Q1.

When heated, a sample of potassium chlorate(V) ($KClO_3$) produced 67.2 cm^3 of oxygen, measured at 298 K and 110 kPa

$$2\ KClO_3(s) \rightarrow 2\ KCl(s) + 3\ O_2(g)$$

What is the amount, in moles, of potassium chlorate(V) that has decomposed?

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

A 9.95×10^{-4} ○

B 1.99×10^{-3} ○

C 2.99×10^{-3} ○

D 4.48×10^{-3} ○

(Total 1 mark)

Q2.

130 cm^3 of oxygen and 40 cm^3 of nitrogen, each at 298 K and 100 kPa, were placed into an evacuated flask of volume 0.50 dm^3.

What is the pressure of the gas mixture in the flask at 298 K?

A 294 kPa ○

B 68.0 kPa ○

C 34.0 kPa ○

D 13.7 kPa ○

(Total 1 mark)

Q3.

In an experiment to identify a Group 2 metal (X), 0.102 g of X reacts with an excess of aqueous hydrochloric acid according to the following equation.

$$X + 2HCl \longrightarrow XCl_2 + H_2$$

The volume of hydrogen gas given off is 65 cm^3 at 99 kPa pressure and 303 K.
The gas constant is R = 8.31 J K^{-1} mol^{-1}.

Which is X?

A Barium ○

B Calcium ○

C Magnesium ⬭

D Strontium ⬭

(Total 1 mark)

Q4.

A sample of 2.18 g of oxygen gas has a volume of 1870 cm^3 at a pressure of 101 kPa.

What is the temperature of the gas?
The gas constant is $R = 8.31$ J K^{-1} mol^{-1}.

A 167 K ⬭

B 334 K ⬭

C 668 K ⬭

D 334 000 K ⬭

(Total 1 mark)

Q5.

Which of these samples of gas contains the largest number of molecules?
The gas constant $R = 8.31$ J K^{-1} mol^{-1}.

A 5.0×10^{-4} m^3 at 1.0×10^6 Pa and 300 K ⬭

B 4.0×10^{-3} m^3 at 2.0×10^5 Pa and 400 K ⬭

C 3.0×10^1 dm^3 at 3.0×10^4 Pa and 500 K ⬭

D 2.0×10^2 dm^3 at 4.0×10^3 Pa and 600 K ⬭

(Total 1 mark)

Q6.

Which one of the following samples of gas, when sealed into a vessel of volume 0.10 m^3, is at the highest pressure?

A 1.6 g of helium (He) at 100 K

B 1.6 g of methane (CH_4) at 100 K

C 1.6 g of oxygen (O_2) at 600 K

D 1.6 g of sulphur dioxide (SO_2) at 1200 K

(Total 1 mark)

Q7.

Which one of the following samples of gas occupies the largest volume?

A 1.0 g of ozone (O_3) at l00 kPa and 300 K

B 1.0 g of oxygen at 100 kPa and 300 K

C 1.0 g of water vapour at 250 kPa and 450 K

D 1.0 g of methane at 333 kPa and 500 K

(Total 1 mark)

Q8.

What is the volume occupied by 10.8 g of the freon CCl_2F_2 at 100 kPa and 273 K?

A 2.02 dm^3

B 2.05 dm^3

C 2.02 cm^3

D 2.05 cm^3

(Total 1 mark)

Q9.

Two sealed flasks with the same volume are left side by side.

Flask **A** contains 4.0×10^{-3} mol of methane.

Flask **B** contains 340 mg of a different gas.

Both gases are at the same temperature and pressure.

Which gas could be in Flask **B**?

A CH_2Cl_2 ☐

B HBr ☐

C Kr ☐

D PF_3 ☐

(Total 1 mark)

Q10.

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)

Q11.

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)

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 two experiments on gases.

(a) In the first experiment, liquid **Y** is injected into a sealed flask under vacuum. The liquid vaporises in the flask.
The table below shows data for this experiment.

Mass of **Y**	717 mg
Temperature	297 K
Volume of flask	482 cm^3
Pressure inside flask	51.0 kPa

Calculate the relative molecular mass of **Y**.

Show your working.

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

Relative molecular mass of **Y** ____________________

(5)

(b) In the second experiment, another flask is used for a combustion reaction.
Method

- Remove all the air from the flask.
- Add 0.0010 mol of 2,2,4-trimethylpentane (C_8H_{18}) to the flask.
- Add 0.0200 mol of oxygen to the flask.
- Spark the mixture to ensure complete combustion.
- Cool the mixture to the original temperature.

The equation is

$$C_8H_{18}(g) + 12\tfrac{1}{2}\ O_2(g) \rightarrow 8\ CO_2(g) + 9\ H_2O(l)$$

Calculate the amount, in moles, of gas in the flask after the reaction.

Amount of gas ______________________________ mol

(2)

(Total 7 marks)

Q14.

(a) A sample of ethanol vapour, C_2H_5OH (M_r = 46.0), was maintained at a pressure of 100 kPa and at a temperature of 366K.

(i) State the ideal gas equation.

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(ii) Use the ideal gas equation to calculate the volume, in cm^3, that 1.36 g of ethanol vapour would occupy under these conditions.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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(5)

(b) Magnesium nitride reacts with water to form magnesium hydroxide and ammonia.

(i) Balance the equation, given below, for the reaction between magnesium nitride and water.

$$Mg_3N_2 \quad + \qquad H_2O \quad \rightarrow \qquad Mg(OH)_2 \quad + \qquad NH_3$$

(ii) Calculate the number of moles, and hence the number of molecules, of NH_3 in 0.263 g of ammonia gas.
(The Avogadro constant L = 6.02 × 10^{23} mol^{-1})

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(4)

(c) (interleave) Sodium carbonate is manufactured in a two-stage process as shown by the equations below.

$$NaCl + NH_3 + CO_2 + H_2O \rightarrow NaHCO_3 + NH_4Cl$$

$$2NaHCO_3 \rightarrow Na_2CO_3 + H_2O + CO_2$$

Calculate the maximum mass of sodium carbonate which could be obtained from 800 g of sodium chloride.

____

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____

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(4)

(Total 13 marks)

Q15.

This question is about iron and its ions.

