AP CHEMISTRY

TOPIC 1: CHEMICAL FOUNDATIONS, PART E EXAMPLES Day 6:

- Percent Composition
- Empirical formulas
- Molecular formulas

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1) Calculate the percent composition by mass of the following compounds:

a) $MgSO_4$

ANSWER: First calculate the total molar mass:

$$24.30\ \frac{g}{mol} + 32.06\ \frac{g}{mol} + 4\left(16\ \frac{g}{mol}\right) = 120.36\ \frac{g}{mol}$$

Next, calculate the percent (by mass) of each element: Take the total mass of the element and divide it by the total mass of the compound:

$$Mg: \quad \frac{\left(24.30\ \frac{g}{mol}\right)}{\left(120.36\ \frac{g}{mol}\right)} \times 100 = 20.2\ \%$$

$$S: \quad \frac{\left(32.06\ \frac{g}{mol}\right)}{\left(120.36\ \frac{g}{mol}\right)} \times 100 = 26.6\ \%$$

$$O: \quad \frac{\left(64.0\ \frac{g}{mol}\right)}{\left(120.36\ \frac{g}{mol}\right)} \times 100 = 53.2\ \%$$

b) $NaC_2H_3O_2$

ANSWER: First calculate the total molar mass:

$$22.99\ \frac{g}{mol} + 2\left(12.01\ \frac{g}{mol}\right) + 3\left(1.008\ \frac{g}{mol}\right) + 2\left(16.0\ \frac{g}{mol}\right) = 82.034\ \frac{g}{mol}$$

Next, calculate the percent (by mass) of each element:

Take the total mass of the element and divide it by the total mass of the compound:

$$Na: \quad \frac{\left(22.99\ \frac{g}{mol}\right)}{\left(82.034\ \frac{g}{mol}\right)} \times 100 = 28.0\ \%$$

$$C: \quad \frac{2\left(12.01\ \frac{g}{mol}\right)}{\left(82.034\ \frac{g}{mol}\right)} \times 100 = 29.3\ \%$$

$$H: \quad \frac{3\left(1.008\ \frac{g}{mol}\right)}{\left(82.034\ \frac{g}{mol}\right)} \times 100 = 3.7\ \%$$

$$O: \quad \frac{2\left(16.0\ \frac{g}{mol}\right)}{\left(82.034\ \frac{g}{mol}\right)} \times 100 = 39.0\ \%$$

2) Calculate the empirical formula for a compound containing 71.47% calcium and 28.53% oxygen.

ANSWER:

When given the percent "amounts" – assume you are given a 100 gram sample – so that you make life easy on yourself !!! You may use any amount, the 100 gram sample is just easier…

When calculating (determining) the empirical formula for a compound, convert the mass amount to moles…

$$Ca: \quad \frac{71.47\ g}{} \times \frac{1\ mol\ Ca}{40.08\ g} = 1.78\ mol$$

$$O: \quad \frac{28.53\ g}{} \times \frac{1\ mol\ O}{16.00\ g} = 1.78\ mol$$

Once you know the number of moles for each element, determine the ratio of each element…

$$Ca: \quad \frac{71.47\ g}{} \times \frac{1\ mol\ Ca}{40.08\ g} = 1.78\ mol \ ; \ \frac{1.78\ mol}{1.78\ mol} = 1$$

$$O: \quad \frac{28.53\ g}{} \times \frac{1\ mol\ O}{16.00\ g} = 1.78\ mol \ ; \ \frac{1.78\ mol}{1.78\ mol} = 1$$

The ratio of calcium to oxygen is a 1 to 1 ratio… Therefore, the empirical formula is $\boldsymbol{CaO}$.

3) Calculate the empirical formula for a sample that contains 251.850 g carbon, 14.09 g of hydrogen, and 149.12 g oxygen (in that order).

