass of the part divided by the mass of the whole:*

$$Percent\ by\ mass\ H_2O = \frac{90.076\ g\ H_2O}{249.69\ g\ CuSO4 \cdot 5H2O} \times 100\% = 36.08\%$$

1. What is the percent by mass of water present in Barium hydroxide octahydrate, $Ba(OH)_2 \cdot 8H_2O$?

1) Determine mole ratio of H2O in Ba(OH)2 · 8H2O

$$\frac{8\ \text{mol H}_2\text{O}}{1\ \text{mol Ba(OH)}_2 \cdot 8\text{H}_2\text{O}} \Big| \frac{18\ g\ H_2O}{1\ \text{mol H}_2\text{O}} \Big| \frac{1\ \text{mol Ba(OH)}_2 \cdot 8\text{H}_2\text{O}}{315\ g\ Ba(OH_2) \cdot 8H_2O} \times 100\%$$

2) Convert mol → g for each to find % H2O (M/m)

$$\frac{144\ g\ H_2O}{315\ g\ Ba(OH)_2 \cdot 8H_2O} \times 100\% = \boxed{45.7\%\ H_2O}$$

2. The chemical formula for Espom salt is $MgSO_4 \cdot 7H_2O$ (Magnesium sulfate heptahydrate). If you need 10.0 g anhydrous $MgSO_4$ for a reaction, how many grams of Epsom salt could you use instead? *(Hint: What percent by mass of the compound is just $MgSO_4$?)*

1) Same process as above!

$$\frac{7\ \text{mol H}_2\text{O}}{1\ \text{mol MgSO}_4 \cdot 7\text{H}_2\text{O}} \Big| \frac{18\ g\ H_2O}{1\ \text{mol H}_2\text{O}} \Big| \frac{1\ \text{mol MgSO}_4 \cdot 7\text{H}_2\text{O}}{246.47\ g\ MgSO_4 \cdot 7H_2O} \times 100\%$$

= 51.1% H2O

2) % MgSO4?

100 − 51.1 = 48.9% MgSO4

3) Use %(M/m) to find mass solution

$$100\% \times \frac{10\ g\ MgSO_4}{x_{MgSO_4 \cdot 7H_2O}} = 48.9\%\ MgSO_4$$

$$\therefore\ x = \frac{10g\ MgSO_4}{0.489\ MgSO_4 \cdot 7H_2O} = \boxed{20.45g\ MgSO_4 \cdot 7H_2O \text{ is needed}}$$

Molarity

Data Collection and Analysis:

1. REVIEW QUESTION: Using your beverage of choice, identify at least one electrolyte and one non-electrolyte present in solution:
   a. Electrolyte:
   b. Non-electrolyte:

2. Calculate the moles of sugar and moles of caffeine present in your beverage and write values into the tables below.

   1) $g_{sugar} \rightarrow mol_{sugar}$

   2) $mg_{caffeine} \rightarrow g_{caffeine} \rightarrow mol_{caffeine}$

3. Calculate the volume of your drink in liters. Record this information in the table below.

   $mL_{drink} \rightarrow L_{drink}$

Concentration of Sugar in Common Drinks

Beverage	Mass of Sugar (g)	Moles of Sugar (mol)	Volume of Drink (L)	Molarity of Drink (moles/L)
Mountain Dew				

Concentration of Caffeine in Common Drinks

Beverage	Mass of Caffeine (g)	Moles of Caffeine (mol)	Volume of Drink (L)	Molarity of Drink (moles/L)
Mountain Dew				

Based on these data:

Which drink has the highest *concentration (i.e. moles/L)* of caffeine? Coffee

Which drink has the highest *concentration (i.e. moles/L)* of sugar? Mountain Dew

Molarity Exercises:

1. How many moles of Na_2CO_3 are in 30.0 mL of a 2.0 M solution?

$M = \frac{mol}{L}$

$2.0\ M = 2.0\ \frac{mol}{L} = \frac{x\ mol}{0.03\ L}$ ∴ $x\ mol = (2\ \frac{mol}{L})(0.03\ L)$

$= 0.06\ mol\ Na_2CO_3$

2. Determine the final volume of 4.67 moles of Li_2SO_3 dissolved to make a 3.89 M solution.

$3.89\ M = \frac{4.67\ mol\ Li_2SO_3}{x\ L}$

$x\ L = \frac{4.67\ mol\ Li_2SO_3}{3.89\ \frac{mol}{L}\ solution}$

$V = 1.20\ L$

3. What is the molarity of the ions in the following scenarios?

2.0 M Na₂SO₄ solution		3.4 M AlCl₃ solution		0.4 M ammonium carbonate solution	
Na^+ ions	4.0 M	Aluminum ions (Al^{3+})	3.4 M	Ammonium ions (NH_4^+)	0.8 M NH_4^+
SO_4^- ions	2.0 M	Chloride ions (Cl^-)	10.2 M	Carbonate ions (CO_3^{2-})	0.4 M CO_3^{2-}