(d) Iron reacts with dilute hydrochloric acid to form iron(II) chloride and hydrogen.

$$Fe(s) + 2\ HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$$

A 0.998 g sample of pure iron is added to 30.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid.

One of these reagents is in excess and the other reagent limits the amount of hydrogen produced in the reaction.

Calculate the maximum volume, in m^3, of hydrogen gas produced at 30 ^oC and 100 kPa.

Give your answer to 3 significant figures.

In your answer you should identify the limiting reagent in the reaction.

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

Volume of hydrogen _______________ m^3

(6)

Q16.

This question is about a toxic chloroalkane, **X**, that has a boiling point of 40 °C.

A student carried out an experiment to determine the M_r of **X** by injecting a sample of **X** from a hypodermic syringe into a gas syringe in an oven at 97 °C and 100 kPa. The student's results are set out in **Table 1** and **Table 2**.

Table 1

Mass of hypodermic syringe filled with **X** before injection / g	10.340
Mass of hypodermic syringe with left over **X** after injection / g	10.070
Mass of **X** injected / g	

Table 2

Volume reading on gas syringe before injection of **X** / cm^3	0.0
Volume of **X** in gas syringe after injection of **X** / cm^3	105.0
Volume of **X** / cm^3	

(a) Complete **Table 1** and **Table 2** by calculating the mass and volume of **X**.

(1)

(b) **X** is known to be one of the following chloroalkanes: CCl_4 $CHCl_3$ CH_2Cl_2 or CH_3Cl

Justify this statement by calculating a value for the M_r of **X** and use your answer to suggest the most likely identity of **X** from this list.

Give your answer for the M_r of **X** to an appropriate precision.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

M_r of **X**

M_r of **X** = ________________________

Identity of **X**
(If you have been unable to calculate a value for M_r, you may assume that the M_r value is 52. This is **not** the correct value).

Identity of **X** = ___________________

(5)

(c) Suggest a reason, other than apparatus inaccuracy, why the M_r value determined from the experimental results differs from the actual M_r. Explain your answer.

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(2)

(d) Suggest, with a reason, an appropriate safety precaution that the student should take when using the toxic chloroalkane, **X**, in the experiment.

Safety precaution ____

____

Reason ____

____

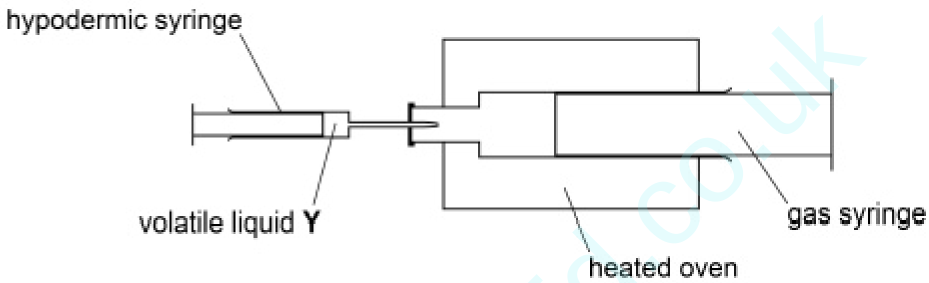
(2)

(Total 10 marks)

Q17.

A student determined the relative molecular mass, M_r, of an unknown volatile liquid Y in an experiment as shown in the diagram.
The student used a hypodermic syringe to inject a sample of liquid Y into a gas syringe in an oven.
At the temperature of the oven, liquid Y vaporised.

The student's results are shown in the table.



Mass of hypodermic syringe and liquid Y before injection	10.91 g
Mass of hypodermic syringe and liquid Y after injection	10.70 g
Oven temperature	98.1 °C
Atmospheric pressure	102 kPa
Increase in volume in gas syringe after injection of Y	85.0 cm^3

(a) Define the term relative molecular mass (M_r).

Use the experimental results in the table to determine the relative molecular mass of Y.
The gas constant R = 8.31 J K^{-1} mol^{-1}

(5)

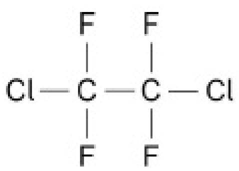
(b) Some of the liquid injected did not evaporate because it dripped into the gas syringe nozzle outside the oven.

Explain how this would affect the value of the M_r of Y calculated from the experimental results.

(2)
(Total 7 marks)

Q18.

The compound 1,2-dichlorotetrafluoroethane is a CFC that was previously used in refrigerators as a coolant.



(c) Butane can be used as a replacement for CFCs in refrigerators.

During its use, the butane is repeatedly converted from liquid to gas and then back to liquid. Liquid butane expands as it turns into a gas.

- Calculate the volume, in cm^3, of 38.8 g of butane gas at 272 K and 101 kPa (the gas constant R = 8.31 J K^{-1} mol^{-1}) (M_r of butane = 58.0)
- Calculate the volume, in cm^3, of 38.8 g of liquid butane. (density of liquid butane = 0.60 g cm^{-3})
- Use your answers to calculate the factor by which butane expands in volume

when it changes from a liquid to a gas.

Show your working.

Volume of butane gas ____ cm^3

Volume of liquid butane ____ cm^3

Expansion factor ____

(6)

(Total 9 marks)

Q19.

(A-LEVEL) Sulfur dioxide reacts with oxygen to form sulfur trioxide.

$$2\ SO_2(g) + O_2(g) \rightleftharpoons 2\ SO_3(g) \qquad \Delta H = -196\ \text{kJ mol}^{-1}$$

(a) Give an expression for the equilibrium constant (K_c) for this reaction.

K_c

(1)

(b) A mixture of sulfur dioxide and oxygen is allowed to reach equilibrium in a container of volume 1800 cm^3 at temperature *T*.

At equilibrium, the mixture contains 0.176 mol of sulfur dioxide and 0.461 mol of sulfur trioxide.

At temperature *T* the equilibrium constant, K_c = 15.0 $mol^{-1}\ dm^3$

Calculate the amount, in moles, of oxygen at equilibrium.

Amount of oxygen _______________ mol

(3)

(c) At a different temperature, a mixture contains
0.025 mol of sulfur dioxide
0.049 mol of oxygen
0.034 mol of sulfur trioxide.

