Empirical and Molecular Formulas

1. A substance known as white lead contains 80.1% lead, 16.5% oxygen, 3.10% carbon, and 0.26% hydrogen. Determine the empirical formula for this compound.

$80.1\text{g Pb} \times \frac{1\text{mol Pb}}{207.2\text{g Pb}} = \frac{0.387\text{mol Pb}}{0.258} = 1.5 \times 2 = 3\ \text{Pb}$

$3.10\text{g C} \times \frac{1\text{mol C}}{12.01\text{g C}} = \frac{0.258\text{mol}}{0.258}\ \text{C} = 1 \times 2 = 2\text{C}$

$16.5\text{g O} \times \frac{1\text{mol O}}{16\text{g O}} = \frac{1.03\text{mol O}}{0.258} = 4 \times 2 = 8\text{O}$

$0.26\text{g H} \times \frac{1\text{mol H}}{1.0079\text{g H}} = \frac{0.258\text{mol}}{0.258}\ \text{H} = 1 \times 2 = 2\text{H}$

$$Pb_3C_2H_2O_8$$

2. A sample of a compound containing magnesium and phosphorus had a mass of 59.0 grams. It was known that 46.0% by mass was because of the phosphorus. Determine the empirical formula for this compound.

$46.0\text{g P} \times \frac{1\text{mol P}}{30.974\text{g P}} = \frac{1.49\text{mol P}}{1.49} = 1 \times 2 = 2\text{P}$

$54.0\text{g Mg} \times \frac{1\text{mol Mg}}{24.305\text{g Mg}} = \frac{2.22\text{mol Mg}}{1.49} = 1.5 \times 2 = 3\text{Mg}$

$$Mg_3P_2$$

3. A hydrated sodium salt containing 39.7% water and the following percentage composition for the salt - 16.9% sodium, 17.6% carbon, 2.2% hydrogen, 23.5% oxygen. Determine the formula for this hydrate and name it.

$39.7\text{g } H_2O \times \frac{1\text{mol } H_2O}{18.01\text{g } H_2O} = \frac{2.2\text{mol}}{0.735} = 3_{H_2O}$

$2.2\text{g H} \times \frac{1\text{mol H}}{1.0079\text{g H}} = \frac{2.18\text{mol}}{0.735} = 3\text{H}$

$16.9\text{g Na} \times \frac{1\text{mol Na}}{22.99\text{g Na}} = \frac{0.735\text{mol}}{0.735} = 1\text{Na}$

$23.5\text{g O} \times \frac{1\text{mol O}}{16\text{g O}} = \frac{1.47\text{mol}}{0.735} = 2\text{O}$

$17.6\text{g C} \times \frac{1\text{mol C}}{12.01\text{g C}} = \frac{1.47\text{mol}}{0.735} = 2\text{C}$

$$NaC_2H_3O_2 \cdot 3H_2O$$

sodium acetate trihydrate

4. Calcium nitrate forms two different hydrated salts. One contains 24.7% water and the other hydrated form contains 30.4% water. What are the formulas for these two hydrated salts?

$24.7\text{g } H_2O \times \frac{1\text{mol } H_2O}{18.01\text{g } H_2O} = \frac{1.37\text{mol}}{0.4589} = 3\ H_2O$

$75.3\text{g } Ca(NO_3)_2 \times \frac{1\text{mol } Ca(NO_3)_2}{164.078\text{g}} = \frac{0.4589\text{mol}}{0.4589} = 1_{Ca(NO_3)_2}$

$$Ca(NO_3)_2 \cdot 3H_2O$$

$30.4\text{g } H_2O \times \frac{1\text{mol } H_2O}{18.01\text{g } H_2O} = \frac{1.688}{0.424} = 4\ H_2O$

$69.6\text{g } Ca(NO_3)_2 \times \frac{1\text{mol } Ca(NO_3)_2}{164.078\text{g}} = \frac{0.424}{0.424} = 1_{Ca(NO_3)_2}$

$$Ca(NO_3)_2 \cdot 4H_2O$$

5. A phosphorus and oxygen compound is known to have the following percent composition - 43.7% phosphorus and 56.3% oxygen. The molar mass of this compound is 283.9 grams. Determine the true or molecular formula for this compound and also name it.

$43.7\text{g P} \times \frac{1\text{mol P}}{30.974\text{g P}} = \frac{1.41\text{ mol}}{1.41} = 1 \times 2 = 2\text{ P}$

$56.3\text{g O} \times \frac{1\text{mol O}}{16\text{g O}} = \frac{3.52\text{ mol}}{1.41} = 2.5 \times 2 = 5\text{ O}$

Empirical = P_2O_5

weight = 141.948g

$141.948\text{g} \times ? = 283.9\text{g}$

$? = 2$

Molecular = P_4O_{10}

6. What is the molecular formula of a compound whose percentage composition is 65.2% arsenic and 34.8% oxygen and whose molar mass is 230.0 grams?

