Atoms, Amount, Equations & Reactions
AS & A Level

Question Paper 3

Level	A Level
Subject	Chemistry
Exam Board	OCR
Module	Foundations in Chemistry
Topic	Atoms, Amount, Equations & Reactions
Paper	AS & A Level
Booklet	Question Paper 3

Time allowed: **78 minutes**

Score: **/58**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E
>85%	73%	60%	47%	34%	21%

Calcium carbonate, $CaCO_3$, reacts with hydrochloric acid as shown in the equation below.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

(a) 7.50×10^{-3} mol $CaCO_3$ reacts with 0.200 mol dm^{-3} HCl.

(i) Calculate the volume, in cm^3, of 0.200 mol dm^{-3} HCl required to react with 7.50×10^{-3} mol $CaCO_3$. [2]

(ii) Calculate the volume, in cm^3, of CO_2 formed at room temperature and pressure. [1]

(b) When heated strongly, $CaCO_3$ decomposes.

Write an equation, including state symbols, for the thermal decomposition of $CaCO_3$. [2]

(c) Calcium oxide reacts with water and with nitric acid.

State the formula of the calcium compound formed when:

(i) calcium oxide reacts with water, [1]

(ii) calcium oxide reacts with nitric acid. [1]

[Total: 7 Marks]

Butyl ethanoate is an ester used as a flavouring.
This ester can be synthesised from butan-1-ol by two different processes.

Process 1 is a one-step process that involves a reversible reaction.

$$CH_3CH_2CH_2CH_2OH + CH_3COOH \rightleftharpoons CH_3COOCH_2CH_2CH_2CH_3 + H_2O$$

The percentage yield for **process 1** is 67.1%.
The atom economy for **process 1** is 86.6%.

Process 2 is a two-step process.

$$CH_3COOH + SOCl_2 \rightarrow CH_3COCl + SO_2 + HCl$$

$$CH_3CH_2CH_2CH_2OH + CH_3COCl \rightarrow CH_3COOCH_2CH_2CH_2CH_3 + HCl$$

The overall percentage yield for **process 2** is 93.3%.
The overall atom economy for **process 2** is 45.8%.

(a) Draw the skeletal formula for the ester butyl ethanoate. [1]

(b) Show that the atom economy for **process 1** is 86.6%. [2]

(c) A research chemist investigates **process 1**.
She finds that 6.25 g of butan-1-ol forms 6.57 g of butyl ethanoate.

(i) Suggest the conditions needed for this reaction. [2]

(ii) Show that the percentage yield of **process 1** is 67.1%. [2]

(d) Explain why **process 2** has a high percentage yield but a low atom economy. [2]

(e) Suggest **two** reasons why butyl ethanoate is manufactured by **process 1** rather than by **process 2**. [2]

[Total: 11 Marks]

A student carries out experiments using acids, bases and salts.

(a) Calcium nitrate, $Ca(NO_3)_2$, is an example of a salt.

The student prepares a solution of calcium nitrate by reacting dilute nitric acid, HNO_3, with the base calcium hydroxide, $Ca(OH)_2$.

(i) Why is calcium nitrate an example of a salt? [1]

(ii) Write the equation for the reaction between dilute nitric acid and calcium hydroxide. Include state symbols. [2]

(iii) Explain how the hydroxide ion in aqueous calcium hydroxide acts as a base when it neutralises dilute nitric acid. [1]

(b) A student carries out a titration to find the concentration of some sulfuric acid.

The student finds that 25.00 cm^3 of 0.0880 mol dm^{-3} aqueous sodium hydroxide, NaOH, is neutralised by 17.60 cm^3 of dilute sulfuric acid, H_2SO_4.

$$H_2SO_4(aq) + 2NaOH(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$$

(i) Calculate the amount, in moles, of NaOH used. [1]

(ii) Determine the amount, in moles, of H_2SO_4 used. [1]

(iii) Calculate the concentration, in mol dm^{-3}, of the sulfuric acid. [1]

(c) After carrying out the titration in **(b)**, the student left the resulting solution to crystallise. White crystals were formed, with a formula of $Na_2SO_4 \cdot \boldsymbol{x} H_2O$ and a molar mass of 322.1 g mol^{-1}. [2]

(i) What term is given to the '$\cdot \boldsymbol{x} H_2O$' part of the formula?

(ii) Calculate the value of $\boldsymbol{x}$ using the molar mass of the crystals.

[Total: 10 Marks]

This question is about the halogen group of elements and some of their compounds.

(a) The halogens show trends in their properties down the group.

The boiling points of three halogens are shown below.

Halogen	Boiling point / °C
Chlorine	–35
Bromine	59
Iodine	184

Explain why the halogens show this trend in boiling points.

