Molecular Weight and Atomic Weight

22.990 Na 35.452 Cl

Molecular Weight or Molar Mass

22.990 + 35.452 = 58.442

Take-Home Calculations

- Molecular Weight = ∑ atomic weights
- Mole = Weight / Molecular Weight
- Number of atoms or molecules = Mole x Avogadro's number (6.022×10^{23})
- Mass of one atom = grams of an element / 6.022×10^{23}

Molar Mass or Molecular Weight

- Molar mass

  mass in grams numerically equal to the atomic weight of the element in grams.

- Molar mass or Molecular weight of NaCl = 22.990 + 35.452 = 58.442 amu
- amu = atomic mass unit

Molar Mass

- How do we calculate the molar mass of a compound?
  - add atomic weights of each atom
- The molar mass of propane, C_3H_8, is:

$$
\begin{aligned}
3 \times \mathrm{C} &= 3 \times 12.01\ \text{amu} &= 36.03\ \text{amu} \\
8 \times \mathrm{H} &= 8 \times \ \ 1.01\ \text{amu} &= \ \ 8.08\ \text{amu} \\
\hline
\text{Molar mass} & &= 44.11\ \text{amu}
\end{aligned}
$$

Molar Mass

Calculate the molar mass of $Ca(NO_3)_2$?

$$1 \times Ca = 1 \times 40.08 \text{ amu} = 40.08 \text{ amu}$$

$$2 \times N = 2 \times 14.01 \text{ amu} = 28.02 \text{ amu}$$

$$6 \times O = 6 \times 16.00 \text{ amu} = 96.00 \text{ amu}$$

$$\text{Molar mass} = 164.10 \text{ amu}$$

The Mole

- A number of atoms, ions, or molecules that is large enough to see and handle.
- A mole = number of things
  - Just like a dozen = 12 things
  - One mole = 6.022×10^{23} things
- Avogadro's number (N_A) = 6.022×10^{23}

The number of moles

- How many moles of Mg atoms are present in 73.4 g of Mg?

$$? \text{ mol Mg} = 73.4 \text{ g Mg} \left(\frac{1 \text{ mol Mg atoms}}{24.30 \text{ g Mg}} \right)$$

$$= 3.02 \text{ mol Mg}$$

The Mole

- <u>One Mole of Cl_2 Contains</u>
  - Cl_2 or 70.90 g
  - contains 6.022×10^{23} Cl_2 molecules

    $2(6.022 \times 10^{23})$ Cl atoms

- <u>One Mole of C_3H_8 Contains</u>
  - C_3H_8 or 44.11 g
  - contains 6.022×10^{23} C_3H_8 molecules

    $3(6.022 \times 10^{23})$ C atoms

    $8(6.022 \times 10^{23})$ H atoms

The mass of a single atom

- Calculate the mass of a single Mg atom, in grams, to 3 significant figures.

$$? \text{ g Mg } = 1 \text{ Mg atom}\left(\frac{1 \text{ mol Mg atoms}}{6.022 \times 10^{23} \text{ Mg atoms}}\right) \times \left(\frac{24.30 \text{ gMg}}{1 \text{ mol Mg atoms}}\right) = 4.04 \times 10^{-23} \text{ g Mg}$$

The number of atoms

- How many atoms are contained in 1.67 moles of Mg?

$$? \text{ Mg atoms} = 1.67 \text{ mol Mg}\left(\frac{6.022\times10^{23}\text{ Mg atoms}}{1\text{ mol Mg}}\right)$$

$$= 1.00\times10^{24}\text{ Mg atoms}$$

The number of molecules

- Calculate the number of C_3H_8 molecules in 74.6 g of propane.

$$? \ C_3H_8 \text{ molecules} = 74.6 \text{ g } C_3H_8 \times$$

$$\left(\frac{1 \text{ mole } C_3H_8}{44.11 \text{ g } C_3H_8}\right)\left(\frac{6.022 \times 10^{23} \ C_3H_8 \text{ molecules}}{44.11 \text{ g } C_3H_8}\right) =$$

$$1.02 \times 10^{24} \text{ molecules}$$

The number of atoms

- Calculate the number of O atoms in 26.5 g of Li_2CO_3.

$$? \text{ O atoms} = 26.5 \text{ g } Li_2CO_3 \times \frac{1 \text{ mol } Li_2CO_3}{73.8 \text{ g } Li_2CO_3} \times$$

$$\frac{6.022 \times 10^{23} \text{ form.units } Li_2CO_3}{1 \text{ mol } Li_2CO_3} \times \frac{3 \text{ O atoms}}{1 \text{ formula unit } Li_2CO_3} =$$

$$6.49 \times 10^{23} \text{ O atoms}$$

Percent Composition and Formulas of Compounds

- % composition = mass of an individual element in a compound divided by the total mass of the compound x 100%
- Determine the percent composition of C in C_3H_8.

$$\% \text{ C} = \frac{\text{mass C}}{\text{mass } C_3H_8} \times 100\%$$

$$= \frac{3 \times 12.01 \text{ g}}{44.11 \text{ g}} \times 100\%$$

$$= 81.68\%$$

Percent Composition and Formulas of Compounds

- What is the percent composition of H in C_3H_8?