$Na_2SO_4 \rightarrow 2Na^+ \ SO_4^{2-}$

$(NH_4)_2CO_3 \rightarrow 2NH_4^+ \ CO_3^{2-}$

Applying molarity to stoichiometry calculations

4. Sea water contains roughly 28.0 g of NaCl per liter. What is the molarity of sodium chloride in sea water?

$\frac{28\ g\ NaCl}{} \times \frac{1\ mol\ NaCl}{58\ g\ NaCl} \times \frac{}{1\ L} = 0.483\ M$

5. How many grams of $AlCl_3$ will be produced when ^10 mL of^ 0.6 M HCl is reacted with excess aluminum metal in a single replacement reaction?

$6HCl_{(aq)} + 2Al_{(s)} \rightarrow 3H_{2\,(g)} + 2AlCl_{3\,(s)}$

$V_{liquid} \rightarrow mol_{liquid} \rightarrow mol_{AlCl_3} \rightarrow g_{AlCl_3}$

$\frac{10\ mL\ HCl}{} \times \frac{1\ L\ HCl}{1000\ mL\ HCl} \times \frac{0.6\ mol\ HCl}{1\ L\ HCl} \times \frac{2\ mol\ AlCl_3}{6\ mol\ HCl} \times \frac{133.3\ g\ AlCl_3}{1\ mol\ AlCl_3} = 0.27\ g$

Using 10 mL 0.6M HCl will produce 0.27g $AlCl_3$ (theoretically ☺)

Dilutions

Your Kool Aid is too concentrated! What should we do? initial

$$M_1V_1 = M_2V_2$$ final (add something to M_1 to get M_2)

1. A concentrated solution of sulfuric acid, H_2SO_4, has a concentration of 18.0 M. How many milliliters of the concentrated acid would be required to make 250 mL of a 1.00 M H_2SO_4 solution?

$M_1 = 18 \frac{mol}{L}$

$V_1 = ?$

$M_2 = 1 \frac{mol}{L}$

$V_2 = 0.25\ L$

$V_1 (18 \frac{mol}{L}) = (1 \frac{mol}{L})(0.25 L)$

$V_1 = \frac{(1 \frac{mol}{L})(0.25 L)}{(18 \frac{mol}{L})} = 0.139\ L$

∴ Need to add mL of 18 M H_2SO_4 to enough H_2O to make 250 mL of 1M solution

2. A 50 L baby pool has a chlorine concentration of 0.200 M. If 20 L of water evaporated on a hot summer day, what is the final concentration of the pool?

lost this much ∴ M_2 should be higher than M_1

$V_1 = 50\ L$

$M_1 = 0.200 \frac{mol}{L}\ Cl^-$

$V_2 = 50 - 20 = 30\ L$

$M_2 = ?$

$M_1V_1 = M_2V_2$

$(0.2 \frac{mol}{L})(50 L) = M_2 (30 L)$

$M_2 = \frac{(0.2 \frac{mol}{L})(50 L)}{(30 L)} = 0.33\ M\ Cl^-$

3. If 20 mL of a 0.5 M NaCl solution is added to 500 mL of a 2 M sugar solution, what is the:

   a. Final volume of the solution? 500 mL + 20 mL = 520 mL

   b. Final molarity of NaCl in solution?

   $M_1 = 0.5 \frac{mol}{L}$ NaCl

   $V_1 = 20\ mL$

   $V_2 = 520\ mL$

   $M_2 = \frac{M_1V_1}{V_2} = \frac{(0.5 \frac{mol}{L})(0.02 L)}{(0.520 L)} = 0.019 \frac{mol}{L}$

   $M_{NaOH} = 0.019\ M$

   c. Final molarity of sugar in solution?

   $M_1 = 2 \frac{mol}{L}$

   $V_1 = 0.5\ L$

   $V_2 = 0.52\ L$

   $M_2 = \frac{(2 \frac{mol}{L})(0.5 L)}{(0.52 L)} = 1.92 \frac{mol}{L}$ ∴ $M_{sugar} = 1.92\ M$

4. CHALLENGE PROBLEM: A 50.0 gram sample of NaOH is dissolved in 0.600 L of water. What volume of this solution would be needed to create a 1.5 L solution that is 0.200 M NaOH?

M_1 V_1 V_2 M_2

1) determine M_1

$$\frac{50 g\ NaOH}{} \Big| \frac{1\ mol\ NaOH}{40\ g\ NaOH} \Big| \frac{}{0.6\ L\ solution} = 1.25\ M$$

2) determine V_1

$V_1 = \frac{M_2V_2}{M_1}$

$V_1 = \frac{(1.5 L)(0.2 \frac{mol}{L} NaOH)}{(1.25 \frac{mol}{L} NaOH)} = 0.248\ L$

∴ Need 248 mL of 1.25 M NaOH