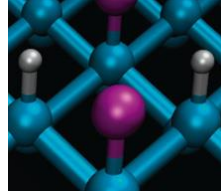


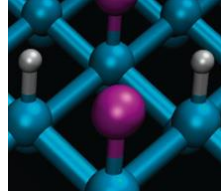



Chapter **3**

Molecules, Moles, and Chemical Equations

CENGAGE

Interpreting Chemical Equations

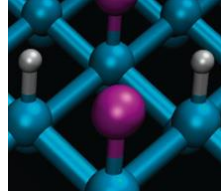


- Balanced chemical reactions provide stoichiometric ratios between reactants and products
- Ratios relate relative numbers of particles

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$$

  - Two molecules of H_2 react with one molecule of O_2 to form two molecules of H_2O
  - 20 molecules of H_2 react with 10 molecules of O_2 to form 20 molecules of H_2O

Avogadro's Number and the Mole (

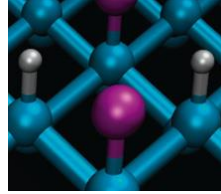


- A mole is a means of counting the large number of particles in samples
  - One mole is the number of atoms in exactly 12 grams of ^{12}C or carbon-12
  - This number is also referred to as Avogadro's number, and its value is 6.022×10^{23} particles/mole
  - The mass of 6.022×10^{23} atoms of any element is the molar mass of that element

Avogadro's Number and the Mole (2 of 3)

- One mole samples of various elements are shown
- All have the same number of particles

Avogadro's Number and the Mole (3 of 3)

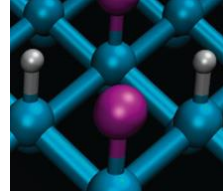


- Balanced chemical reactions also provide mole ratios between reactants and products

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(g)$$

  - 2 moles of H_2 and 1 mole of O_2 react to form 2 moles of H_2O

Determining Molar Mass

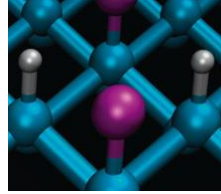


- The molar mass of a compound is the sum of the molar masses of all the atoms in a compound

$$\left(2\ \text{mol H} \times \frac{1.0\ \text{g H}}{1\ \text{mol H}}\right) + \left(1\ \text{mol O} \times \frac{16.0\ \text{g}}{1\ \text{mol O}}\right)$$

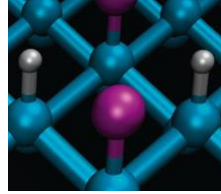
$$= 18.0\ \text{g/mol } H_2O$$

Example Problem 3.5



- Determine the molar mass of each of the following compounds, all of which are used as fertilizers for the production of biomass:
  - Calcium sulfate, $CaSO_4$
  - Urea, $CO(NH_2)_2$
  - Carnallite, $H_{12}Cl_3KMgO_6$

Example Problem 3.5



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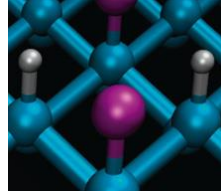

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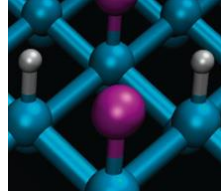
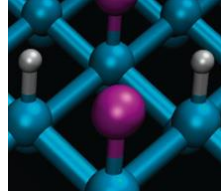


- Determine the molar mass of each of the following compounds, all of which are used as fertilizers for the production of biomass:
  - Carnallite, $H_{12}Cl_3KMgO_6$ (Discussion Question)

Calculations Using Moles and Molar Mass (1 of 2)

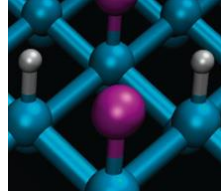


- Molar mass allows conversion from mass to the number of moles, much like a unit conversion
  - 1 mol $C_7H_5N_3O_6$ = 227.133 g $C_7H_5N_3O_6$

$$300.0\ \text{g}\ C_7H_5N_3O_6 \times \frac{1\ \text{mol}\ C_7H_5N_3O_6}{227.133\ \text{g}\ C_7H_5N_3O_6}$$

$$= 1.320\ \text{mol}\ C_7H_5N_3O_6$$

Calculations Using Moles and Molar Mass (2 of 2)

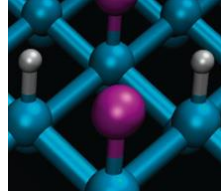


- Avogadro's number functions much like a unit conversion between moles to the number of particles
  - $1\,\text{mol}\ C_7H_5N_3O_6 = 6.022 \times 10^{23} C_7H_5N_3O_6\,\text{molecules}$
  - How many molecules are in 1.320 moles of nitroglycerin?

$$1.320\ \text{mol}\ C_7H_5N_3O_6 \times \frac{6.022 \times 10^{23}\ \text{molecules}\ C_7H_5N_3O_6}{1\ \text{mol}\ C_7H_5N_3O_6}$$

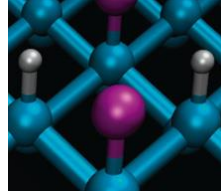
$$= 7.949 \times 10^{23}\ \text{molecules}\ C_7H_5N_3O_6$$

Example Problem 3.6



- A 245.3-g sample of glutamic acid, $C_5H_9NO_4$, is recovered from an experiment using fermentation to convert biomass
  - How many moles of $C_5H_9NO_4$ are in this sample?
  - How many molecules are in this sample?

