3.5 Solution Stoichiometry

- Solutions – homogeneous mixtures
  - Solvent and solute(s)
  - Solution concentration

Molarity (*M*)

- Measure of the solute concentration

$$M = \left(\frac{\text{amount of solute (mol)}}{\text{volume of solution (L)}}\right) \quad \text{or} \quad M = \frac{n}{V}$$

- Units – molar (M) **1 M = 1 mol/L**

- Preparation of solutions with known molarity
  - Transfer a known mass of solute in a volumetric flask
  - Dissolve in small amount of water
  - Add water to the mark

Example:

Calculate the molarity of a solution prepared by dissolving **5.33 g NaOH** in water using a **100.0 mL** volumetric flask.

⇒ **convert the mass to moles:**

$$5.33\text{ g NaOH} \times \left(\frac{1\text{ mol NaOH}}{40.00\text{ g NaOH}}\right) = 0.133\text{ mol NaOH}$$

⇒ **convert volume to liters: 100.0 mL = 0.1000 L**

⇒ **divide moles by solution volume:**

$$\frac{0.133\text{ mol NaOH}}{0.1000\text{ L solution}} = 1.33\text{ mol NaOH/L} \rightarrow 1.33\text{ M NaOH}$$

- Molarity as a conversion factor

Example:

Calculate the mass of NaOH in **2.50 L** of **1.33 M NaOH** solution.

$$2.50\ \cancel{\text{L}}\left(\frac{1.33\ \cancel{\text{mol NaOH}}}{1\ \cancel{\text{L}}}\right)\left(\frac{40.00\text{ g NaOH}}{1\ \cancel{\text{mol NaOH}}}\right) = 133\text{ g NaOH}$$

Example:

Calculate the volume of **1.33 M NaOH** solution that contains **5.00 mol NaOH**.

$$5.00\ \cancel{\text{mol NaOH}} \times \left(\frac{1\text{ L}}{1.33\ \cancel{\text{mol NaOH}}}\right) = 3.76\text{ L}$$

Dilution

- Reducing the concentration of the solute by adding more solvent
- Stock solutions – concentrated solutions used to store reagents
- Dilution Procedure
  – Use a pipette to measure a small volume of the concentrated solution and transfer it to a volumetric flask
  – Add solvent to fill the volumetric flask to the mark

- Dilution calculations
  – dilution doesn't change the total # of moles of solute in the solution

$$n = M \times V \qquad n_d = n_c \qquad M_d \times V_d = M_c \times V_c$$

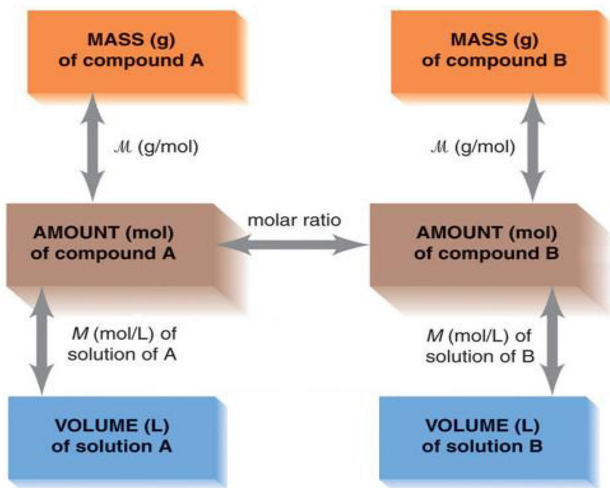
Example:

Calculate the molarity of a solution prepared by dilution of **5.00 mL 2.0 M HCl** stock solution to **100.0 mL.**

$$M_d = \frac{M_c \times V_c}{V_d} = \frac{2.0 \text{ M} \times 5.00 \text{ mL}}{100.0 \text{ mL}} = 0.10 \text{ M}$$

Stoichiometric calculations in solution

– For a reaction involving substances A and B



Example:

What volume of **0.0836 M H_2SO_4** solution will react completely with **16.4 mL 0.255 M KOH**.

⇒ **balanced equation:**

$2KOH_{(aq)} + H_2SO_{4(aq)} \rightarrow K_2SO_{4(aq)} + 2H_2O_{(l)}$

⇒ **mole ratio: [1 mol H_2SO_4/2 mol KOH]**

$$16.4 \times 10^{-3} \cancel{\text{L}} \times \left(\frac{0.255 \cancel{\text{ mol KOH}}}{1 \cancel{\text{ L}}}\right) \times \left(\frac{1 \cancel{\text{ mol } H_2SO_4}}{2 \cancel{\text{ mol KOH}}}\right)$$

$$\times \left(\frac{1 \text{ L}}{0.0836 \cancel{\text{ mol } H_2SO_4}}\right) = 25.0 \times 10^{-3} \text{ L} = 25.0 \text{ mL}$$

Limiting reactant problems in solution

Example:

What mass of $\mathbf{H_2}$ gas can be produced by the reaction of **2.5 g Zn** with **2.0 L 0.15 M HCl** solution. The other product is $ZnCl_2(aq)$.

⇒ **balanced equation:**

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

⇒ **mole ratios:** $[1 \text{ mol } H_2/2 \text{ mol } HCl]$

$[1 \text{ mol } H_2/1 \text{ mol } Zn]$

⇒ **Calculate the mass of H_2 produced based on both reactants and choose the smaller amount**

⇒ **calculation based on HCl:**

$$2.0\ \cancel{L} \times \left(\frac{0.15\ \cancel{\text{mol HCl}}}{1\ \cancel{L}}\right) \times \left(\frac{1\ \cancel{\text{mol } H_2}}{2\ \cancel{\text{mol HCl}}}\right) \times \left(\frac{2.02\ \text{g } H_2}{1\ \cancel{\text{mol } H_2}}\right)$$

$= 0.30 \text{ g } H_2$

⇒ **calculation based on Zn:**

$$2.5\ \cancel{\text{g Zn}} \times \left(\frac{1\ \cancel{\text{mol Zn}}}{65.4\ \cancel{\text{g Zn}}}\right) \times \left(\frac{1\ \cancel{\text{mol } H_2}}{1\ \cancel{\text{mol Zn}}}\right) \times \left(\frac{2.02\ \text{g } H_2}{1\ \cancel{\text{mol } H_2}}\right)$$

$= \boxed{0.077 \text{ g } H_2}$ ← **smaller amount**

⇒ **The calculation based on Zn yields less product so Zn is the limiting reactant**