Q1.

Some runners take tablets to help muscle recovery after long races.
These tablets contain magnesium oxide.

A student wants to find the percentage by mass of magnesium oxide in the tablets. Magnesium oxide reacts with hydrochloric acid to form magnesium chloride.

$$MgO + 2\ HCl \longrightarrow MgCl_2 + H_2O$$

In an experiment, the student adds excess hydrochloric acid to some tablets.
The student then does a titration using sodium hydroxide to find how much of the excess acid is left.

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

The student follows this method:

Step **1** Place a beaker on a balance and record the mass.

Step **2** Add 6 tablets to the beaker and record the mass.

Step **3** Add 25.0 cm^3 of 2.00 mol dm^{-3} hydrochloric acid to the beaker and stir until all the magnesium oxide has reacted.

Step **4** Make the mixture up to 250 cm^3 with distilled water in a volumetric flask.

Step **5** Transfer 25.0 cm^3 of this diluted mixture to a conical flask.

Step **6** Add 3 drops of a suitable indicator.

Step **7** Add 0.0900 mol dm^{-3} sodium hydroxide solution from a burette until the indicator changes colour.

Repeat Steps **5** to **7** until concordant results are obtained.

Results:

Mass of 6 tablets = 2.14 g Mean titre = 20.38 cm^3

(a) Each reading from the balance has an uncertainty of ±0.005 g

Calculate the percentage uncertainty in using the balance in this experiment.

Percentage uncertainty ______________________

(1)

(b) Calculate the amount, in moles, of hydrochloric acid that was added to the tablets in Step **3**.
Give your answer to an appropriate precision.

Amount of hydrochloric acid ____________________ mol

(1)

(c) Use your answer to part (b) and the information given to calculate the percentage by mass of magnesium oxide in the tablets.

Percentage by mass of MgO ____________________

(6)

(Total 8 marks)

Q2.

This question is about the volumes of gases involved in some reactions.

(a) Magnesium reacts with hydrochloric acid.

$$Mg(s) + 2\ HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

0.400 g of magnesium is added to 20.0 cm^3 of 1.50 mol dm^{-3} hydrochloric acid.

Identify the limiting reagent.

Justify your answer.

Calculate the volume, in m^3, of hydrogen produced at 101 kPa and 15 °C

The gas constant, R = 8.31 J K^{-1} mol^{-1}

Limiting Reagent ______________________________

Justification ______________________________

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Volume of hydrogen ______________ m^3

(7)

(b) Propane (C_3H_8) undergoes complete combustion in a plentiful supply of oxygen.

Give an equation for the complete combustion of propane.

Use this equation to calculate the minimum volume, in cm^3, of oxygen gas needed for the complete combustion of 50 cm^3 of propane gas.
Assume that the volumes of both gases are measured at the same temperature and pressure.

Equation for combustion

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Volume of oxygen gas ______________________ cm^3

(2)

(Total 9 marks)

Q3.

This question is about an experiment to determine the solubility of strontium hydroxide in water at 20 °C

Strontium hydroxide is slightly soluble in water. Strontium hydroxide solution reacts in a similar way to calcium hydroxide solution.

- Some solid strontium hydroxide is added to approximately 1 dm^3 of distilled water in a stoppered flask.
- The mixture is kept at 20 °C. Every day, the mixture is checked. If no solid is present in the flask, more solid strontium hydroxide is added.
- On the day when no more solid needs to be added, the flask is opened and the mixture is filtered into another flask and stoppered.
- A 25.0 cm^3 sample of the filtrate is transferred to a conical flask with a pipette and a few drops of indicator added.
- This sample is titrated with 0.100 mol dm^{-3} hydrochloric acid.
- The titration is repeated several times with further samples of the filtrate. The results are shown in the below table in part (e).

(a) Suggest why the solution is kept until no more solid needs to be added.

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(1)

(b) Suggest why it is important to remove the undissolved strontium hydroxide before the titration.

