CH100- lecture 02

Titration experiment – example

Goal: determine the concentration of an analyte

25 mL of hydrochloric acid (HCl) of an unknown concentration (=**analyte**) is titrated with 0.1M sodium hydroxide (NaOH) solution. The endpoint is reached when 32.6 mL of NaOH has been added. What is the concentration of HCl?

1. Write the equation

$$HCl + NaOH \rightarrow NaCl + H_2O$$

→ HCl and NaOH have a 1:1 ratio

2. How many moles of NaOH were added?

$$n_{NaOH} = c\ x\ V = \ 0.1\ mol \cdot L^{-1}\ x\ 0.0326\ L = 3.26\ x\ 10^{-3}\ mol$$

3. How many moles of HCl are then present?

$$n_{NaOH} = n_{HCl} = 3.26\ x\ 10^{-3}\ mol$$

4. What is the concentration of HCl?

$$c = \frac{n}{V} = \frac{3.26\ x\ 10^{-3}\ mol}{0.025\ L} = 0.130\ M$$

Combustion experiment - example

Goal: determine the composition (in C, H, O) of an organic compound

1.5 g of an unknown sample (C, H, O) is completely burned. It produces 2.2g CO_2 and 0.90 g H_2O. What is the empirical formula of the compound?

1. How many moles of CO_2 are obtained?
Each mole of CO_2 contains 1 mole of C

$$mol_{CO_2} = \frac{2.2\ g}{44.01\ g/mol} = 0.049\ mol$$

So, we have **0.049 mol of C**

2. How many moles of H_2O are obtained?
Each mole of H_2O contains 2 moles of H

$$mol_{H_2O} = \frac{0.90\ g}{18.016\ g/mol} = 0.049\ mol$$

So, we have **2 x 0.049=0.099 mol of H (as in one mole of H_2O, you have two moles of H)**

3. Convert to mass to know how much oxygen is there.

$$mass\ C\ =\ 0.049\ mol\ x\ 12.011\ g/mol = 0.6g$$
$$mass\ H\ =\ 0.099\ mol\ x\ 1.008\ g/mol = 0.1g$$

$$mass\ O\ =\ 1.5\ g\ -(0.6g + 0.1g) = 0.8g$$

4. How many moles of oxygen are there?

$$mol_O = \frac{0.8\ g}{15.99\ g/mol} = 0.049\ mol$$

5. Find the right ratio

$$\frac{mol\ C}{0.049} = 1$$

$$\frac{mol\ H}{0.049} = 2$$

$$\frac{mol\ O}{0.049} = 1$$

So, the empirical formula is **CH_2O**

Limiting reactant – example

Goal: identifying the limiting reactant in a chemical reaction, and inferring the amount of product produced

When **4.00 g of hydrogen gas (H_2)** reacts with **28.0 g of nitrogen gas (N_2)**, ammonia (NH_3) is formed according to the balanced chemical equation:

$$N_2(g) + 3H_2(g) \quad \rightarrow \quad 2NH_3(g)$$

Use atomic masses $H = 1.008$, $N = 14.007$.

1. Calculate the moles of each reactant

$$M_{H_2} =\ 2.016\ g.mol^{-1}, M_{N_2} =\ 28.014\ g.mol^{-1}$$
$$n_{H_2} = \frac{4.00\ g}{2.016\ g.mol^{-1}} = 1.984\ mol$$
$$n_{N_2} = \frac{28.00\ g}{28.014\ g.mol^{-1}} = 0.9995\ mol$$

2. Determine the limiting reactant

The reaction requires 3 mol H_2 per mol N_2.
The amount of H_2 required to react with all N_2:

$$3\ x\ n_{N_2} = 2.9985\ mol\ required$$

We only have 1.984 mol H_2 so H_2 is the limiting reactant.

3. What is the maximum moles and mass of NH_3 produced?

$$3\ H_2 \rightarrow\ 2\ NH_3$$

$$n_{NH_3} = \frac{2}{3} n_{H_2} = 1.323\ mol$$

Molar mass of NH_3=14.007+3 (1.008) = 17.031 g.mol^{-1}

$$m_{NH_3} = 1.323\ mol\ x\ 17.031\ g.mol^{-1} = 22.5g$$