$65.2\text{g As} \times \frac{1\text{mol}}{74.922\text{g As}} = \frac{0.870\text{mol As}}{0.870} = 1 \times 2 = 2\text{ As}$

$34.8\text{g O} \times \frac{1\text{mol O}}{16\text{g O}} = \frac{2.175\text{mol O}}{0.870} = 2.5 \times 2 = 5\text{ O}$

As_2O_5

Empirical

+

Molecular

b/c = 229.8g

7. Calcium chloride can exist as the anhydrous salt, $CaCl_2$, or in three different hydrated forms which are mono-, di-, and hexa- hydrates.
   a. Calculate the percent calcium in each of the four compounds.
   b. Calculate the percent of water in each of the 3 hydrates.

$CaCl_2 \cdot H_2O \rightarrow 128.994\text{g}$

a. $\%\text{ Ca} = \frac{40.1\text{g Ca}}{128.994\text{g}} \times 100 = 31.1\%\text{ Ca}$

b. $\%\ H_2O = \frac{18.01\text{g } H_2O}{128.994\text{g}} \times 100 = 14.0\%\ H_2O$

$CaCl_2 \cdot 2H_2O \rightarrow 147.004\text{g}$

a. $\%\text{ Ca} = \frac{40.1\text{g Ca}}{147.004\text{g}} \times 100 = 27.3\%\text{ Ca}$

b. $\%\ H_2O = \frac{36.0\text{g } H_2O}{147.004\text{g}} \times 100 = 24.5\%\ H_2O$

$CaCl_2 \cdot 6H_2O \rightarrow 219.1\text{g}$

a. $\%\text{ Ca} = \frac{40.1\text{g Ca}}{219.1\text{g}} \times 100 = 18.3\%\text{ Ca}$

b. $\%\ H_2O = \frac{108\text{g } H_2O}{219.1\text{g}} \times 100 = 49.3\%\ H_2O$

$CaCl_2 \rightarrow 111.1\text{g}$

$\%\text{ Ca} = \frac{40.1\text{g Ca}}{111.1\text{g}} \times 100 = 36.1\%\text{ Ca}$

8. What is the volume, in liters, of a gas at STP that contains 3.24×10^{28} molecules?

$$3.24\times10^{28}\ \text{molecules gas} \times \frac{1\ \text{mol gas}}{6.022\times10^{23}\ \text{molecules gas}} \times \frac{22.4\ \text{L gas}}{1\ \text{mol gas}} = 1.21\times10^{6}\ \text{L gas}$$

9. Why in question 8 did you not need to know the identity of the gas?

The question was only asking about mole/particle and mole/volume relationships. Those are the same for every substance regardless of its identity.

10. What is the total mass of a mixture of gases at STP if there is 4250 L of oxygen, 36,700 L of He, 8900 L of nitrogen, and 27,000 L of argon?

$$4250\ \text{L}\ O_2 \times \frac{1\ \text{mol}\ O_2}{22.4\ \text{L}\ O_2} \times \frac{32.0\ \text{g}\ O_2}{1\ \text{mol}\ O_2} = 6070\ \text{g}\ O_2$$

$$8900\ \text{L}\ N_2 \times \frac{1\ \text{mol}\ N_2}{22.4\ \text{L}\ N_2} \times \frac{28.0\ \text{g}\ N_2}{1\ \text{mol}\ N_2} = 11{,}000\ \text{g}\ N_2$$

$$36{,}700\ \text{L He} \times \frac{1\ \text{mol He}}{22.4\ \text{L He}} \times \frac{4.0\ \text{g He}}{1\ \text{mol He}} = 6600\ \text{g He}$$

$$27{,}000\ \text{L Ar} \times \frac{1\ \text{mol Ar}}{22.4\ \text{L Ar}} \times \frac{39.9\ \text{g Ar}}{1\ \text{mol Ar}} = 48{,}000\ \text{L}$$

71,670 g total

11. What is the total number of ions present in 875 grams of barium sulfate?

$$875\ \text{g}\ BaSO_4 \times \frac{1\ \text{mol}\ BaSO_4}{233.395\ \text{g}\ BaSO_4} \times \frac{6.022\times10^{23}\ \text{f.u.}\ BaSO_4}{1\ \text{mol}\ BaSO_4} \times \frac{2\ \text{ions}}{1\ \text{mol}\ BaSO_4\ \text{f.u.}} = 4.51\times10^{24}\ \text{ions}$$

12. A sample of bromine is known to have a mass of 1250.0 grams. How many molecules of this substance are in this sample?

$$1250.0\ \text{g}\ Br_2 \times \frac{1\ \text{mol}\ Br_2}{159.808\ \text{g}\ Br_2} \times \frac{6.022\times10^{23}\ \text{molecules}\ Br_2}{1\ \text{mol}\ Br_2} = 4.71\times10^{24}\ \text{molecules}\ Br_2$$