The total pressure of the mixture in a 3500 cm^3 reaction vessel is 255 kPa

Use the data to calculate the temperature, in °C, of the mixture.

The ideal gas constant, R = 8.31 J K^{-1} mol^{-1}Temperature ____________________ °C

(5)
(Total 9 marks)

Q20.

A sample of pure $Mg(NO_3)_2$ was decomposed by heating as shown in the equation below.

$$2Mg(NO_3)_2(s) \longrightarrow 2MgO(s) + 4NO_2(g) + O_2(g)$$

(a) A 3.74×10^{-2} g sample of $Mg(NO_3)_2$ was completely decomposed by heating.

Calculate the total volume, in cm^3, of gas produced at 60.0 °C and 100 kPa.
Give your answer to the appropriate number of significant figures.
The gas constant $R = 8.31$ J K^{-1} mol^{-1}.

Total volume of gas = ___________ cm^3

(5)

(b) The mass of MgO obtained in this experiment is slightly less than that expected from the mass of $Mg(NO_3)_2$ used.
Suggest **one** practical reason for this.

___

___

___

(1)
(Total 6 marks)

Q21.

(OTHER PARTS OF Q TAKEN OUT) A student does an experiment to determine the percentage of copper in an alloy.

The student

- reacts 985 mg of the alloy with concentrated nitric acid to form a solution (all of the copper in the alloy reacts to form aqueous copper(II) ions)
- pours the solution into a volumetric flask and makes the volume up to 250 cm^3 with distilled water
- shakes the flask thoroughly
- transfers 25.0 cm^3 of the solution into a conical flask and adds an excess of potassium iodide

- uses exactly 9.00 cm^3 of 0.0800 mol dm^{-3} sodium thiosulfate ($Na_2S_2O_3$) solution to react with all the iodine produced.

The equations for the reactions are

$$2\ Cu^{2+} + 4\ I^- \rightarrow 2\ CuI + I_2$$

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

(f) Iodine vaporises easily.

Calculate the volume, in cm^3, that 5.00 g of iodine vapour occupies at 185 °C and 100 kPa

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

Give your answer to 3 significant figures.

Volume ________________________________ cm^3

(4)

(Total 16 marks)

Q22.

Phosphoric(V) acid (H_3PO_4) is an important chemical. It can be made by two methods. The first method is a two-step process.

(a) In the first step of the first method, phosphorus is burned in air at 500 ºC to produce gaseous phosphorus(V) oxide.

$$P_4(s) \quad + \quad 5O_2(g) \quad \longrightarrow \quad P_4O_{10}(g)$$

220 g of phosphorus were reacted with an excess of air.

Calculate the volume, in m^3, of gaseous phosphorus(V) oxide produced at a pressure of 101 kPa and a temperature of 500 ºC.
The gas constant R = 8.31 J K^{-1} mol^{-1}
Give your answer to 3 significant figures.

____

____

(4)

Q23.

(b) If a car is involved in a serious collision, the sodium azide decomposes to form sodium and nitrogen as shown in the equation.

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

The nitrogen produced then inflates the airbag to a volume of 7.50×10^{-2} m^3 at a pressure of 150 kPa and temperature of 35 °C.

Calculate the minimum mass of sodium azide that must decompose.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

(6)

Q24.

Ammonia is used to make nitric acid (HNO_3) by the Ostwald Process.
Three reactions occur in this process.

Reaction **1** $4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$

Reaction **2** $2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

Reaction **3** $3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq) + NO(g)$

(a) In one production run, the gases formed in Reaction **1** occupied a total volume of 4.31 m^3 at 25 °C and 100 kPa.

Calculate the amount, in moles, of NO produced.
Give your answer to 3 significant figures.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

(4)

(b) In another production run, 3.00 kg of ammonia gas were used in Reaction **1** and all of the NO gas produced was used to make NO_2 gas in Reaction **2**.

(i) Calculate the amount, in moles, of ammonia in 3.00 kg.

(2)

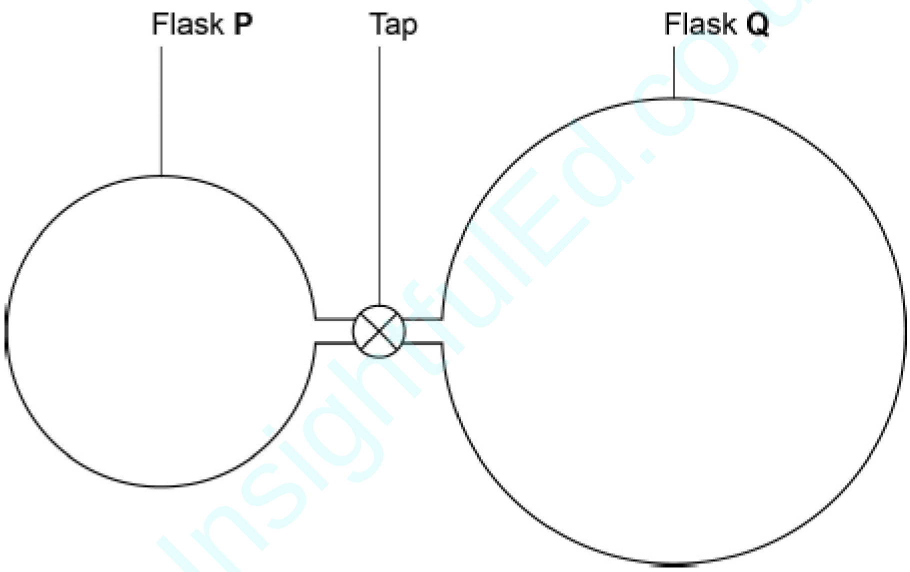
(ii) Calculate the mass of NO_2 formed from 3.00 kg of ammonia in Reaction **2** assuming an 80.0% yield.
Give your answer in kilograms.
(If you have been unable to calculate an answer for part (b)(i), you may assume a value of 163 mol. This is **not** the correct answer.)

(3)

Q25.

The diagram represents two glass flasks, **P** and **Q**, connected via a tap.

