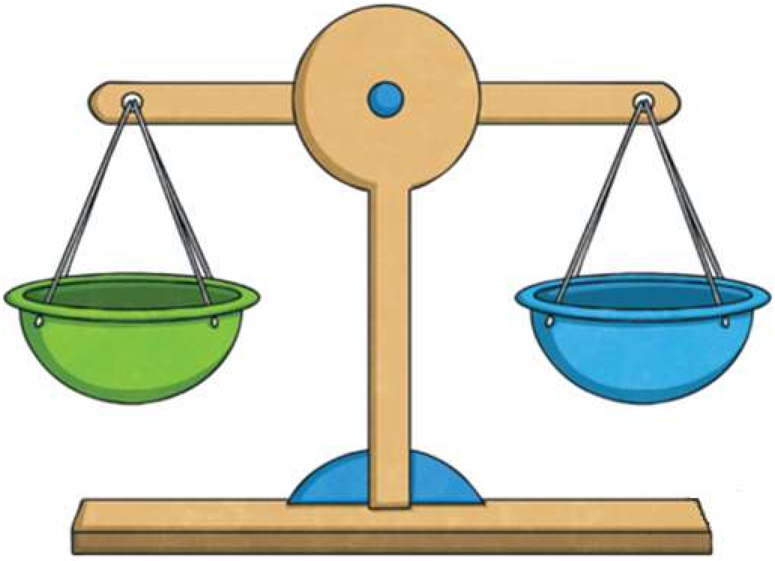
Master

Kirkcaldy High School



Higher Chemistry

Unit 3 - part 3

Equilibrium and Chemical Analysis

Name: ______________________

Class: ______________________

Teacher: ______________________

Assessment Page

Homework

Homework title	Date	Mark/Total Mark
		/

Notes/comments

Check tests

Test title	Date	Mark/Total Mark
		/

Notes/comments

Date: ________________

Equilibrium

Overarching question(s) for this topic

- How can the conditions of a reversible reaction affect the product yield.

Dynamic Equilibrium

In a an irreversible reaction, all of the reactants (in the correct proportions) will be converted into products given enough time.

$$A + B \rightarrow C + D$$

Before the reaction begins:	100%	0%
After completion:	0%	100%

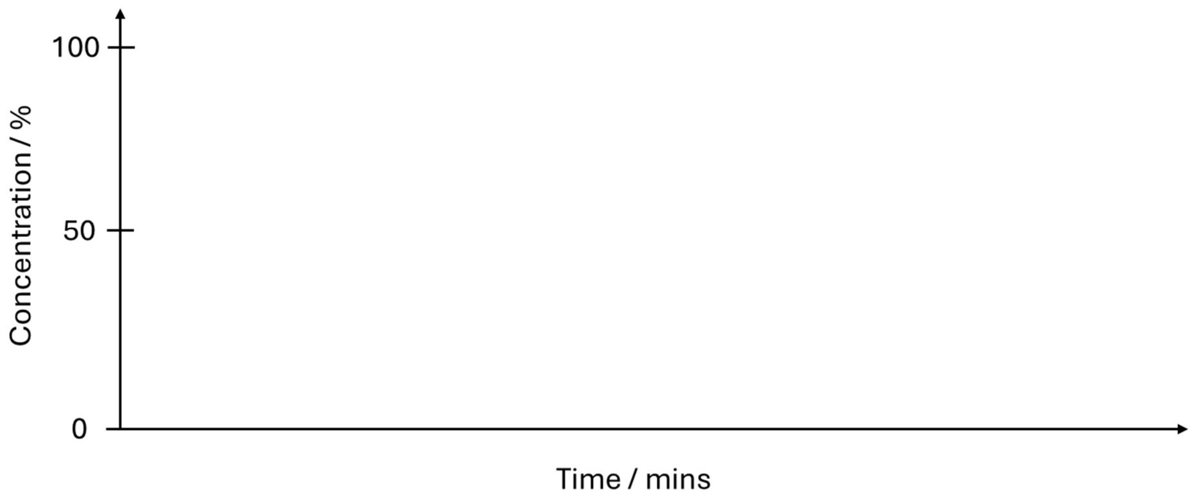
This is not the case with **reversible reactions** where the reaction does not '**complete'**. The forward and backward reactions are occuring **constantly** but there will become a time when they are in **equilibrium**.

