

Empirical and Molecular Formulas

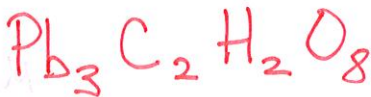
1. A substance known as white lead contains 80.1% lead, 16.5% oxygen, 3.10% carbon, and 0.26% hydrogen. Determine the empirical formula for this compound.

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

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

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

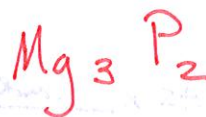
$$0.26 \text{ g H} \times \frac{1 \text{ mol H}}{1.0079 \text{ g H}} = \frac{0.258 \text{ mol H}}{0.258} = 1 \times 2 = 2 \text{ H}$$



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.

$$46.0 \text{ g P} \times \frac{1 \text{ mol P}}{30.97 \text{ g P}} = \frac{1.49 \text{ mol P}}{1.49} = 1 \times 2 = 2 \text{ P}$$

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



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.

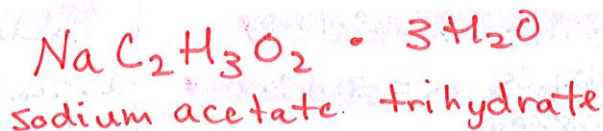
$$39.7 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.01 \text{ g H}_2\text{O}} = \frac{2.2 \text{ mol}}{0.735} = 3 \text{ H}_2\text{O}$$

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

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

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

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



4. Calcium nitrate forms two different hydrated salts. One contains 24.8% water and the other hydrated form contains 30.4% water. What are the formulas for these two hydrated salts?

$$24.7 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.01 \text{ g H}_2\text{O}} = \frac{1.37 \text{ mol}}{0.4589} = 3 \text{ H}_2\text{O}$$

$$30.4 \text{ g H}_2\text{O} \times \frac{1 \text{ mol H}_2\text{O}}{18.01 \text{ g H}_2\text{O}} = \frac{1.688 \text{ mol}}{0.424} = 4 \text{ H}_2\text{O}$$

$$75.3 \text{ g Ca(NO}_3)_2 \times \frac{1 \text{ mol Ca(NO}_3)_2}{164.078 \text{ g}} = \frac{0.4589 \text{ mol}}{0.4589} = 1 \text{ Ca(NO}_3)_2$$

$$69.6 \text{ g Ca(NO}_3)_2 \times \frac{1 \text{ mol Ca(NO}_3)_2}{164.078 \text{ g}} = \frac{0.424 \text{ mol}}{0.424} = 1 \text{ Ca(NO}_3)_2$$



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.

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

$$\text{Empirical} = \text{P}_2\text{O}_5$$

$$\text{weight} = 141.948 \text{ g}$$

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

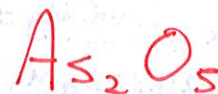
$$141.948 \text{ g} \times ? = 283.9 \text{ g}$$

$$? = 2$$

$$\text{Molecular} = \text{P}_4\text{O}_{10}$$

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?

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



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

Empirical
+

Molecular

$$b/c = 230.0 \text{ g}$$

7. Calcium chloride can exist as the anhydrous salt, CaCl_2 , or in three different hydrated forms which are mono-, di-, and hexa- hydrates.

- Calculate the percent calcium in each of the four compounds.
- Calculate the percent of water in each of the 3 hydrates.



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

$$b. \% \text{H}_2\text{O} = \frac{18.01 \text{ g H}_2\text{O}}{128.994 \text{ g}} \times 100 = 14.0\% \text{ H}_2\text{O}$$



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

$$b. \% \text{H}_2\text{O} = \frac{36.0 \text{ g H}_2\text{O}}{147.004 \text{ g}} \times 100 = 24.5\% \text{ H}_2\text{O}$$



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

$$b. \% \text{H}_2\text{O} = \frac{108 \text{ g H}_2\text{O}}{219.1 \text{ g}} \times 100 = 49.3\% \text{ H}_2\text{O}$$



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

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

$$3.24 \times 10^{28} \frac{\text{molecules}}{\text{gas}} \times \frac{1 \text{ mol gas}}{6.022 \times 10^{23} \frac{\text{molecules}}{\text{gas}}} \times \frac{22.4 \text{ L gas}}{1 \text{ mol gas}} = 1.21 \times 10^6 \text{ L gas}$$

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?

$$875 \text{ g BaSO}_4 \times \frac{1 \text{ mol BaSO}_4}{233.39 \text{ g BaSO}_4} \times \frac{6.022 \times 10^{23} \text{ f.u.}}{1 \text{ mol BaSO}_4} \times \frac{2 \text{ ions}}{1 \text{ mol BaSO}_4 \text{ f.u.}} = 4.51 \times 10^{24} \text{ ions}$$

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?

$$1250.0 \text{ g Br}_2 \times \frac{1 \text{ mol Br}_2}{159.808 \text{ g Br}_2} \times \frac{6.022 \times 10^{23} \text{ molecules Br}_2}{1 \text{ mol Br}_2} = 4.71 \times 10^{24} \text{ molecules Br}_2$$