Flask **Q** (volume = 1.00×10^3 cm^3) is filled with ammonia (NH_3) at 102 kPa and 300 K. The tap is closed and there is a vacuum in flask **P**.
(Gas constant R = 8.31 J K^{-1} mol^{-1})



(a) Calculate the mass of ammonia in flask **Q**.
Give your answer to the appropriate number of significant figures.

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(3)

(b) When the tap is opened, ammonia passes into flask **P**. The temperature decreases by 5 °C. The final pressure in both flasks is 75.0 kPa.
Calculate the volume, in cm^3, of flask **P**.

____

(3)
(Total 6 marks)

Q26.

(a) Sodium hydrogencarbonate ($NaHCO_3$) can also be used to neutralise ethanoic acid spillages. The equation for this reaction is shown below.

$$CH_3COOH + NaHCO_3 \longrightarrow CH_3COONa + H_2O + CO_2$$

State the ideal gas equation.

(1)

(b) There are several methods by which ethanoic acid is synthesised on an industrial scale. One method is the oxidation of butane in the presence of metal ion catalysts. Balance the equation given below which summarises this reaction.

..........C_4H_{10} + ...O_2 $\longrightarrow$ ....CH_3COOH + ...H_2O

(1)

(c) A second method by which ethanoic acid is synthesised involves the oxidative fermentation of ethanol in the presence of bacteria. The equation representing this reaction is given below.

$$C_2H_5OH + O_2 \longrightarrow CH_3COOH + H_2O$$

In a small scale experiment using this second method it was found that 23.0 g of ethanol produced only 4.54 g of ethanoic acid. Calculate the percentage yield for this experiment.

(2)
(Total 4 marks)

Q27.

An unknown metal carbonate reacts with hydrochloric acid according to the following equation.

$$M_2CO_3(aq) + 2HCl(aq) \rightarrow 2MCl(aq) + CO_2(g) + H_2O(l)$$

A 3.44 g sample of M_2CO_3 was dissolved in distilled water to make 250 cm^3 of solution. A 25.0 cm^3 portion of this solution required 33.2 cm^3 of 0.150 mol dm^{-3} hydrochloric acid for complete reaction.

Qa) omitted

(b) In another experiment, 0.658 mol of CO_2 was produced. This gas occupied a volume of 0.0220 m^3 at a pressure of 100 kPa.
Calculate the temperature of this CO_2 and state the units.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

(3)

(c) Suggest **one** possible danger when a metal carbonate is reacted with an acid in a sealed flask.

(1)

Q28.

Two reactions occurred when the impure quicklime was added to the acid. Calcium oxide reacted according to this equation

$$CaO(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l)$$

Some carbon dioxide was evolved by the reaction of any remaining calcium carbonate that had not decomposed in the kiln.

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

The carbon dioxide was collected and its volume was found to be 18.3 dm^3 at a temperature of 25 ºC and pressure of 100 kPa. The gas constant R = 8.31 J K^{-1} mol^{-1}

(a) Calculate the amount, in moles, of carbon dioxide that was given off when the impure quicklime reacted with the hydrochloric acid. Show your working.

(2)

(b) Calculate the amount, in moles, of hydrochloric acid used up by the reaction with calcium carbonate. Show your working.

(1)

(c) Use your Periodic Table to calculate the relative formula mass of $CaCO_3$
Give your answer to one decimal place.

(1)

(d) Use your answers to part **(a)** and part **(c)** to calculate the mass of calcium carbonate in the sample of quicklime.

(1)
(Total 5 marks)

(c) A gas cylinder, of volume 5.00×10^{-3} m^3, contains 325 g of argon gas.

(i) Give the ideal gas equation.

(ii) Use the ideal gas equation to calculate the pressure of the argon gas in the cylinder at a temperature of 298 K.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

(4)
(Total 12 marks)

Q30.

Potassium nitrate, KNO_3, decomposes on strong heating, forming oxygen and solid **Y** as the only products.

(a) A 1.00 g sample of KNO_3 (M_r = 101.1) was heated strongly until fully decomposed into **Y**.

(i) Calculate the number of moles of KNO_3 in the 1.00 g sample.

___

___

(ii) At 298 K and 100 kPa, the oxygen gas produced in this decomposition occupied a volume of 1.22×10^{-4} m^3.

State the ideal gas equation and use it to calculate the number of moles of oxygen produced in this decomposition.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation ___

Moles of oxygen ___

___

___

___

___

(5)

Q31.

Compound **A** is an oxide of sulphur. At 415 K, a gaseous sample of **A**, of mass 0.304 g, occupied a volume of 127 cm^3 at a pressure of 103 kPa.

State the ideal gas equation and use it to calculate the number of moles of **A** in the sample, and hence calculate the relative molecular mass of **A**.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

Ideal gas equation ___

Calculation ___

___

___

___

___

(Total 5 marks)

Q32.

(a) The mass of one mole of $_1H$ atoms is 1.0078 g and that of one $_1H$ atom is 1.6734×10^{-24} g.
Use these data to calculate a value for the Avogadro constant accurate to five significant figures. Show your working.

(2)

(b) How does the number of atoms in one mole of argon compare with the number of molecules in one mole of ammonia?

(1)

(c) A sample of ammonia gas occupied a volume of 0.0352 m^3 at 298 K and 98.0 kPa. Calculate the number of moles of ammonia in the sample.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

(3)

Q33.

Nitroglycerine, $C_3H_5N_3O_9$, is an explosive which, on detonation, decomposes rapidly to form a large number of gaseous molecules. The equation for this decomposition is given below.

$$4C_3H_5N_3O_9(l) \rightarrow 12CO_2(g) + 10H_2O(g) + 6N_2(g) + O_2(g)$$

(a) A sample of nitroglycerine was detonated and produced 0.350 g of oxygen gas.

(i) State what is meant by the term *one mole* of molecules.

(ii) (a-level) Calculate the number of moles of oxygen gas produced in this reaction, and hence deduce the total number of moles of gas formed.

Moles of oxygen gas ______

Total moles of gas ______

(iii) Calculate the number of moles, and the mass, of nitroglycerine detonated.

Moles of nitroglycerine ____

____

Mass of nitroglycerine ____

____

____

(7)

(b) A second sample of nitroglycerine was placed in a strong sealed container and detonated. The volume of this container was 1.00×10^{-3} m^3. The resulting decomposition produced a total of 0.873 mol of gaseous products at a temperature of 1100 K.