$$A + B \rightleftharpoons C + D$$

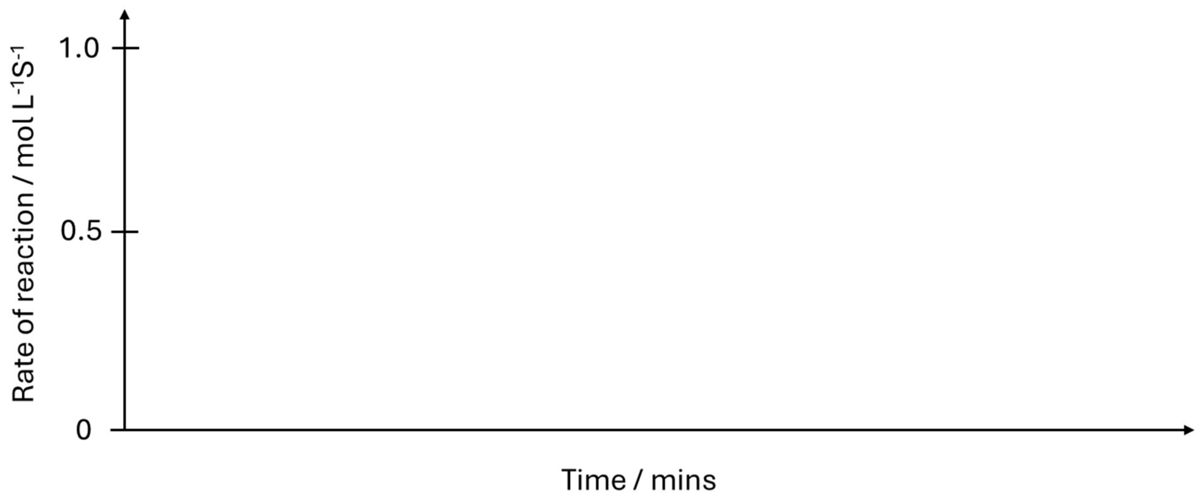
Before the reaction begins:	100%	0%
At Equilibrium:	30%	70%

There are two definitions for when the equilibrium is established:

1. The **concentration** of the reactants and products remain **constant**.



2. The **rate** of the forward and backward reaction are **equal**.



The effect of catalysts on equilibrium

Catalysts have **no effect** on the **position** of the equilibrium.

Catalysts **increase** the rate of **both** the **forward** and **backward** reaction.

Catalysts therefore only **decrease** the time taken to **reach** equilibrium.

Factors that change the position of the equilibrium

It is possible to **change** the position of the equilibrium which can **increase** or **decrease** the yield of a reaction.

There are three **factors** that can **affect** the **position** of the equilibrium: **Temperature**, **pressure** and **concentration**.

Effect of a Temperature on Equilibrium

With temperature changes, the enthalpy change of both the forward and backward reaction must be considered. The stated enthalpy change in the equation is for the forward reaction, therefore the reverse reaction will have the opposite sign (+ to -, and vice versa).

Remember, '**+ kJ/mol**' is **endothermic** and '**– kJ/mol**' is **exothermic**.

Endothermic reactions can be **favoured** (the reaction rate will speed up) by **increasing** the temperature.

Exothermic reactions can be favoured by **decreasing** the temperature.

$$A + B \rightleftharpoons C + D \qquad \Delta H = +\ kJ/mol$$

Increasing the **temperature** in the above reaction favours the **forwards** reaction, **increasing** the concentration of the **products,** while **decreasing** the concentration of **reactants** (moving the equilibrium **right**).

Decreasing the **temperature** in the above reaction favours the **backwards** reaction, **increasing** the concentration of the **reactants**, while **decreasing** the concentration of **products** (moving the equilibrium **left**).

