Reaction Stoichiometry

– quantitative relationships between reactants and products

4.1 Mole-to-Mole Calculations

- Stoichiometric relations in chemical equations

$$2H_2 + O_2 \rightarrow 2H_2O$$

$$2 \text{ mol } H_2 \Leftrightarrow 1 \text{ mol } O_2$$

$$1 \text{ mol } O_2 \Leftrightarrow 2 \text{ mol } H_2O$$

- Conversion method
  - mole ratios (conversion factors)

[2 mol H_2O/1 mol O_2]

(mol given)×(mole ratio)= (mol required)

Example: Determine the number of moles of water produced from **3.4 mol O_2**.

$$3.4 \text{ mol } O_2 \times \left(\frac{2 \text{ mol } H_2O}{1 \text{ mol } O_2}\right) = 6.8 \text{ mol } H_2O$$

- Stoichiometric conversion factors are reaction specific

Example: Calculate the amount of **O_2** needed to produce **3.5 mol H_2O** by combustion of methane (**CH_4**).

⇒**balanced equation:**

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

⇒**mole ratio (conversion factor):**

$$2 \text{ mol } O_2 \Leftrightarrow 2 \text{ mol } H_2O$$

[2 mol O_2/2 mol H_2O]

$$3.5 \text{ mol } H_2O \times \left(\frac{2 \text{ mol } O_2}{2 \text{ mol } H_2O}\right) = 3.5 \text{ mol } O_2$$

4.2 Mass-to-Mass Calculations

- Conversion method

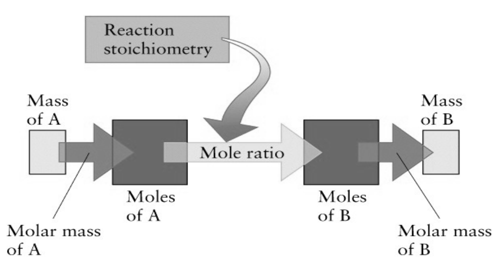

Fig. 4.4

Example:

- Calculate the mass of oxygen needed to completely burn **5.4 kg** of butane (**C_4H_{10}**).

⇒**balanced equation:**

$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$$

⇒**mole ratio (conversion factor):**

$$13 \text{ mol } O_2 \Leftrightarrow 2 \text{ mol } C_4H_{10}$$

[13 mol O_2/2 mol C_4H_{10}]

⇒**molar masses:**

$C_4H_{10} \rightarrow 58.1$ g/mol $O_2 \rightarrow 32.0$ g/mol

$$5.4\,\mathrm{kg\,C_4H_{10}} \times \left(\frac{10^3\ \mathrm{g\,C_4H_{10}}}{1\,\mathrm{kg\,C_4H_{10}}}\right) \times \left(\frac{1\,\mathrm{mol\,C_4H_{10}}}{58.1\,\mathrm{g\,C_4H_{10}}}\right) \times$$

$$\times \left(\frac{13\,\mathrm{mol\,O_2}}{2\,\mathrm{mol\,C_4H_{10}}}\right) \times \left(\frac{32.0\,\mathrm{g\,O_2}}{1\,\mathrm{mol\,O_2}}\right) = 1.9\times10^4\ \mathrm{g\,O_2} =$$

$$= 19\,\mathrm{kg\,O_2}$$

- Gravimetric analysis - uses measurements of mass to obtain the amount of analyte
  - precipitation reactions
  - gas formation reactions

Example:

- A sample of ore of mass 5.324 g was analyzed for Ba by dissolving the sample and then precipitating the Ba^{2+} ions with sulfuric acid. After drying, the mass of the precipitate was found to be 3.752 g. What is the mass % of Ba in the sample?

⇒net ionic equation:

$$\mathbf{Ba^{2+} + SO_4^{2-} \rightarrow BaSO_{4}(s)}$$

⇒mole ratio:

$$\mathbf{[1\ mol\ Ba^{2+}/1\ mol\ BaSO_4]}$$

⇒molar masses:

$BaSO_4 \rightarrow$ 233.40 g/mol   Ba $\rightarrow$ 137.34 g/mol

$$3.752\,\mathrm{g\ BaSO_4} \times \left(\frac{1\,\mathrm{mol\,BaSO_4}}{233.40\,\mathrm{g\ BaSO_4}}\right) \times$$

$$\times \left(\frac{1\,\mathrm{mol\,Ba^{2+}}}{1\,\mathrm{mol\,BaSO_4}}\right) \times \left(\frac{137.34\,\mathrm{g\ Ba}}{1\,\mathrm{mol\,Ba^{2+}}}\right) = 2.208\,\mathrm{g\ Ba}$$

⇒mass %:

$$\left(\frac{2.208\,\mathrm{g\ Ba}}{5.324\,\mathrm{g\ sample}}\right) \times 100\% = 41.47\%\ \mathrm{Ba}$$

Fig. 4.5