State the ideal gas equation and use it to calculate the pressure in the container after detonation.

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

Ideal gas equation ____

Pressure ____

____

____

____

(4)

(Total 11 marks)

Mark schemes

Q1.

B

[1]

Q2.

C

[1]

Q3.

B

[1]

Q4.

B

[1]

Q5.

B

[1]

Q6.

A

[1]

Q7.

C

[1]

Q8.

A

[1]

Q9.

A

[1]

Q10.

M1 $V = 225\times10^{-6}\ m^3$; $T = 723$ K

***M1** converts units of V and T*

M2

$n = \frac{pV}{RT} = \frac{101\,000 \times 225 \times 10^{-6}}{8.31 \times 723}$ = 3.78 × 10^{-3} mol

__M2__ calculates the amount, in moles, of gas produced

M3

n = M2 × $\frac{2}{5}$ = 1.51 × 10^{-3} mol

__M3__ calculates the amount, in moles, of $M(NO_3)_2$

n = (M2 × $\frac{2}{5}$)

M4

$Mr = \frac{\text{mass}}{\text{mol}} = \frac{0.320}{(\text{M3})}$ = 211.9

__M4__ calculation of Mr

(allow 211.5 to 212)

M5

Ar (*M*) = 211.9 - 124.0 = 87.9, so

M is **Sr**

__M5__ determination of Metal, M using M4

Consequential to M_r value on answer line: must be a Group 2 metal

[5]

Q11.

(a) M1 n(propanone) = $\frac{0.146}{58}$ (= 2.52 × 10^{-3})

M2 Conversion of T and P (T = 368K and P = 103000Pa)

M3 V = $\frac{nRT}{P}$ rearranged for V as subject (in algebraic or numbers)

$V = \frac{\text{M1} \times 8.31 \times 368}{103000}$ scores M2 and M3

M4 their evaluated M3 × 1 × 10^6 = 75 cm^3

Allow 74-75

4

(b) M1 V = $\frac{348}{368}$ × M4 = 71 cm^3

Marked with (a)

Using alternate answer

M1 V = $\frac{348}{368}$ × 89 = 84 cm^3

M2 Decrease = M4 - M1 = 4 cm^3

M2 89 - 84 = 5 cm^3

Allow answer for M1 calculated as 70.8 cm^3 after substitution *of values into pV = nRT. Could then lead to a difference of 18.2 cm³ if compared to the alternate value for M4 of 89 cm³*

2

(c) M1 % uncertainty = $\frac{0.001}{0.146}$ × 100 = 0.685%

Marked with (a)

M2 Vol uncertainty = $\frac{M1}{100}$ × M4 = 0.5 cm^3

Allow 0.6 cm^3 if 89 cm^3 used

2

(d) M1 Vol CO_2 formed = 3 × 600 = 1800 cm^3

If PV = nRT method used

M1 $n(CO_2)$ = 0.0651

M2 Total Vol left = 1800 + 400 = 2200 cm^3

2

[10]

Q12.

(a) **M1** amount of TNT = $\frac{1000}{227.0}$ (= 4.41 mol)

1

M2 amount of gases formed = 10 × **M1** (= 44.1 mol)

1

M3 **V** = $\frac{nRT}{P}$

1

M4 **V** = converting T to 1523 (K) (or 273 + 1250)

1

M5 **V** = $\frac{M2 \times 8.31 \times 1523}{101000}$ = 5.52 (m^3) range 5.5(1) tp 5.53 (m^3)

1

Final answer should be at least 2sf

Correct final answer scores 5 marks

*Allow ECF from **M1** to **M2**, **M2** to **M5**, **M4** to **M5** and **M3** to **M5***

*0.552 (m^3) for using 4.41 mol in **M5** scores 4 marks (loses **M2**)*

*4.54 (m^3) for using 1250 K scores 4 marks (loses **M4**)*

*3.54 (m^3) for using (1250 − 273) K scores 4 marks (loses **M4**)*

*0.18 (m^3) for inverted expression scores 4 marks (loses **M3** or **M5**)*

***M3** can score from a substituted expression*

(b) 1200 (cm^3)

200 × $\frac{3n}{2}$ where n = 4 200 × $\frac{12}{2}$

1

(c) $\frac{3n+1}{2}$

1.5n + 0.5

allow other correct expressions (e.g. n + $\frac{(n+1)}{2}$ *)*

1

[7]

Q13.

(a) ***METHOD 1***

Stage 1

M1 $n = \frac{PV}{RT}$ 1

M2 converting P to 51.0 x 10^3, V to 482 x 10^{-6} 1

M3 $\frac{51.0 \times 10^3 \ \times \ 482 \times 10^{-6}}{8.31 \times 297}$ $(= 0.00996)$ 1

Stage 2

M4 converting mass to 0.717 1

M5 $M_r \left(= \frac{mass}{moles}\right) = \frac{\mathbf{M4}}{\mathbf{M3}}$ = 72.0 (at least 2 sf) 1

METHOD 2

M1 $n = \frac{PV}{RT}$

M2 $M_r = \frac{mRT}{PV}$

M3 converting P to 51.0 x 10^3, V to 482 x 10^{-6}

M4 converting mass to 0.717

M5 $M_r = \left(\frac{0.717 \times 8.31 \times 297}{51.0 \times 10^3 \ \times \ 482 \times 10^{-6}}\right)$ = 72.0 (at least 2 sf)

Both methods:

72.0 can be achieved with incorrect working and may not score because individual steps need to be assessed as correct

72.0 with no working scores no marks

If expression not written out, ***M1*** *could score from a substituted correct expression later on (even if any unit conversions are incorrect)*

METHOD 1

- *ECF from **M2** to **M3***
- *ECF from **M3** to **M4***
- *ECF from **M4** to **M5***
- *Ignore units for **M3***

METHOD 2

- *ECF from **M3** to **M4***
- *ECF from **M2** to **M4***
- *ECF from **M4** to **M5***

(b) **M1** amount of CO_2 formed in flask = 0.008 mol

*Allow ECF from **M1** to **M2***

1

M2 amount of gas in flask

= 0.0075 (O_2) + 0.0080 (**M1**) = 0.0155 mol

1

[7]

Q14.