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(1)

(c) After the filtration, the solution is stored in a stoppered flask.

Suggest a reason for stoppering the flask.

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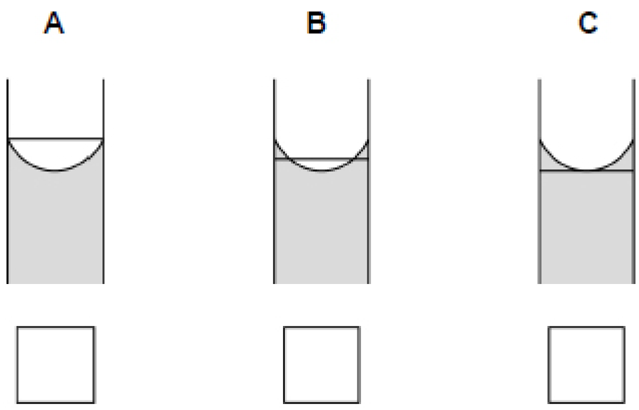
(1)

(d) The diagrams in the figure below show the part of a pipette with the graduation line.

Which diagram identifies the pipette that is correctly filled?

Tick (✓) **one** box.



(1)

(e) Solubility can be quoted as ‘g of solute per 100 cm^3 of solution’.

The table below shows the results of the titrations between strontium hydroxide and hydrochloric acid. These can be used to determine the solubility of strontium hydroxide.

Titration	**Rough**	**1**	**2**	**3**
Final burette reading / cm^3	34.40	38.00	41.05	37.00
Initial burette reading / cm^3	0.00	5.55	8.05	4.60
Titre / cm^3	34.40	32.45	33.00	32.40

Give the equation for the reaction between strontium hydroxide and hydrochloric acid.

Use the results in the above table to calculate the mean titre.

Use the mean titre to calculate the solubility of strontium hydroxide, in g per 100 cm^3 of solution, at 20 °C

Equation

____

Mean titre _______________ cm^3

Solubility of strontium hydroxide ____________________ g per 100 cm^3 solution

(6)

(Total 10 marks)

Q4.

This question is about an equilibrium.

$$2\ \mathbf{P}(aq) + \mathbf{Q}(aq) \rightleftharpoons \mathbf{R}(aq) + 3\ \mathbf{S}(aq)$$

A 25.0 cm^3 sample of a solution of **P** is added to a 20.0 cm^3 sample of a solution of **Q**. The mixture is allowed to reach equilibrium.

The amounts in the equilibrium mixture are

P = 0.0145 mol **Q** = 0.0275 mol **R** = 0.0115 mol **S** = 0.0345 mol

(a) Calculate the amount, in moles, of **P** before the reaction with **Q**.

Use your answer to calculate the concentration, in mol dm^{-3}, of **P** in the initial 25.0 cm^3 sample.

Amount of **P** ____________________ mol

Concentration ____________________ mol dm^{-3}

(2)

(b) Give the expression for the equilibrium constant, K_c

Calculate the value of K_c and deduce its units.

K_c

Value of K_c ____________________ Units ____________________

(4)

(c) Explain why the amount of **S** increases when water is added to the equilibrium mixture.

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(2)

(Total 8 marks)

Q5.

Compound **L** (M_r = 88.0) contains carbon, hydrogen and oxygen only.

A 6.56×10^{-4} mol sample of **L** burns completely in air to form 2.62×10^{-3} mol of water and 2.62×10^{-3} mol of carbon dioxide.

Deduce the formula of **L**.

Show your working.

Formula of **L** ___________________________

(Total 4 marks)

Q6.

This question is about the elements in Group 2.

(a) Describe the structure and bonding in magnesium.

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(2)

(b) State the trend in the atomic radius of the elements down Group 2 from Mg to Ba

Give a reason for this trend.

Trend ___

Reason ___

___

___

(2)

(c) Give an equation, including state symbols, for the reaction of magnesium with steam.

State **two** observations for this reaction.