[3]

(b) Hydrogen iodide, HI, is decomposed by heat into its elements:

$2HI(g) \rightarrow H_2(g) + I_2(g) \qquad \Delta H = +9.5\,kJ\,mol^{-1}$

The decomposition is much faster in the presence of a platinum catalyst.

Complete the enthalpy profile diagram for this reaction using formulae for the reactants and products.

[3]

- Use E_a to label the activation energy **without** a catalyst.
- Use E_c to label the activation energy **with** a catalyst.
- Use ΔH to label the enthalpy change of reaction.

(c) Compound **A** is an oxide of chlorine that is a liquid at room temperature and pressure and has a boiling point of 83 °C.

When 0.4485 g of **A** is heated to 100 °C at 1.00×10^5 Pa, 76.0 cm^3 of gas is produced.

Determine the molecular formula of compound **A**.

Show all your working.

[4]

(d) Compound **B** is an iodate(V) salt of a Group 1 metal.
The iodate(V) ion has the formula IO_3^-.

A student carries out a titration to find the formula of compound **B**.

Step 1: The student dissolves 1.55 g of **B** in water and makes up the solution to 250.0 cm^3 in a volumetric flask.

Step 2: The student pipettes 25.00 cm^3 of the solution of **B** into a conical flask, followed by 10 cm^3 of dilute sulfuric acid and an excess of KI(aq).

The iodate(V) ions are reduced to iodine, as shown below.

$$IO_3^-(aq) + 6H^+(aq) + 5I^-(aq) \rightarrow 3I_2(aq) + 3H_2O(l)$$

Step 3: The resulting mixture is titrated with 0.150 mol dm^{-3} $Na_2S_2O_3(aq)$.

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

The student repeats **step 2** and **step 3** until concordant titres are obtained.

Titration readings

Titration	**Trial**	**1**	**2**	**3**
Final burette reading / cm^3	24.00	47.40	23.75	47.05
Initial burette reading / cm^3	0.00	24.00	0.00	23.20
Titre / cm^3				

Table 20.1

(i) Complete **Table 20.1** and calculate the mean titre that the student should use for analysing the results.

[2]

(ii) The uncertainty in each burette reading is ±0.05 cm^3.

Calculate the percentage uncertainty in the titre obtained from **titration 1**.

Give your answer to **two** decimal places.

[1]

(iii) Describe and explain how the student should determine the end point of this titration accurately.

[2]

(iv) Determine the relative formula mass and formula of the Group 1 iodate(V), **B**.

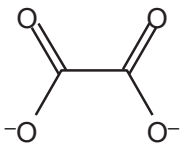
Show your working.

[5]

(Total 20 marks)

This question is about ethanedioic acid, $(COOH)_2$, and ethanedioate ions, $(COO^-)_2$.

(a) The ethanedioate ion, shown below, can act as a bidentate ligand.



Fe^{3+} forms a complex ion with three ethanedioate ions.
The complex ion has two optical isomers.

Draw the 3D shapes of the optical isomers.

In your diagrams, show the structure of the ethanedioate ligands and any overall charge.

[3]

(b) Ethanedioic acid, $(COOH)_2$, is present in rhubarb leaves.

A student carries out a redox titration using aqueous cerium(IV) sulfate, $Ce(SO_4)_2(aq)$, to determine the percentage, by mass, of ethanedioic acid in rhubarb leaves.

In the titration, $Ce^{4+}(aq)$ ions oxidise ethanedioic acid in hot acid conditions:

$$2Ce^{4+}(aq) + (COOH)_2(aq) \rightarrow 2Ce^{3+}(aq) + 2CO_2(g) + 2H^+(aq)$$

$Ce^{4+}(aq)$ ions have a yellow colour. $Ce^{3+}(aq)$ ions are colourless.

The student weighs 82.68 g of rhubarb leaves and extracts ethanedioic acid from the leaves.

The ethanedioic acid is added to dilute sulfuric acid to form a colourless solution which is made up to 250.0 cm^3 with distilled water.

The student heats 25.00 cm^3 of this solution to 70 °C and titrates this volume with 0.0500 mol dm^{-3} $Ce(SO_4)_2$ from the burette.

The student repeats the titration to obtain concordant (consistent) titres.

Titration results
The trial titre has been omitted.

	1	2	3
Final reading/cm^3	24.30	47.80	23.65
Initial reading/cm^3	1.05	24.30	0.50

(i) This titration is self-indicating and the student does not need to add an indicator.

What colour change would the student observe at the end point?

Colour change from ..... to ..... **[1]**

(ii) Calculate the percentage, by mass, of ethanedioic acid in the rhubarb leaves.

Give your answer to an **appropriate** number of significant figures.

[6]

(Total 10 marks)