(a) (i) pV = nRT **(1)**

(ii) Moles ethanol = n = 1.36/46 (=0.0296 mol) **(1)**

$V = nRT/p = \frac{0.0296 \times 8.31 \times 366}{100000}$ **(1)**

if V = p/nRT lose M3 and M4

= 8.996×10^{-4} (m^3) **(1)**

= 899 (900) cm^3 **(1)** *range = 895 – 905*

*If final answer = 0.899 award (2 + M1); if = 0.899 dm^3 **or** if = 912 award (3 + M1)*

***Note:** If 1.36 **or** 46 or 46/1.36 used as number of moles (**n**) then M2 and M4 not available*

***Note:** If pressure = 100 then, unless answer = 0.899 **dm^3**, deduct M3 and mark consequentially*

5

(b) (i) Mg_3N_2 + **6**H_2O → **3**$Mg(OH)_2$ + **2**NH_3 **(1)**

(ii) Moles NH_3 = $\frac{0.263}{17}$ (=0.0155 mol) **(1)**

Number of molecules of NH_3 = $0.0155 \times 6.02 \times 10^{23}$ **(1)**

[mark conseq] = 9.31×10^{21} **(1)**

[range 9.2×10^{21} to 9.4×10^{21}]

*Conseq (**min** 2 sig fig)*

4

(c) Moles NaCl = 800/58.5 (= 13.68) **(1)**

Moles of $NaHCO_3$ = 13.68 **(1)**

Moles of Na2CO_3 = 13.68/2 = 6.84 **(1)**

Mass of Na_2CO_3 = 6.84 × 106 = 725 g **(1)** **[**range = 724 – 727]

[1450 g (range 1448 – 1454) is worth 3 marks]

Accept valid calculation method, e.g. reacting masses or calculations via the mass of sodium present. Also, candidates may deduce a direct 2:1 ratio for NaCl:Na_2CO_3

4

[13]

Q15.

(d) M1 Amount of Fe = 0.998 ÷ 55.8 = 0.0179 mol 1

M2 Amount of HCl = 0.0300 mol 1

M3 HCl is the limiting reagent 1

M4 Amount of H_2 produced = 0.0150 mol

M4 = M2÷2 1

M5 T = 303 K P = 100 000 Pa 1

M6 $V \left(= \frac{0.0150 \times 8.31 \times 303}{100\ 000}\right) = 3.78 \times 10^{-4}$ (m^3)

M6 $V \left(= \frac{M4 \times 8.31 \times 303}{100\ 000}\right)$ (m^3)

1
1

Q16.

(a) Mass of **X** = 0.270

Volume of **X** = 105.0

Both must be correct 1

(b) pV = nRT

$$\frac{100\ 000 \times 105/1000000}{8.31 \times 370} = n$$ 1

n = 3.41 × 10^{-3} 1

$M_r = {}^{mass}/_{mol}$ or ${}^{0.270}/_{3.41 \times 10^{-3}}$ 1

$M_r = 79.1$ 1

Identity of **X** = CH_2Cl_2

If M_r = 52 used, allow CH_3Cl 1

(c) **M1** The volume of the gas in the syringe (V) is greater than the true volume (because some air leaked into the syringe)

If the M_r value of 52 is used and CH_3Cl is identified in 01.2: 1

M2 M_r = m/n = m × RT/PV so if V is too large, M_r is too small

OR

M1 The temperature measured (T) is less than the temperature of the gas in the syringe (because the syringe heated faster than the oven and the oven temperature was not constant)

M2 M_r = m/n = m × RT/PV so if T is too small, M_r is too small

OR

M1 The measured mass of liquid transferred to the syringe (m) is less than the actual mass transferred

M2 M_r = m/n = m × RT/PV so if m is too small, M_r is too small

***M1** The volume of the gas in the syringe (V) is less than the true volume (because not all the liquid vaporised in the syringe)*

***M2** M_r = m/n = m × RT/PV so if V is too small, M_r is too large*

OR

***M1** The temperature measured (T) is greater than the temperature of the gas in the syringe (because the syringe heated more slowly than the thermometer and the oven temperature was not constant)*

***M2** M_r = m/n = m × RT/PV so if T is too large, M_r is too large*

OR

***M1** The measured mass of liquid transferred to the syringe (m) is greater than the actual mass transferred*

***M2** M_r = m/n = m × RT/PV so if m is too large, M_r is too large* 1

(d) Carry out in a fume cupboard

Do not allow safety glasses / labcoat 1

To avoid toxic vapour 1

[10]

Q17.

(a) The sum of $\frac{\text{(weighted) average masses of atoms in formula}}{\text{1/12 mass of an atom of } ^{12}\text{C}}$

$\frac{\text{Average mass of one molecule}}{\text{1/12 mass of an atom of } ^{12}\text{C}}$ 1

Method 1 | **Method 2**

Mass of Y = 0.21g | Mass of Y = 0.21g

If incorrect lose M5 also, unless AE 1

$M_r = \frac{mRT}{pV}$ | $n = \frac{pV}{RT}$ and $M_r = \frac{m}{n}$

Can be implied in calculations 1

$M_r = \frac{0.21 \times 8.31 \times 371.1}{102000 \times 85x10^{-6}}$ | $n = \frac{102000 \times 85x10^{-6}}{8.31 \times 371.1}$ (= 2.81 × 10^{-3})

M4 – awarded for all 3 unit conversions 1

M_r = 74.7 | M_r = 74.7

Allow 75 1

(b) Lower volume recorded

Allow

(Evaporated) mass of gas is less than the recorded mass of liquid / 0.21g (or converse) 1

M_r would be greater (than the real M_r)

Ignore other references to mass 1

[7]

Q18.