Equation

___

Observation 1 ___

Observation 2 ___

(3)

(d) The sulfates of the elements in Group 2 from Mg to Ba have different solubilities.

State the formula of the least soluble of these sulfates.

Give a use for this sulfate.

Formula ______________________________

Use ______________________________

(2)

(e) A sample of strontium is made up of only three isotopes: ^{86}Sr, ^{87}Sr and ^{88}Sr
This sample contains 83.00% by mass of ^{88}Sr
This sample of strontium has A_r = 87.73

Calculate the percentage abundance of each of the other two isotopes in this sample.

% abundance ^{87}Sr = ______________

% abundance ^{86}Sr = ______________

(4)

(f) $Mg(OH)_2$ is used as an antacid to treat indigestion.
A student does an experiment to determine the percentage by mass of $Mg(OH)_2$ in an indigestion tablet.

40.0 cm^3 of 0.200 mol dm^{-3} HCl (an excess) is added to 0.200 g of a powdered tablet.
The mixture is swirled thoroughly.
All of the $Mg(OH)_2$ reacts with HCl as shown.

$$Mg(OH)_2 + 2\,HCl \rightarrow MgCl_2 + 2\,H_2O$$

The amount of HCl remaining after this reaction is determined by titration with 0.100 mol dm^{-3} NaOH

29.25 cm^3 of 0.100 mol dm^{-3} NaOH are needed.

Calculate the percentage by mass of $Mg(OH)_2$ in the indigestion tablet.

Percentage by mass ____________________

(6)

(Total 19 marks)

Q7.

A student uses this method to prepare a standard solution of sodium carbonate.

1. Weigh a clean, dry, empty container on a balance that reads to 2 decimal places.
2. Add about 2.5 g of solid sodium carbonate to the container.
3. Tip the solid into a beaker.
4. Add approximately 100 cm^3 of distilled water to the beaker and stir until all the solid has dissolved.
5. Pour the solution into a 250 cm^3 volumetric flask.
6. Add distilled water until the top of the meniscus is level with the graduation mark.

(a) Suggest **three** improvements to this method.

1 ____

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2 ____

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3 ____

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(3)

(b) A different student uses the correct method to prepare 250 cm^3 of sodium carbonate solution in a volumetric flask.
The uncertainty for the volumetric flask is ±0.20 cm^3

Calculate the percentage uncertainty in the volume of this sodium carbonate solution.

Percentage uncertainty ____________________

(1)

(Total 4 marks)

Q8.

M is a Group 2 metal that forms the nitrate $M(NO_3)_2$
0.320 g of **M**$(NO_3)_2$ is heated strongly and decomposes completely.

$$2\ \mathbf{M}(NO_3)_2(s) \rightarrow 2\ \mathbf{M}O\ (s) + 4\ NO_2\ (g) + O_2\ (g)$$

The mixture of gases formed has a volume of 225 cm^3 at 450 °C and 101 000 Pa

Determine the M_r of **M**$(NO_3)_2$

Identify **M**.

The gas constant, R = 8.31 J K^{-1} mol^{-1}

M_r of **M**$(NO_3)_2$ ____________________

Identity of **M** ____________________

(Total 5 marks)

Q9.

The concentration of dilute hydrochloric acid can be found by titration using a standard solution of barium hydroxide.

(a) Calculate the mass, in g, of solid barium hydroxide (M_r = 171.3) needed to prepare 250 cm^3 of 0.100 mol dm^{-3} barium hydroxide solution.

Mass ____________________ g

(1)

(b) The mass of barium hydroxide from part (a) is dissolved in a beaker containing 150 cm^3 of distilled water.

Describe how this solution is used to make 250 cm^3 of the 0.100 mol dm^{-3} barium hydroxide solution.

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(3)

(c) Before the first titration, the 25 cm^3 pipette is rinsed with a small volume of the 0.100 mol dm^{-3} barium hydroxide solution.

State why it is good practice to rinse the pipette in this way.