ANSWER:

When calculating (determining) the empirical formula for a compound, convert the mass amount to moles…

$$C: \quad \frac{251.850\ g}{} \times \frac{1\ mol\ C}{12.01\ g} = 20.97\ mol$$

$$H: \quad \frac{14.09\ g}{} \times \frac{1\ mol\ H}{1.008\ g} = 13.978\ mol$$

$$O: \quad \frac{149.12\ g}{} \times \frac{1\ mol\ O}{16.00\ g} = 9.32\ mol$$

Once you know the number of moles for each element, determine the ratio of each element…

$$C: \quad \frac{251.850\ g}{} \times \frac{1\ mol\ C}{12.01\ g} = 20.97\ mol \quad ; \quad \frac{20.97\ mol}{9.32\ mol} = 2.25 = 2\frac{1}{4} \times 4 = 9$$

$$H: \quad \frac{14.09\ g}{} \times \frac{1\ mol\ H}{1.008\ g} = 13.978\ mol \quad ; \quad \frac{13.978\ mol}{9.32\ mol} = 1.50 = 1\frac{1}{2} \times 4 = 6$$

$$O: \quad \frac{149.12\ g}{} \times \frac{1\ mol\ O}{16.00\ g} = 9.32\ mol \quad ; \quad \frac{9.32\ mol}{9.32\ mol} = 1.00 \times 4 = 4$$

Recall, one cannot have fractional values (ratios) for a chemical formula – therefore, you must multiply all the values until you have whole numbers…

The ratio of calcium to hydrogen to oxygen is 9 to 6 to 4 ratio… Therefore, the empirical formula is $\boldsymbol{C_9H_6O_4}$ **.**

4) Determine the molecular formula for the sample of SNH with a molecular mass of 188.35 grams / mole.

ANSWER:

In the problem, the empirical formula has been determined for you already… The question wants you to determine the molecular formula …

First, calculate the empirical formula mass…

$$\textbf{\textit{SNH :}}\ 32.06\ \frac{g}{mol} + 14.01\ \frac{g}{mol} + 1.008\ \frac{g}{mol} = 47.078\ \frac{g}{mol}$$

Now that you have the empirical formula mass, take the "given" molecular formula mass and divide it with the empirical formula mass to get a ratio value…

$$n = \frac{molecular\ \ formula\ \ molar\ \ mass}{empirical\ \ formula\ \ molar\ \ mass}\ ;\ \frac{188.35\ g}{47.078\ g} = n = 4$$

Now take the ratio (that you just calculated) and multiply this value by the empirical value…

$$\left(SNH\right)_n = \left(SNH\right)_4 = S_4N_4H_4$$

5) Determine the molecular formula for a sample that contains 12.09 g nitrogen, 26.73 g phosphorus, and 61.18 g of chlorine where the molecular mass is 347.64 grams / mole

ANSWER:

When calculating (determining) the empirical formula for a compound, convert the mass amount to moles…

$$N: \quad \frac{12.09\ g}{} \times \frac{1\ mol\ N}{14.01\ g} = 0.8630\ mol$$

$$P: \quad \frac{26.73\ g}{} \times \frac{1\ mol\ P}{30.97\ g} = 0.8631\ mol$$

$$Cl: \quad \frac{61.18\ g}{} \times \frac{1\ mol\ Cl}{35.45\ g} = 1.7258\ mol$$

Once you know the number of moles for each element, determine the ratio of each element…

$$N: \quad \frac{12.09\ g}{} \times \frac{1\ mol\ N}{14.01\ g} = 0.8630\ mol \quad ; \quad \frac{0.8630\ mol}{0.8630\ mol} = 1$$

$$P: \quad \frac{26.73\ g}{} \times \frac{1\ mol\ P}{30.97\ g} = 0.8631\ mol \quad ; \quad \frac{0.8631\ mol}{0.8630\ mol} = 1$$

$$Cl: \quad \frac{61.18\ g}{} \times \frac{1\ mol\ Cl}{35.45\ g} = 1.7258\ mol \quad ; \quad \frac{1.7258\ mol}{0.8630\ mol} = 2$$

Empirical Formula : $NPCl_2$

Once you know the empirical formula, you can now calculate and determine the molecular formula.

To find the molecular formula, first calculate the empirical formula molar mass:

$$\boldsymbol{NPCl_2:} \quad 14.01\ \frac{g}{mol} + 30.97\ \frac{g}{mol} + 2\left(35.45\ \frac{g}{mol}\right) = 115.88\ \frac{g}{mol}$$

Next, find the "multiplier" for the empirical formula to obtain the molecular formula…

$$n = \frac{Molecular\ formula\ molar\ mass\ (given)}{Empirical\ formula\ molar\ mass\ (you\ calculate)} = \frac{347.64\ g}{115.88\ g} = 3$$

Molecular Formula : $(NPCl_2)_3 = N_3P_3Cl_6$