(c) Volume as a gas:

*Answers to **M4**, **M5** and **M6** should be 2sf or more*

M1-M4 *15000 (cm^3) (14971) scores **M1-M4***

M1 moles butane = $\frac{38.8}{58.0}$ (= 0.669)

__M1__ may score from a value or expression within __M3__

1

M2 $V = \frac{nRT}{P}$

__M2__ could score from an attempt at __M3__ that shows attempts at values for n, R, T and P in suitable places

1

M3 $V = \frac{0.669 \times 8.31 \times 272}{101000}$

1

M4 (= 0.0150 m^3) = 15000 (cm^3) (14971)

__M4__ ignore additional answers following this in other units (if incorrect it will be penalised in __M6__)

Allow ECF in __M3__ and __M4__ based on incorrect moles of butane from __M1__; allow ECF in __M4__ based on incorrect units in __M3__

Allow ECF in __M3__ and __M4__ based on inverted expression for volume = $V = \frac{P}{nRT}$*; for other incorrect expressions, allow a maximum of one mark for __M3__ or __M4__ for correct unit conversion for P to Pa in __M3__ or volume to cm^3 in __M4__*

1

Volume as a liquid:

M5 $V = \frac{38.8}{0.60}$ = 65 or 64.7 or 64.666… (cm^3)

__M5__ ignore additional answers following this in other units (if incorrect it will be penalised in __M6__)

64.6 (cm^3) is outside range and does not score __M5__

64.6 (cm^3) (i.e. 66.6 dot scores __M5__)

1

Expansion factor

M6 $(\frac{M4}{M5}) = (\frac{15000}{64.7}) = 232$ (allow 230 – 232)

1

__M6__ allow ECF based on values for __M4__ and __M5__

[9]

Q19.

(a)

$$K_c = \frac{[SO_3]^2}{[SO_2]^2[O_2]}$$

1

(b) M1: dividing by volume for SO_2 and SO_3 / calculation of concentrations of SO_2 and SO_3

$$15.0 = \frac{\left(\frac{0.461}{1.80}\right)^2}{\left(\frac{0.176}{1.80}\right)^2 [O_2]}$$

15.0 =

Or $[SO_2] = 0.0978$ mol dm^{-3} and $[SO_3] = 0.256$ mol dm^{-3}

1

M2: correct substitution into rearranged expression

$$[O_2] = \frac{\left(\frac{0.461}{1.80}\right)^2}{\left(\frac{0.176}{1.80}\right)^2 (15.0)}$$

or

$$[O_2] = \frac{(0.256)^2}{(0.0978)^2(15.0)}$$

($[O_2] = 0.457$ mol dm^{-3})

1

M3 amount of oxygen = $[O_2] \times 1.80 = 0.823$ mol

At least 2sf

1

(c) (pV = nRT)

T = pV ÷ nR

M1: rearranged expression for ideal gas equation

1

n = 0.025 + 0.049 + 0.034

n = 0.108

M2: total number of moles

1

Conversions: pressure = 255000 Pa ; volume = 0.0035 m^3

M3: unit conversions

1

$$T = \frac{255000 \times 0.0035}{8.31 \times 0.108}$$

1

M4: temperature in K

T = 994.5 K

T = 721 °C

M5: temperature in °C (allow 720 – 722)

M5 = M4 – 273

1

[9]

Q20.

(a) Stage 1

M_r for $Mg(NO_3)_2$ = 148.3

Moles of $Mg(NO_3)_2$ = $\frac{3.74 \times 10^{-2}}{148.3}$ = 2.522×10^{-4} mol

Extended response calculation

1

Stage 2

Total moles of gas produced = 5/2 × moles of $Mg(NO_3)_2$

= 5/2 × 2.522×10^{-4} = 6.305×10^{-4}

If ratio in stage 2 is incorrect, maximum marks for stage 3 is 2

1

Stage 3

$PV = nRT$ so volume of gas $V = nRT / P$

1

$V = \frac{nRT}{P} = \frac{6.305 \times 10^{-4} \times 8.31 \times 333}{1.00 \times 10^{5}}$ = 1.745×10^{-5} m^3

1

$V = 1.745 \times 10^{-5} \times 1 \times 10^{6} = 17.45$ cm^3 = 17.5 (cm^3)

Answer must be to 3 significant figures (answer could be 17.4 cm^3 dependent on intermediate values)

1

(b) Some of the solid is lost in weighing product / solid is blown away with the gas

1

[6]

Q21.

(f) **M1**: n = (5.00/253.8) = 0.0197 mol

Allow 254

*If 126.9 or 127 used lose **M1** only*

1

M2: T = 458 K and P = 100 000 Pa 1

M3 $V = \frac{nRT}{P}$ or $\frac{0.0197 \times 8.31 \times 458}{100\ 000}$ or 7.50×10^{-4} (m^3)

*M3 If rearrangement incorrect can only score **M1** and **M2*** 1

M4: V = 750 (cm^3)

***M4**: Allow **M3** × 10^6*

***M4**: Allow 749* 1

[16]

Q22.

(a) Correct conversion of temperature and pressure (773 and 101 × 10^3)

Correct answer with or without working scores 4 marks 1

No moles P = (220 / 4 × 31.0) = 1.77

Max 2 (M1 and M3) if 31.0 used

(=0.451 m^3 or if 220/31 rounded to 2 sf ie 7.1 then 0.452) 1

V = nRT/P (correct rearrangement **or** insert of values V = 1.77 × 8.31 × 773/101 × 10^3 =0.1128 m^3)

Max 2 (M1 and M3) if 284 (P_4O_{10}) used then 0.0493 1

V = <u>0.113</u> (m^3)

Must be 3 sig figs 1

Q23.

(b) M1 308 K and 150 000 Pa 1

M2 n = $\frac{PV}{RT}$ or $\frac{150\ 000 \times 7.5 \times 10^{-2}}{8.31 \times 308}$ 1

M3 = 4.4(0) or 4.395 moles N_2

Allow only this answer but allow to more than 3 sig figs 1

M4 Moles NaN_3 = 4.395 × $\frac{2}{3}$ (= 2.93)

M4 is for M3 × $\frac{2}{3}$ 1

M5 Mass NaN_3 = (2.93) <u>× 65</u>

M5 is for moles M4 × 65 1

M6 = 191 g

Allow 190 to 191 g allow answers to 2 sig figs or more

1

Q24.