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(1)

(d) Hydrochloric acid is added to the burette using a funnel.

State why it is good practice to remove the funnel from the burette before the titration.

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(1)

(e) In a different experiment, 0.952 g of solid barium hydroxide is used to make 250 cm^3 of standard barium hydroxide solution.

25.0 cm^3 of this barium hydroxide solution reacts with exactly 24.50 cm^3 of hydrochloric acid.

Calculate the concentration of the hydrochloric acid.

Concentration ___ mol dm^{-3}

(3)

(f) The uncertainty in the 25.0 cm^3 of solution from the pipette is ±0.05 cm^3

The total uncertainty in the 24.50 cm^3 of solution from the burette is ±0.15 cm^3

Calculate the total percentage error in using the pipette and burette.

Percentage error ___

(1)

(Total 10 marks)

Q10.

A gas syringe that does not have any graduations is calibrated using a known mass of propanone (boiling point = 56.2 °C).

The sealed gas syringe contains 0.146 g of propanone (M_r = 58.0) at a temperature of 95 °C and a pressure of 103 kPa

(a) Calculate the volume, in cm^3, of propanone in the gas syringe.

The gas constant, R = 8.31 J K^{-1} mol^{-1}

Volume of propanone ____________________ cm^3

(4)

(b) The gas syringe is then cooled to 75 °C, without changing the pressure.

Calculate the decrease in volume.

(If you were unable to calculate the volume in part (a), you should use the volume 89 cm^3. This is not the correct answer.)

Decrease in volume ____________________ cm^3

(2)

(c) The total uncertainty in using the balance to measure the mass of propanone in part (a) is ±0.001 g

Calculate the uncertainty that this causes in the volume, in cm^3, of propanone calculated in part (a).

(If you were unable to calculate the volume in part (a), you should use the volume 89 cm^3. This is not the correct answer.)

Uncertainty ____________________ cm^3

(2)

(d) A 600 cm^3 sample of propanone is mixed with 2800 cm^3 of oxygen in a container at 60 °C and 100 kPa. The mixture is ignited.
When the reaction is complete, the remaining mixture of gases is cooled to 60 °C at 100 kPa

$$CH_3COCH_3(g) + 4\ O_2(g) \rightarrow 3\ CO_2(g) + 3\ H_2O(l)$$

Calculate the total volume of the remaining gas mixture.

Volume ____________________ cm^3

(2)

(Total 10 marks)

Q11.

This question is about acid–base titrations.

Citric acid reacts with sodium hydroxide.

$$C_6H_8O_7(aq) + 3\ NaOH(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3\ H_2O(l)$$

(a) A student makes a solution of citric acid by dissolving some solid citric acid in water.

Describe a method to add an accurately known mass of solid to a beaker to make a solution.

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(2)

(b) The student dissolves 0.834 g of citric acid in water and makes the solution up to 500 cm^3

Calculate the concentration, in mol dm^{-3}, of citric acid in this solution.

Concentration ________________ mol dm^{-3}

(3)

(c) The student uses this method to complete a titration.

- Rinse a burette with distilled water.
- Fill the burette with sodium hydroxide solution.
- Use a measuring cylinder to transfer 25 cm^3 of the citric acid solution into a conical flask.
- Add 5 cm^3 of indicator.
- Slowly add the sodium hydroxide solution from the burette into the conical flask.
- Add the sodium hydroxide solution dropwise near the end point until the indicator just changes colour.
- Repeat the titration to get concordant results.

The method used by the student includes three practical steps that will lead to an inaccurate final result.

For each of these three steps
- identify the mistake
- explain why it is a mistake
- suggest how the mistake can be overcome.

(6)

(d) The table below shows the student's burette readings after the mistakes in the practical procedure have been corrected.

	Rough	**Run 1**	**Run 2**	**Run 3**
Final reading / cm^3	23.65	22.95	46.05	26.30
Start reading / cm^3	0.00	0.00	22.95	3.40
Titre / cm^3	23.65			

Complete the table.

