Outline

- Moles and Molar Mass
- Percent Composition
- Empirical Formula

Mole and Molar Mass

Number of atoms can be counted by weighing…

1 ^{12}C atom weighs 12 amu (exact)

How many in 48 amu?

$$48\ \text{amu} \times \frac{1\ \text{atom}}{12.00\ \text{amu}} = \underline{4.0\ \text{atoms}}$$

How many in 12.00 g?

$$12.00\ \text{g C x} \frac{1\ \text{amu}}{1.6606 \times 10^{-24}\ \text{g}} \times \frac{1\ \text{atom}}{12\ \text{amu}} = \underline{6.022 \times 10^{23}\ \text{atoms}}$$

The number of ^{12}C atoms in 12 g of ^{12}C is called a <u>mole</u> (mol):

1 mol = 6.022×10^{23} things (Avogadro's number)

1 mole of any element is equal to the element's atomic mass in grams

1 mol of Cu = 63.55 g Cu

1 mol of Na = 22.99 g Na

131.29 g Xe = 1 mol of Xe

The mass of 1 mol of a substance is its <u>molar mass</u>

How many moles are in 2.25 g of Li?

$$2.25\ \text{g Li} \times \frac{1\ \text{mol Li}}{6.941\ \text{g Li}} = \underline{0.324\ \text{mol Li}}$$

How many atoms are in 3.5 g He?

$$3.5\ \text{g He} \times \frac{1\ \text{mol He}}{4.003\ \text{g He}} \times \frac{6.022 \times 10^{23}\ \text{atoms}}{1\ \text{mol}} = \underline{5.3 \times 10^{23}\ \text{He atoms}}$$

What's the mass (in g) of 2.00×10^{22} Ca atoms?

$$2.00 \times 10^{22}\ \text{atoms} \times \frac{1\ \text{mol}}{6.022 \times 10^{23}\ \text{atoms}} \times \frac{40.08\ \text{g Ca}}{1\ \text{mol}} = \underline{1.33\ \text{g Ca}}$$

A compound's molar mass is it's formula mass in units of grams

1 mol of NaCl = 58.44 g NaCl

44.01 g CO_2 = 1 mol of CO_2

How many moles are in 5.6 g of CF_4?

$$5.6\text{ g } CF_4 \times \frac{1\text{ mol}}{88.01\text{ g}} = 0.06\underline{3}6\text{ mol } CF_4 = \underline{0.064\text{ mol } CF_4}$$

How many molecules in 5.6 g of CF_4?

$$0.06\underline{3}6\text{ mol } CF_4 \times \frac{6.022 \times 10^{23}\text{ molec}}{1\text{ mol}} = \underline{3.8 \times 10^{22}\text{ molec } CF_4}$$

Percent Composition

Percent composition is the percent by mass of each element present in a compound

$$\% \text{ element} = \frac{\text{mass of element in formula unit}}{\text{formula mass}} \text{ x } 100$$

Calculate the % comp of CF_4

$$\% \text{ C} = \frac{12.01 \text{ amu}}{88.01 \text{ amu}} \text{ x } 100 = \underline{13.65 \text{ \% C}}$$

$$\% \text{ F} = \frac{4(19.00 \text{ amu})}{88.01 \text{ amu}} \text{ x } 100 = \underline{86.35 \text{ \% F}}$$

Calculate the % comp of water in $MgSO_4 \cdot 7H_2O$.

Formula masses:

(24.31 amu) + (32.07 amu) + 11(16.00 amu) + 14(1.008 amu)

= $\underline{246.49 \text{ amu for } MgSO_4 \cdot 7H_2O}$

2(1.008 amu) + (16.00 amu) = $\underline{18.02 \text{ amu for } H_2O}$

Percent Composition:

$$\% \, H_2O = \frac{7(18.02 \text{ amu})}{246.49 \text{ amu}} \times 100 = \underline{51.17 \, \% \, H_2O}$$

From experimental data…

$$\%\ \text{element} = \frac{\text{mass of element}}{\text{mass of compound}} \times 100$$

What's % comp if 0.500 g metal combine with 0.400 g O?

compound mass = 0.500 g + 0.400 g = 0.900 g

$$\%\ \text{metal} = \frac{0.500\ \text{g}}{0.900\ \text{g}} \times 100 = \underline{55.56\ \%\ \text{metal}}$$

$$\%\ \text{O} = \frac{0.400\ \text{g}}{0.900\ \text{g}} \times 100 = \underline{44.44\ \%\ \text{O}}$$

Empirical Formula

Empirical formula is the smallest whole number ratio of atoms in a compound…

molecular formula = (empirical formula) × n

glucose	$C_6H_{12}O_6$	CH_2O	(x 6)
acetic acid	$C_2H_4O_2$	CH_2O	(x 2)
formaldehyde	CH_2O	CH_2O	(x 1)

formulas for all ionic compounds are empirical formulas

found from percent composition of a compound…

To determine empirical formula….