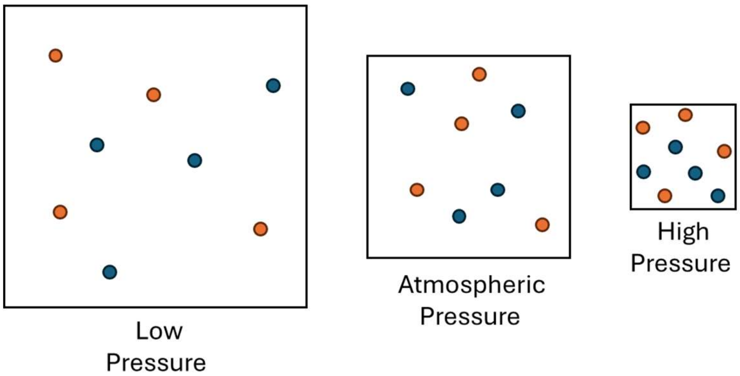
$$A + B \rightleftharpoons C + D \qquad \Delta H = -\ kJ/mol$$

Increasing the **temperature** in the above reaction favours the **backwards** reaction, **decreasing** the concentration of the **products,** while **increasing** the concentration of **reactants** (moving the equilibrium **left**).

Decreasing the **temperature** in the above reaction favours the **forward** reaction, **increasing** the concentration of the **products**, while decreasing the concentration of **reactants** (moving the equilibrium **right**).

Effect of a Pressure on Equilibrium

Pressure is related to the concentration of gas particles in a **given** volume.



Gas particles in high pressure **collide** more frequently so there is a **faster** rate of reaction.

If the number of **gaseous reactant** and **product** particles **differ** (by comparing the number of moles in the formulae) **changing** the pressure **will affect** the **position** of the **equilibrium**.

Increasing the pressure makes the side of the equation with a **greater number** of **moles** of **gas** particles react **faster**, which increases the rate of that reaction moving the equilibrium to the **opposite side** of the equation.

Therefore, by **increasing** favours the **pressure** the side of the equation with **less** moles of gas is **favoured** (the concentration increases).

Following this, **decreasing** the **pressure** does the opposite and **favours** the side with the **greater number** of **moles** of **gas**.

$$2A(g) + B(g) \rightleftharpoons C(g)$$

Increasing the pressure in the above reaction favours the **forward** reaction (moving the equilibrium **right**).

Decreasing the pressure favours the **backward** reaction (moving the equilibrium **left**).

$$2A(g) + B(s) \rightleftharpoons 3C(g)$$

Increasing the pressure in the above reaction favours the **backward** reaction (moving the equilibrium **left**).

Decreasing the pressure favours the **forward** reaction (moving the equilibrium **right**).

$$A(g) + B(g) \rightleftharpoons 2C(g)$$

The pressure has **no effect** on the **equilibrium** in the above equation as the number of moles of gas are **equal**.

Effect of a Concentration on Equilibrium

Changing the concentration can be either done by the **addition** of a reactant or product, or by the **removal** of a reactant or product.

The **addition** of a chemical to one side of the equation will result in a **greater rate** of reaction for that side of the equation, **shifting** the **equilibrium** to the **opposite** side.

The removal of a chemical on one side of the equation will result in the equilibrium shifting to the same side to **restore** the lost concentration.

$$A + B \rightleftharpoons C + D$$

Increasing the **concentration** of **A or B** moves the equilibrium to the **right**.

Increasing the **concentration** of **C or D** moves the equilibrium to the **left**.

Removal of A or B moves the equilibrium to the **left**.

Removal of C or D moves the equilibrium to the **right**.

The main reaction used to show the removal of a chemical is the neutralisation reaction:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

Example

$$CH_3COOH(aq) \rightleftharpoons H^+(aq) + CH_3COO^-(aq)$$

Addition of **H^+** from an **acid** such as HCl or H_2SO_4, etc. would move the equilibrium to the **left**.