Use the data in the table above to calculate the mean titre.

Mean titre ___________ cm^3

(2)

(e) The total uncertainty in the use of the burette is ±0.15 cm^3

Calculate the percentage uncertainty in the use of the burette in **Run 1**.

Percentage uncertainty ________________

(1)

(Total 14 marks)

Q12.

This question is about gas volumes.

(a) TNT ($C_7H_5N_3O_6$) is an explosive because it can decompose very quickly and exothermically to form a large volume of gas. An equation for this decomposition is

$$2\ C_7H_5N_3O_6(s) \rightarrow 3\ N_2(g) + 5\ H_2(g) + 12\ CO(g) + 2\ C(s)$$

Calculate the volume of gas, in m^3, measured at 1250 °C and 101 000 Pa, produced by the decomposition of 1.00 kg of TNT (M_r = 227.0).

The gas constant, R = 8.31 J mol^{-1} K^{-1}

Volume of gas ____________________ m^3

(5)

(b) Alkenes have the general formula C_nH_{2n}

When alkenes undergo complete combustion, 1.0 mol of C_nH_{2n} reacts with $\frac{3n}{2}$ mol of oxygen.

Calculate the volume of oxygen needed for the complete combustion of 200 cm^3 of but-1-ene.

The volumes of all gases are measured at the same temperature and pressure.

Volume of oxygen _______________ cm^3

(1)

(c) Alkanes have the general formula C_nH_{2n+2}

Alkanes undergo complete combustion in a plentiful supply of oxygen.

$$C_nH_{2n+2} + x\,O_2 \rightarrow n\,CO_2 + (n+1)\,H_2O$$

Determine x in terms of n

x _______________

(1)

(Total 7 marks)

Q13.

This question is about the synthesis of propylamine ($CH_3CH_2CH_2NH_2$) by the reaction of 1-iodopropane ($CH_3CH_2CH_2I$) with an excess of ammonia.

$$CH_3CH_2CH_2I + 2\ NH_3 \rightarrow CH_3CH_2CH_2NH_2 + NH_4I$$

(a) Name and outline the mechanism for this reaction.

Name of mechanism ________________________________

Outline of mechanism

(5)

(b) 1-iodopropane is a liquid at room temperature.

Calculate the number of molecules in 5.0 cm^3 of 1-iodopropane (M_r = 169.9). Give your answer in standard form.

For 1-iodopropane, density = 1.75 g cm^{-3}

The Avogadro constant, $L = 6.022 \times 10^{23}$ mol^{-1}

Number of molecules ________________

(2)

(c) In an experiment, 10.3 g of 1-iodopropane (M_r = 169.9) are reacted with an excess of ammonia. 2.3 g of propylamine (M_r = 59.0) are produced.

Calculate the percentage yield in this experiment.

Percentage yield ________________

(2)

(Total 9 marks)

Q14.

This question is about hydrogen peroxide, H_2O_2

The half-equation for the oxidation of hydrogen peroxide is

$$H_2O_2 \longrightarrow O_2 + 2\,H^+ + 2e^-$$

Hair bleach solution contains hydrogen peroxide.

A sample of hair bleach solution is diluted with water.
The concentration of hydrogen peroxide in the diluted solution is 5.00% of that in the original solution.
A 25.0 cm^3 sample of the diluted hair bleach solution is acidified with dilute sulfuric acid.
This acidified sample is titrated with 0.0200 mol dm^{-3} potassium manganate(VII) solution.
The reaction is complete when 35.85 cm^3 of the potassium manganate(VII) solution are added.

(a) Give an ionic equation for the reaction between potassium manganate(VII) and acidified hydrogen peroxide.

Calculate the concentration, in mol dm^{-3}, of hydrogen peroxide in the original hair bleach solution.

(If you were unable to write an equation for the reaction you may assume that the mole ratio of potassium manganate(VII) to hydrogen peroxide is 3:4
This is **not** the correct mole ratio.)

