

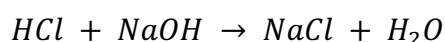
## CH100- lecture 02

### 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 and NaOH have a 1:1 ratio

2. How many moles of NaOH were added?

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

3. How many moles of HCl are then present?

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

4. What is the concentration of HCl?

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

### 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<sub>2</sub> and 0.90 g H<sub>2</sub>O. What is the empirical formula of the compound?

1. How many moles of CO<sub>2</sub> are obtained?

Each mole of CO<sub>2</sub> contains 1 mole of C

$$\text{mol}_{\text{CO}_2} = \frac{2.2 \text{ g}}{44.01 \text{ g/mol}} = 0.049 \text{ mol}$$

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

2. How many moles of H<sub>2</sub>O are obtained?

Each mole of H<sub>2</sub>O contains 2 moles of H

$$\text{mol}_{\text{H}_2\text{O}} = \frac{0.90 \text{ g}}{18.016 \text{ g/mol}} = 0.049 \text{ mol}$$

So, we have  $\underline{2 \times 0.049} = 0.099$  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.

$$\text{mass } C = 0.049 \text{ mol} \times 12.011 \text{ g/mol} = 0.6 \text{ g}$$

$$\text{mass } H = 0.099 \text{ mol} \times 1.008 \text{ g/mol} = 0.1 \text{ g}$$

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

4. How many moles of oxygen are there?

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

5. Find the right ratio

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

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

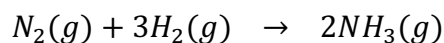
$$\frac{\text{mol } O}{0.049} = 1$$

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:



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

1. Calculate the moles of each reactant

$$M_{H_2} = 2.016 \text{ g} \cdot \text{mol}^{-1}, M_{N_2} = 28.014 \text{ g} \cdot \text{mol}^{-1}$$

$$n_{H_2} = \frac{4.00 \text{ g}}{2.016 \text{ g} \cdot \text{mol}^{-1}} = 1.984 \text{ mol}$$

$$n_{N_2} = \frac{28.00 \text{ g}}{28.014 \text{ g} \cdot \text{mol}^{-1}} = 0.9995 \text{ mol}$$

2. Determine the limiting reactant

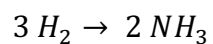
The reaction requires 3 mol H<sub>2</sub> per mol N<sub>2</sub>.

The amount of H<sub>2</sub> required to react with all N<sub>2</sub>:

$$3 \times n_{N_2} = 2.9985 \text{ mol required}$$

We only have 1.984 mol H<sub>2</sub> so H<sub>2</sub> is the limiting reactant.

3. What is the maximum moles and mass of NH<sub>3</sub> produced?



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

Molar mass of NH<sub>3</sub>=14.007+3 (1.008) = 17.031 g.mol<sup>-1</sup>

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