Addition of **OH^-** from an **alkaline** solution such as **NaOH** (sodium hydroxide) would **react with H^+**, **removing** the **H^+** ions and **decreasing** their **concentration**, moving the equilibrium to the **right**.

Questions

1 . N_2 (g) + $2O_2$ (g) $\rightleftharpoons$ $2NO_2$ (g) $\Delta H = + 180\ KJ\ mol^{-1}$

Predict how the equilibrium will be affected by:

a) an increase in temperature

b) Decreasing the pressure

c) Decreasing the concentration of oxygen

2. $3O_2$ (g) $\rightleftharpoons$ $2O_3$ (g) $\Delta H = + 285.5\ KJ\ mol^{-1}$

Predict how the equilibrium will be affected by:

a) an increase in pressure

b) an increase in temperature

3. ICl_3 (l) + Cl_2 (g) $\rightleftharpoons$ ICl_5 (s) ΔH =-ve
(brown liquid) (yellow solid)

Predict what would be seen to happen to a mixture at equilibrium if:

a) more chlorine was added

b) the temperature was increased

c) the pressure was decreased

4. N_2O_4 (g) $\rightleftharpoons$ $2NO_2$ (g) ΔH = +ve
(pale yellow) (dark brown)

Explain what would be seen to happen if the equilibrium mixture was:

a) placed in a freezer

b) compressed

5. C_2H_4 (g) + H_2O (g) $\rightleftharpoons$ C_2H_5OH (g) $\Delta H = -46$ KJ mol^{-1}

Predict how the equilibrium will be affected by:

a) an increase in pressure

b) an increase in temperature

c) increasing the concentration of alcohol

6. NH_3 (g) + H_2O (l) $\rightleftharpoons$ NH_4^+ (aq) + OH^- (aq) $\Delta H = -30.6$ KJ mol^{-1}

Predict how each of the following changes would affect the equilibrium position:

a) increasing the temperature

b) increasing the pressure

c) adding an alkali

d) adding a dilute acid

7. Sulphuric acid is produced in industry by the Contact Process. The reaction that takes place using a catalyst is:

$2SO_2$ (g) + O_2 (g) $\rightleftharpoons$ $2SO_3$ (g)

a) State the effect of a catalyst on

i) the rate of the forward reaction

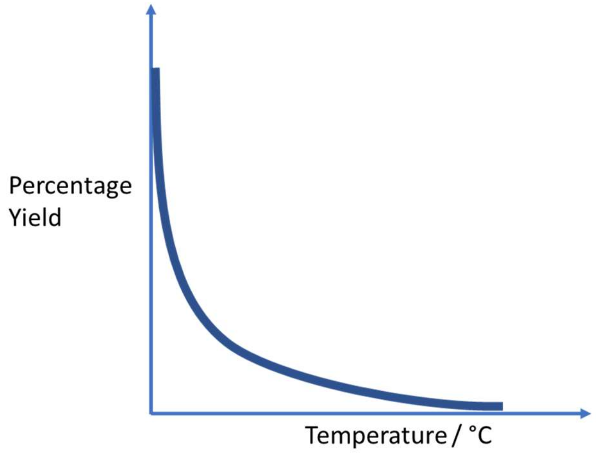
ii) the rate of the backward reaction

iii) the rate of the formation of product

iv) the composition of the equilibrium mixture

b) Suggest why the reaction is carried out at atmospheric pressure rather than a significantly higher pressure.

c) The graph shows how the percentage yield changes with temperature.



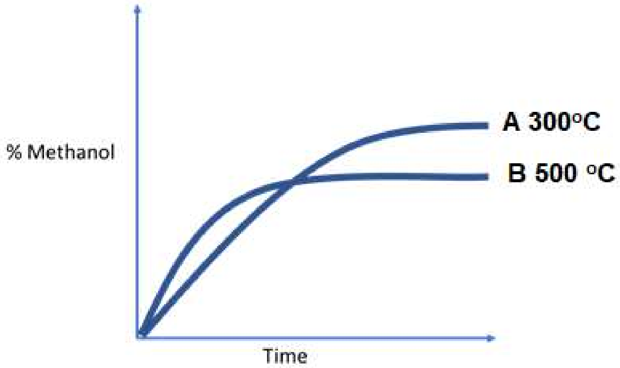
i) is the reaction exothermic or endothermic?