Concentration ____________________ mol dm^{-3}

(5)

(b) State why an indicator is **not** added in this titration.

____

____

(1)

(c) Give the oxidation state of oxygen in hydrogen peroxide.

____

(1)

(d) Hydrogen peroxide decomposes to form water and oxygen.

Give an equation for this reaction.

Calculate the amount, in moles, of hydrogen peroxide that would be needed to produce 185 cm^3 of oxygen gas at 100 kPa and 298 K

The gas constant, $R = 8.31$ J K^{-1} mol^{-1}

Equation

____

Amount ______________________ mol

(5)

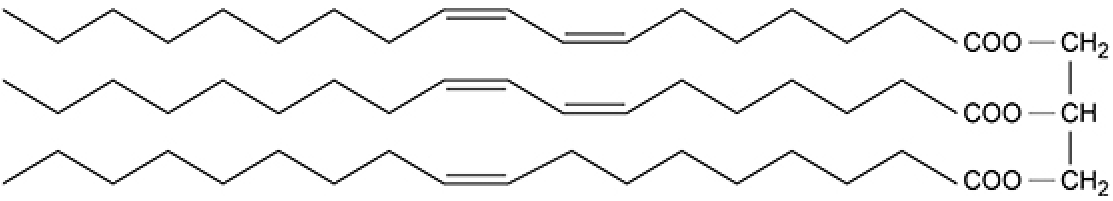
(Total 12 marks)

Q15.

This question is about olive oil.

A sample of olive oil is mainly the unsaturated fat **Y** mixed with a small amount of inert impurity.

The structure of **Y** in the olive oil is shown.
Y has the molecular formula $C_{57}H_{100}O_6$ (M_r = 880).



The amount of **Y** is found by measuring how much bromine water is decolourised by a sample of oil, using this method.

- Transfer a weighed sample of oil to a 250 cm^3 volumetric flask and make up to the mark with an inert organic solvent.
- Titrate 25.0 cm^3 samples of the olive oil solution with 0.025 mol dm^{-3} Br_2(aq).

(a) A suitable target titre for the titration is 30.0 cm^3 of 0.025 mol dm^{-3} Br_2(aq).

Justify why a much smaller target titre would **not** be appropriate.

Calculate the amount, in moles, of bromine in the target titre.

Justification ____

____

____

____

Amount of bromine ____________________ mol

(2)

(b) Calculate a suitable mass of olive oil to transfer to the volumetric flask using your answer to part (a) and the structure of **Y**.
Assume that the olive oil contains 85% of **Y** by mass.

(If you were unable to calculate the amount of bromine in the target titre, you should assume it is 6.25×10^{-4} mol. This is **not** the correct amount.)

Mass of olive oil _______________ g

(5)

The olive oil solution can be prepared using this method.

- Place a weighing bottle on a balance and record the mass, in g, to 2 decimal places.
- Add olive oil to the weighing bottle until a suitable mass has been added.
- Record the mass of the weighing bottle and olive oil.
- Pour the olive oil into a 250 cm^3 volumetric flask.
- Add organic solvent to the volumetric flask until it is made up to the mark.
- Place a stopper in the flask and invert the flask several times.

(c) Suggest an extra step to ensure that the mass of olive oil in the solution is recorded accurately.

Justify your suggestion.

Extra step ____

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Justification ____

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(2)

(d) State the reason for inverting the flask several times.

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(1)

(e) A sample of the olive oil was dissolved in methanol and placed in a mass spectrometer. The sample was ionised using electrospray ionisation. Each molecule gained a hydrogen ion (H^+) during ionisation.

The spectrum showed a peak for an ion with $\frac{m}{z}$ = 345 formed from an impurity in the olive oil.

The ion with $\frac{m}{z}$ = 345 was formed from a compound with the empirical formula $C_5H_{10}O$

Deduce the molecular formula of this compound.

Show your working.

Molecular formula __________________________________

(2)

(Total 12 marks)