1. Convert mass percents to grams (Assume 100 g!)

2. Convert grams to moles

3. Divide by the smallest number of moles

4. Multiply values by integer to obtain whole numbers

Determine empirical formula for a compound that is 32.4% sodium, 22.6% sulfur, and 45.1% oxygen.

$$32.4\ \text{g Na} \times \frac{1\ \text{mol}}{22.99\ \text{g}} = 1.4\underline{0}9\ \text{mol Na} \qquad \frac{1.4\underline{0}9\ \text{mol Na}}{0.70\underline{4}7\ \text{mol}} = 2.00\ \text{Na}$$

$$22.6\ \text{g S} \times \frac{1\ \text{mol}}{32.07\ \text{g}} = 0.70\underline{4}7\ \text{mol S} \qquad \frac{0.70\underline{4}7\ \text{mol S}}{0.70\underline{4}7\ \text{mol}} = 1.00\ \text{S}$$

$$45.1\ \text{g O} \times \frac{1\ \text{mol}}{16.00\ \text{g}} = 2.8\underline{1}8\ \text{mol O} \qquad \frac{2.8\underline{1}8\ \text{mol O}}{0.70\underline{4}7\ \text{mol}} = 4.00\ \text{O}$$

$\underline{Na_2SO_4}$

Determine empirical formula for a compound that is 26.6% potassium, 35.4% chromium, and 38.1% oxygen.

$$26.6\ \text{g K} \times \frac{1\ \text{mol}}{39.10\ \text{g}} = 0.68\underline{0}3\ \text{mol K} \qquad \frac{0.68\underline{0}3\ \text{mol K}}{0.68\underline{0}3\ \text{mol}} = 1.00\ \text{K}$$

$$35.4\ \text{g Cr} \times \frac{1\ \text{mol}}{52.00\ \text{g}} = 0.68\underline{0}7\ \text{mol Cr} \qquad \frac{0.68\underline{0}7\ \text{mol Cr}}{0.68\underline{0}3\ \text{mol}} = 1.00\ \text{Cr}$$

$$38.1\ \text{g O} \times \frac{1\ \text{mol}}{16.00\ \text{g}} = 2.3\underline{8}1\ \text{mol O} \qquad \frac{2.3\underline{8}1\ \text{mol O}}{0.68\underline{0}3\ \text{mol}} = 3.50\ \text{O}$$

$$KCrO_{3.5} \Rightarrow \underline{K_2Cr_2O_7}$$

Determine molecular formula for a compound that is 30.4% nitrogen and 69.6% oxygen, and has a molecular mass of 92.0 amu

$$30.4 \text{ g N} \times \frac{1 \text{ mol}}{14.01 \text{ g}} = 2.1\underline{6}9 \text{ mol N} \qquad \frac{2.1\underline{6}9 \text{ mol N}}{2.1\underline{6}9 \text{ mol}} = 1.00 \text{ N}$$

$$69.6 \text{g O} \times \frac{1 \text{ mol}}{16.00 \text{ g}} = 4.3\underline{5}0 \text{ mol O} \qquad \frac{4.3\underline{5}0 \text{ mol O}}{2.1\underline{6}9 \text{ mol}} = 2.01 \text{ O}$$

$$NO_2 \quad \Rightarrow \quad 1(14.01 \text{ amu}) + 2(16.00 \text{ amu}) = 46.01 \text{ amu}$$

$$92.0 \text{ amu} \div 46.01 \text{ amu} = 2.00 \quad \Rightarrow \quad 2 \times NO_2 \quad \Rightarrow \quad \underline{N_2O_4}$$

Determine molecular formula for a compound that is 56.4% phosphorus and 43.6% oxygen, and has a molecular mass of 220.0 amu

$$56.4\ \text{g P} \times \frac{1\ \text{mol}}{30.97\ \text{g}} = 1.8\underline{2}1\ \text{mol P} \qquad \frac{1.8\underline{2}1\ \text{mol P}}{1.8\underline{2}1\ \text{mol}} = 1.00\ \text{P}$$

$$43.6\ \text{g O} \times \frac{1\ \text{mol}}{16.00\ \text{g}} = 2.7\underline{2}5\ \text{mol O} \qquad \frac{2.7\underline{2}5\ \text{mol O}}{1.8\underline{2}1\ \text{mol}} = 1.50\ \text{O}$$

$$PO_{1.5} \Rightarrow P_2O_3 \Rightarrow 2(30.97\ \text{amu}) + 3(16.00\ \text{amu}) = 109.94\ \text{amu}$$

$$220.0\ \text{amu} \div 109.94\ \text{amu} = 2.00 \Rightarrow 2 \times P_2O_3 \Rightarrow \underline{P_4O_6}$$