ii) Explain your answer

8. The industrial preparation of methanol involves the combination of carbon monoxide and hydrogen.

$$CO (g) + 2H_2 (g) \rightleftharpoons CH_3OH (g)$$

The curves show the percentages of methanol in the equilibrium mixture under different conditions



a) In industry, the reaction is usually carried out at 300 atmospheres pressure. Explain the use of high pressure

b) i) is the reaction that produces methanol exothermic or endothermic?

ii) Explain your answer

Flash Cards

Past Papers

	2015	**2016**	**2017**	**2018**	**2019**	**2021**	**2022**	**2023**
MC	18	15	17, 20	15, 20	23	21, 25	20	
S2	8b	8a	2aiii		12c	4ei	7d, 8aii	6ci-iiA

TEAMS: Check Test – Unit 1: Key Area 3d

Date: _______________

Chemical Analysis

Overarching question(s) for this topic

- How can we use chemical analysis methods to identify chemicals in a mixture and measure the concentration of solutions?

Chromatography

Chromatography is a technique used to **separate** the **components** present within a **mixture**.

Chromatography separates substances by making use of differences in their **polarity** or **molecular size**.

Depending on the type of chromatography used, the identity of a component can be indicated either by the distance it has travelled (in TLC), or by the time it has taken to travel through the apparatus (retention time in GLC).

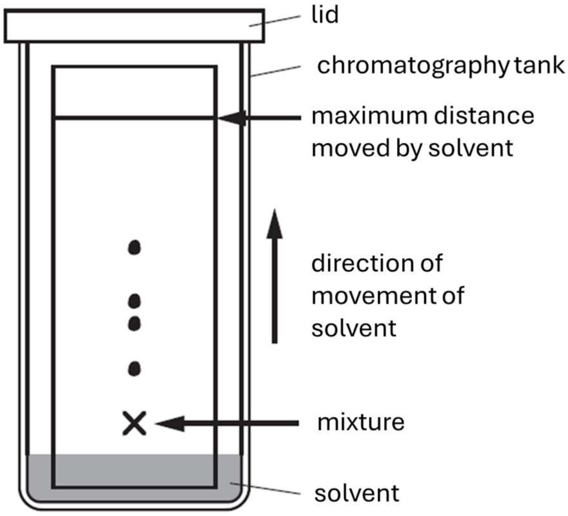
Thin Layer Chromatography (TLC)

Thin Layer Chromatography (TLC) is a simple, rapid, and inexpensive analytical technique used to separate and identify compounds in a mixture.

It involves applying a small sample to a thin layer of adsorbent material (e.g., silica gel) coated on a glass or plastic plate.

The plate is placed in a solvent, which moves up by capillary action, carrying the sample components at different rates based on their **polarity** and **molecular** size.

TLC is commonly used for monitoring reactions, assessing purity, and identifying compounds.

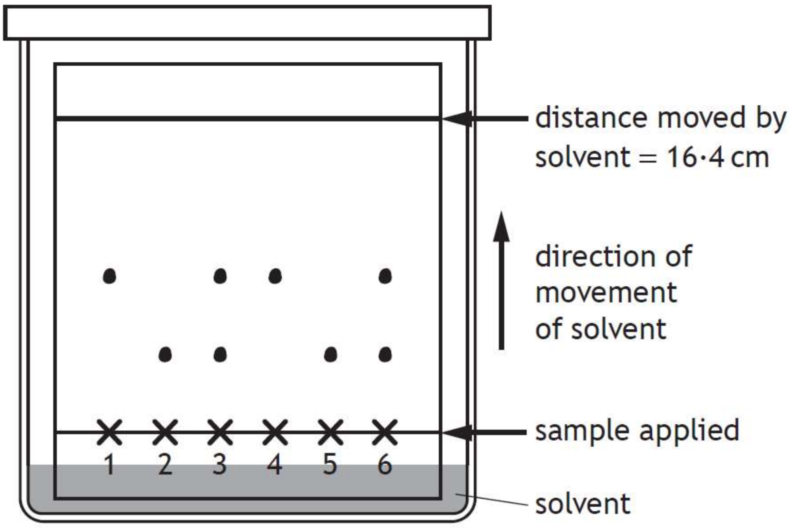


On a chromatogram, the retention factor R_f, for a substance can be a useful method of identifying the substance.

