Name _____

Empirical & Molecular Formulas

I. Percent Composition

1. **Define the term percent composition.**

Percent Composition – percent by mass of each element in a compound

2. **Write out the formula for determining percent composition (*by mass*).**

Percent by Mass (***element***) = $\frac{\text{mass of element}}{\text{mass of compound}} \times 100$

3. **Determine the percent compositions of a 150-g sample of a compound that contains 85 g of Element X and 65 g of Element Y.**

1. $\frac{85\text{ g element X}}{150\text{ g compound}} \times 100 = 56.\bar{6}\ \%$

2. $\frac{65\text{ g element Y}}{150\text{ g compound}} \times 100 = 43.\bar{3}\ \%$

4. **Write out the formula for determining percent composition (from the chemical formula).**

Percent by Mass (***from formula***) = $\frac{\text{mass of element} \mid \text{mol of comp}}{\text{molar mass of compound}} \times 100$

5. **Determine the percent by mass of $NaHCO_3$ (*baking soda*).**

Step 1 : Determine molar masses of each element

$1\text{ mol Na} \times \frac{22.99\text{ g Na}}{1\text{ mol Na}} \mid 1\text{ mol H} \times \frac{1.008\text{ g H}}{1\text{ mol H}} \mid 1\text{ mol C} \times \frac{12.01\text{ g C}}{1\text{ mol C}} \mid 3\text{ mol O} \times \frac{16.00\text{ g O}}{1\text{ mol O}}$

$84.01\text{ g/mol } NaHCO_3 = (22.99\text{ g Na} + 1.008\text{ g H} + 12.01\text{ g C} + 48.00\text{ g O})$

Step 2 : Determine percent by mass of each element

$\frac{22.99\text{ g/mol}}{84.01\text{ g/mol}} \times 100 = 27.37\%\ \text{Na}$ | $\frac{1.008\text{ g/mol}}{84.01\text{ g/mol}} \times 100 = 1.200\%\ \text{H}$ | $\frac{12.01\text{ g/mol}}{84.01\text{ g/mol}} \times 100 = 14.30\%\ \text{C}$ | $\frac{48.00\text{ g/mol}}{84.01\text{ g/mol}} \times 100 = 57.14\%\ \text{O}$

II. Empirical & Molecular Formulas

1. **Define the term empirical formula.**

Empirical Formula – formula with the smallest whole-number mole ratio of the elements

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2. **Determine the mole ratio of a 150-g compound in which the percent composition is 40.05% sulfur (S) and 59.95% oxygen (O).**

Step 1 : Determine the mass of each element.

(1) $150\text{g} \times .4005 = 60.07\text{g}$ (S) (2) $150\text{g} \times .5995 = 89.93\text{g}$ (O)

Step 2 : Convert each element mass to moles.

(1) $60.07\text{g S} \times \frac{1\text{ mol S}}{32.07\text{g S}} = 1.873\text{ mol S}$ | (2) $89.93\text{g O} \times \frac{1\text{ mol O}}{16.00\text{g O}} = 5.621\text{ mol O}$

Step 3 : Divide the moles of each element by the smallest number of moles.

(1) $\frac{1.873\text{ mol S}}{1.873} = 1\text{ mol S}$ | (2) $\frac{5.621\text{ mol O}}{1.873} = 3\text{ mol O}$

Step 4 : Identify the empirical formula (based on ratios).

SO_3

3. **Define the term molecular formula.**

Molecular Formula – the actual number of atoms of each element in one molecule (or formula unit) of the substance.

4. **Benzene (liquid) and acetylene (gas) have similar percent compositions but different empirical formulas.**

Paints, plastic, gas — Welding, Torches — and similar

(Circle One) : True (False) Empirical = CH

5. **Write the equation to determine *n* (empirical formula multiplier) of a molecular formula.**

$$n = \frac{\text{experimentally determined molar mass}}{\text{mass of empirical formula}}$$

6. **Write the equation for determining molecular formula.**

Molecular Formula = (empirical formula) n

7. **If the Experimentally-Determined molar mass of ~~benzene~~ acetylene is 26.04 g/mol and ~~acetylene~~ benzene is 78.12 g/mol, what is the molecular formula of each compound?**

C = 12.011 amu
H = 1.008 amu

Acetylene ~~Benzene~~ $\frac{26.04\text{ g/mol}}{13.02\text{ g/mol}} = 2.00$ C_2H_2

Benzene ~~Acetylene~~ $\frac{78.12\text{ g/mol}}{13.02\text{ g/mol}} = 6.00$ C_6H_6

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III. Hydrates

1. Define the term hydrate

Hydrate - Compound that has a specific number of water molecules bound to its atoms

2. Identify each hydrate name for each molecule of water bound.

Molecules		Hydrate Name	Molecules		Hydrate Name
1	=	monohydrate	6	=	hexahydrate
2	=	dihydrate	7	=	heptahydrate
3	=	trihydrate	8	=	octahydrate
4	=	tetrahydrate	9	=	nonahydrate
5	=	pentahydrate	10	=	decahydrate

3. Determine the hydrate formula of $BaCl_2 * xH_2O$.

Step 1 : Find the difference between hydrate $BaCl_2$ (5.00 g) and anhydrous $BaCl_2$ (4.26 g).

5.00 g $BaCl_2$ hydrate − 4.26 g anhydrous $BaCl_2$ = 0.74 g H_2O

Step 2 : Convert $BaCl_2$ and H_2O to moles.

1. $4.26\ g\ BaCl_2 \times \frac{1\ mol\ BaCl_2}{208.23\ g\ BaCl_2} = 0.0205\ mol\ BaCl_2$

2. $0.74\ g\ H_2O \times \frac{1\ mol\ H_2O}{18.02\ g\ H_2O} = 0.041\ mol\ H_2O$

Step 3 : Calculate the ratio of H_2O to $BaCl_2$.

$$x = \frac{0.041\ mol\ H_2O}{0.0205\ mol\ BaCl_2} = \frac{2}{1}$$

$BaCl_2 \cdot 2H_2O$

4. List uses for each of the following anhydrous or hydrate compounds.

Calcium chloride (anhydrous) : Dessicators (dry air container)

Calcium sulfate (anhydrous) : Ethanol additive (free from water)

Sodium sulfate (decahydrate) : Stores solar energy (when above 32°C)

below 32°C → hydrate recrystallizes