Example Problem 3.6



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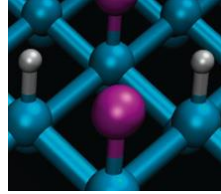

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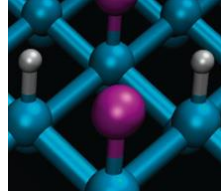
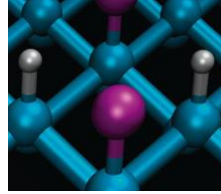
Elemental Analysis: Determining Empirical Formulas



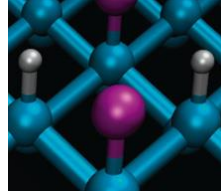
- Empirical formulas can be determined from an elemental analysis
  - An elemental analysis measures the mass percentage of each element in a compound
  - The formula describes the composition in terms of the number of atoms of each element
  - The molar masses of the elements provide the connection between the elemental analysis and the formula

Elemental Analysis: Determining Empirical Formula



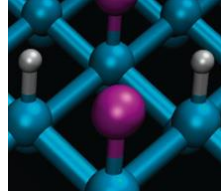
- Assume a 100-gram sample size
- Percentage element multiplied by sample size equals mass element in compound
  - Example: 16% carbon equals 16 g carbon
- Convert mass of each element to moles using the molar mass
- Divide by the smallest number of moles to get the mole-to-mole ratio for the empirical formula

Example Problem 3.8



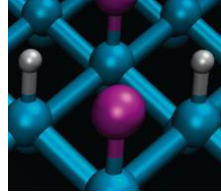
- Nitroaniline had been observed in experiments on biomass from pine needles and can be used as a precursor for pharmaceuticals
  - It contains 52.17% carbon, 4.38% hydrogen, 20.28% nitrogen, and 23.17% oxygen by mass
    - Determine the empirical formula of nitroaniline

Example Problem 3.9



- An alloy contains 70.8 mol % palladium and 29.2 mol % nickel
  - Express the composition of this alloy as weight percentage or wt %

Example Problem 3.9



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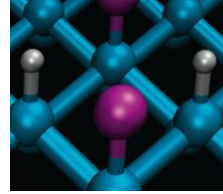
Molarity

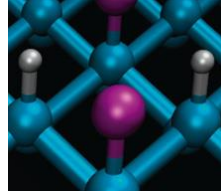


- Molarity or molar concentration, *M*, is the number of moles of solute per liter of solution
  - Provides relationship among molarity, moles of solute, and liters of solution

$$\text{Molarity}\,(M) = \frac{\text{moles of solute}}{\text{liter of solution}}$$

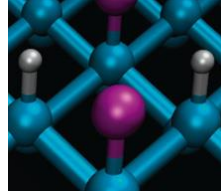
  - If we know any two of these quantities, we can determine the third one

Example Problem 3.10



- A solution is prepared by dissolving 45.0 g of NaClO in enough water to produce exactly 750 mL of solution
  - What is the molarity of this solution?

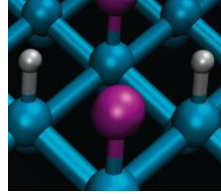
Dilution



- Dilution is the process in which solvent is added to a solution to decrease the concentration of the solute
  - The number of moles of solute is the same before and after dilution
  - Since the number of moles of solute equals the product of molarity and volume, we can write the following equation, where the subscripts denote initial and final values

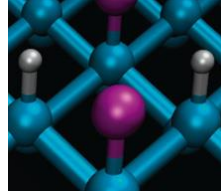
$$M_i \times V_i = M_f \times V_f$$

Example Problem 3.11



- A chemist requires 1.5 M hydrochloric acid, HCl, for a series of reactions. The only solution available is 6.0 M HCl.
  - What volume of 6.0 M HCl must be diluted to obtain 5.0 L of 1.5 M HCl?

Join In, 12



What volume of 9.0 M HCl(aq) is needed initially to produce 2.5 L of 0.20 M solution?

- 0.055 mL
- 0.72 mL
- 4.5 mL
- 55 mL