$$R_f = \frac{distance\ moved\ by\ the\ substance}{maximum\ distance\ moved\ by\ the\ solvent}$$

The maturing process in cider samples can be monitored using thin layer chromatography.

Samples of lactic acid, malic acid and ciders A, B, C, and D are spotted on a silica plate and the solvent allowed to travel up the plate. The chromatogram obtained is shown below.



Number	Sample applied	Distance moved by spot(s) (cm)
1	lactic acid	8·2
2	malic acid	4·1
3	cider A	4·1, 8·2
4	cider B	8·2
5	cider C	4·1
6	cider D	4·1, 8·2

1. Calculate the Rf values of lactic and malic acid.

2. The maturing process is complete when all of the malic acid has been converted to lactic acid. The cider is now ready to be bottled.

   Use the chromatogram to determine which cider is ready to be bottled.

Gas Liquid Chromatography (GLC)

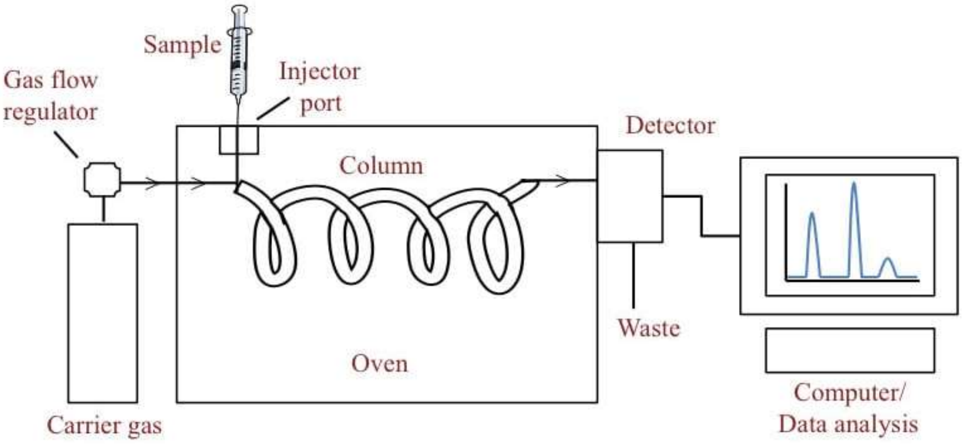
In GLC, the sample is injected an **inert carrier gas** (such as **Argon** or **Nitrogen**) pushes the mixutre through the column. The **larger** substances with go through the column **slower** than the **smaller** substances.

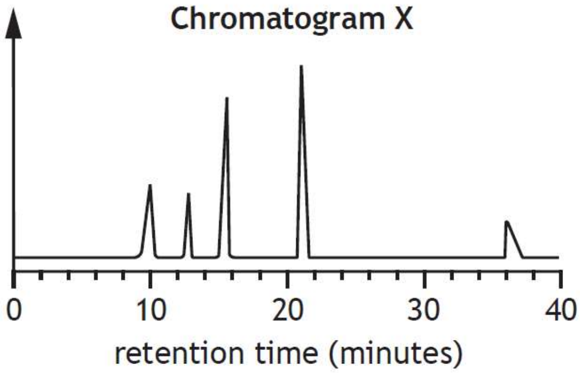
The detector **triggers** when substances pass through it, the **computer** then produces a graph of retention time againt intensity.