$$\% \text{ H} = \frac{\text{mass H}}{\text{mass } C_3H_8} \times 100\%$$

$$= \frac{8 \times \text{H}}{C_3H_8} \times 100\%$$

$$= \frac{8 \times 1.01 \text{ g}}{44.11 \text{ g}} \times 100\% = 18.32\ \%$$

or

$$18.32\% = 100\% - 81.68\%$$

Percent Composition and Formulas of Compounds

- Calculate the percent composition of $Fe_2(SO_4)_3$ to 3 significant figures

$$\%Fe = \frac{2 \times Fe}{Fe_2(SO_4)_3} \times 100\% = \frac{2 \times 55.8g}{399.9g} \times 100\% = 27.9\%Fe$$

$$\%S = \frac{3 \times S}{Fe_2(SO_4)_3} \times 100\% = \frac{3 \times 32.1g}{399.9g} \times 100\% = 24.1\%S$$

$$\%O = \frac{12 \times O}{Fe_2(SO_4)_3} \times 100\% = \frac{12 \times 16.0g}{399.9g} \times 100\% = 48.0\%O$$

Total $= 100\%$

Derivation of Formulas from Elemental Composition

- **Empirical Formula** - smallest whole-number ratio of atoms present in a compound
  - CH_2 is the empirical formula for alkenes ($CH_2CH_2CH_2CH_2CH_2$)

- Molecular Formula - actual numbers of atoms of each element present in a molecule of the compound
  - Ethene – CH_2CH_2 is C_2H_4
  - Pentene – $CH_2CH_2CH_2CH_2CH_2$ is C_5H_{10}

  - percent composition is determined experimentally

Derivation of Formulas from Elemental Composition

- A compound contains 24.74% K, 34.76% Mn, and 40.50% O by mass. What is its empirical formula?
- Make the simplifying assumption that we have 100.0 g of compound.
- In 100.0 g of compound there are:
  - 24.74 g of K
  - 34.76 g of Mn
  - 40.50 g of O

Derivation of Formulas from Elemental Composition

$$? \text{ mol K} = 24.74 \text{ g K} \times \frac{1 \text{ mol K}}{39.10 \text{ g K}} = 0.6327 \text{ mol K}$$

$$? \text{ mol Mn} = 34.76 \text{ g Mn} \times \frac{1 \text{ mol Mn}}{54.94 \text{ g Mn}} = 0.6327 \text{ mol Mn}$$

$$? \text{ mol O} = 40.50 \text{ g O} \times \frac{1 \text{mol O}}{16.00 \text{ g O}} = 2.531 \text{ mol O}$$

$$\underline{\underline{\text{obtain smallest whole number ratio}}}$$

$$\text{for K} \Rightarrow \frac{0.6327}{0.6327} = 1 \text{ K} \qquad \text{for Mn} \Rightarrow \frac{0.6327}{0.6327} = 1 \text{ Mn}$$

$$\text{for O} \Rightarrow \frac{2.531}{0.6327} = 4 \text{ O}$$

$$\text{thus the chemical formula is } KMnO_4$$

Derivation of Formulas from Elemental Composition

- A sample of a compound contains 6.541g of Co and 2.368g of O. What is the empirical formula for this compound?

$$? \text{ mol Co} = 6.541 \text{ g Co} \times \frac{1 \text{ mol Co}}{58.93 \text{ gCo}} = 0.1110 \text{ mol Co}$$

$$? \text{ mol O} = 2.368 \text{ g O} \times \frac{1 \text{mol O}}{16.00 \text{ g O}} = 0.1480 \text{ mol O}$$

find smallest whole number ratio

Derivation of Formulas from Elemental Composition

- A sample of a compound contains 6.541g of Co and 2.368g of O. What is the empirical formula for this compound?

$$\text{for Co} \Rightarrow \frac{0.1110}{0.1110} = 1\ \text{Co} \qquad \text{for O} \Rightarrow \frac{0.1480}{0.1110} = 1.333\ \text{O}$$

multipy both by 3 to turn fraction to whole number

$$1\ \text{Co} \times 3 = 3\ \text{Co} \quad 1.333\ \text{O} \times 3 = 4\ \text{O}$$

Thus the compound's formula is:

$$Co_3O_4$$

Purity of Samples

- The percent purity of a sample of a substance is always represented as

$$\%\ \text{purity} = \frac{\text{mass of pure substance}}{\text{mass of sample}} \times 100\%$$

mass of sample includes impurities

Chemistry is fun!

Purity of Samples

- A bottle of sodium phosphate, Na_3PO_4, is 98.3% pure Na_3PO_4. What are the masses of Na_3PO_4 and impurities in 250.0 g of this sample of Na_3PO_4?

$$\text{unit factor} \quad \frac{98.3 \text{ g } Na_3PO_4}{100.0 \text{ g sample}}$$

$$? \text{ g } Na_3PO_4 = 250.0 \text{ g sample} \times \frac{98.3 \text{ g } Na_3PO_4}{100.0 \text{ g sample}}$$

$$= 246 \text{ g } Na_3PO_4$$

$$? \text{ g impurities} = 250.0 \text{ g sample} - 246 \text{ g } Na_3PO_4$$

$$= 4.00 \text{ g impurities}$$