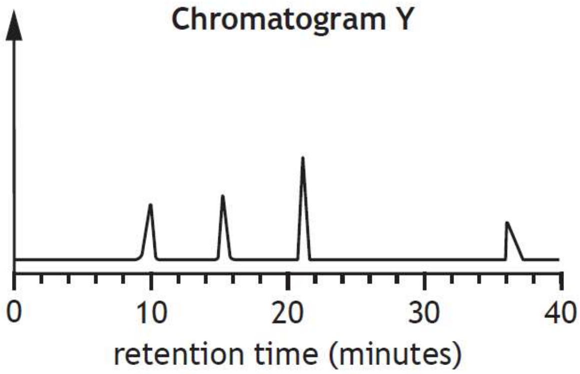
Small substances have a **lower** retention time and **larger** molecules have a **higher** retention time.

Higher concentrations of substances have a **larger** peak area.

This technique can be used to analyse **cosmetics**, **pharmaceuticals**, **counterfeits**, etc.







Volumetric analysis - Redox Titrations

Volumetric analysis involves using a solution of accurately known concentration in a quantitative reaction to determine the concentration of another substance.

Titration is used to determine, **accurately**, the volumes of solution required to reach the **end-point** of a chemical reaction.

An **indicator** is normally used to show when the **end-point** is reached. Titre volumes within 0·2 cm^3 are considered **concordant**.

Solutions of **accurately known concentration** are known as **standard solutions**.

The most accurate piece of equipment for measuring volumes is a **pippete**.

Redox titrations are based on **redox** reactions.

In titrations using **acidified permanganate**, an indicator is not required, as **purple permanganate** solution turns **colourless** when **reduced**.

Performing redox titration calculations

Example:

The equation for the reaction of oxalic acid and sodium hydroxide is shown.

$$H_2C_2O_4(aq) + 2NaOH(aq) \rightarrow Na_2C_2O_4(aq) + 2H_2O(\ell)$$

The concentration of sodium hydroxide solution was determined by titrating 25.0 cm^3 samples with 0.126 mol l^{-1} oxalic acid solution.

The average volume of oxalic acid solution required in the titration was 26.75 cm^3.

Calculate the concentration, in mol l^{-1}, of the sodium hydroxide.

Calcium ions are commonly found in tap water. The concentration of calcium ions in a tap water sample was determined by titrating with a chemical called EDTA, $C_{10}H_{12}N_2O_8^{4-}$.

A 50.0 cm^3 water sample was collected and reacted with a standard solution of EDTA, with a concentration of 0.0045 mol l^{-1}. The average titre volume was 9.3 cm^3.

$$Ca^{2+}(aq) \quad + \quad C_{10}H_{12}N_2O_8^{4-}(aq) \quad \rightarrow \quad [Ca(C_{10}H_{12}N_2O_8)]^{2-}(aq)$$

Calculate the concentration, in mol l^{-1}, of calcium ions in the tap water.

For the titrations, the student diluted the soft drink to improve the accuracy of results.

25·0 cm^3 samples of the diluted soft drink were titrated with Fehling's solution which had a Cu^{2+} concentration of 0·0250 mol l^{-1}.

The average volume of Fehling's solution used in the titrations was 19·8 cm^3.

$$C_6H_{12}O_6 \quad + \quad 2Cu^{2+} \quad + \quad H_2O \quad \rightarrow \quad C_6H_{12}O_7 \quad + \quad 2Cu^{+} \quad + \quad 2H^{+}$$

reducing sugar	Fehling's solution

Calculate the concentration, in mol l^{-1}, of reducing sugars present in the diluted sample of the soft drink.

Experimental Information/reports

Past Papers

	2015	2016	2017	2018	2019	2021	2022	2023
MC		20	15			1,22,23,24	16,23,24,24	16,19
S2	3a,10, 12a	1bi,6d,11	2b,5ai, 5ci,7	2d, 3a-b, 9d, 11a	4ii, 9b, 10	4b, 6b, 8bi, 9aii, 11a	2c, 6aiv, 11b-d	3aiv,7aii,7b, 10a-bii,10d

TEAMS: Check Test – Unit 1: Key Area 3e