(a) P = 100 000 Pa and T = 298 K

Wrong conversion of V or incorrect conversion of P / T lose M1 + M3

1

$n = \frac{PV}{RT}$ or $\frac{100\ 000 \times 4.31}{8.31 \times 298}$

If not rearranged correctly then cannot score M2 and M3

1

n(total) = 174(.044)

1

n (NO) = <u>69.6</u>

Allow student's M3 × 4 / 10 but must be to 3 significant figures

1

(b) (i) $\frac{3000}{17}$

Allow answer to 2 significant figures or more

1

176.5

Allow 176 − 177
But if answer = 0.176 − 0.18 (from 3 / 17) then allow 1 mark

1

(ii) 176.47 × 46 = 8117.62

M1 is for the answer to (b)(i) × 46. But lose this mark if 46 ÷ 2 at any stage
However if 92 ÷ 2 allow M1

1

$8117.62 \times \frac{80}{100}$ $(= 6494\ g)$

M2 is for M1 × 80 / 100

1

$\frac{6494}{1000} = 6.5$

M3 is for the answer to M2 ÷ 1000 to min 2 significant figures

(kg)

OR

If 163 mol used:
163 × 46 = 7498 (1)

$$7498 \times \frac{80}{100} = 5998.4\,\text{g}(1)$$

6.00 kg (1)

1

(f) Neutralisation

Allow acid vs alkali or acid base reaction

1

[14]

Q25.

(a) n = PV/RT

If PV=nRT rearranged incorrectly then M3 only

1

$$\frac{102\,000 \times (1.00 \times 10^{-3})}{8.31 \times 300} = n = (4.091456077 \times 10^{-2})$$

1

Mass = M2 × 17 = 0.696 (g) (3 sig figs only)

Allow 0.695 or 0.697

1

(b) If pV = nRT

$$\text{Total volume} = \frac{nRT}{P}$$

Incorrect unit conversion loses M1 only; can get M2/M3 if possible volume obtained

$$= \frac{n \times 8.31 \times 295}{75\,000}$$

= 1.34×10^{-3} m^3

Inserts correct numbers (inc pressure in Pa)

1

Volume of Q in m^3 = 1.00×10^{-3}

Volume of bulb P = $1.34 \times 10^{-3} - 1.00 \times 10^{-3}$

Volume of bulb P = 3.42×10^{-4} m^3

No subtraction M1 only

1

= 342 cm^3 (Allow 310 − 342 cm^3)

Alternative method also worth full credit

(note if mol in M2 of 05.1 rounded to 0.04 this could lead to a final answer of 3.1×10^{-4} m^3 so allow range 310 − 342 cm^3

1

[6]

Q26.

(a) pV = nRT

Do not penalise incorrect use of capitals / lower case letters.

Accept correct rearrangement of equation.

1

(b) **2**C_4H_{10} + **5**O_2 → **4**CH_3COOH + **2**H_2O

Accept any correct combination of multiples, including fractions.

1

(c) 23.0 g ethanol produces 30.0 g ethanoic acid

1

15.1% (4.54 ×100 / 30)

Do not penalise precision.
15.1% scores 2 marks.

Accept consequential answer on wrong mass of ethanoic acid for second mark only.

1

[4]

Q27.

(b) PV = n RT or rearranged

If incorrectly rearranged CE = 0

1

$$T = \frac{0.022 \times 100000}{0.658 \times 8.31}$$

Correct M2 also scores M1

1

402(.3) K (or 129 °C)

allow 402-403K

or 129-130 °C

do not penalise °K

M3 must include units for mark

1

(c) Pressure build up from gas/may explode/stopper fly out/glass shatters/breaks

Penalise incorrect gas

1

(d) (i) M_r = 84.3

If 84 used, max 1

1

$\frac{6.27}{84.3}$ = 0.074(4)

CE if not 84 or 84.3

Allow answers to 2 or more significant figures

M2 = 0.074-0.075

1

(ii) M1 M_r $MgSO_4$ = 120(.4)

allow 120.3 and 120.1

CE if wrong Mr

1

M2 Expected mass $MgSO_4$ = 0.074(4) × 120(.4) = 8.96 g

Allow 8.8 – 9.0 or candidate's answer to (d)(i) × 120(.4)

1

M3 95% yield = $\frac{8.96 \times 95}{100}$ = 8.51 g

Allow 8.3 – 8.6

M3 dependent on M2

Alternative method

M2 0.074(4) × 95/100 = 0.0707

M3 0.0707 × 120(.4) = 8.51 g

Allow (d)(i) × 95/100

Allow 8.3 – 8.6

M3 dependent on M2

1

[15]

Q28.

(a) n = pV/RT **M1**

Do not accept pV=nRT as the sole working.

Allow correct substitution of numbers.

1

0.739 **M2**

Answer must be to a minimum of 2 s.f.

*Correct answer without working scores **M2** only.*

1

(b) (a) × 2

Answer will often be 1.48 (or 1.5 or 1.478)
Answer must be to a minimum of 2 s.f.

1

(c) 100.1

Answer must be to 1 d.p.

1

(d) (a) × (c)

Answer will often be 74.0
Answer must be to a minimum of 2 s.f.

1

[5]

Q30.

(penalty for sig fig error =1mark per question)

(a) (i) moles KNO_3 = 1.00/101.1 = 9.89 × 10^{-3} (mol)

1

(ii) pV = nRT or n = pV/RT

1

moles O2 = n = $\frac{pV}{RT}$ = **(1)** $\frac{100000 \times 1.22 \times 10^{-4}}{8.31 \times 298}$ **(1)**

2

= 4.93 × 10^{-3} (mol)

1

(mark answer first – check back if wrong)
(transcription error lose M3, mark M4 conseq on error)
(if 'untraceable' figures used M3=M4=0)
(if wrong temp conversion – lose M3 – conseq M4)
(if n = RT/pV CE, lose M3 and M4)

(c) $2KNO_3 \rightarrow 2KNO_2 + O_2$ or fractions/multiples
(accept $2KNO_3 \rightarrow K_2N_2O_4 + O_2$)
(do NOT accept 'Y' in equation)

1

[10]

Q31.

Ideal gas equation: pV = nRT **(1)**

Calculation: n = pV/RT = $\frac{103000 \times 127 \times 10^{-6}}{(8.31 \times 415)}$ **(1)**
mark for volume conversion fully correct

= 3.79 × 10^{-3} (mol) **(1)**
range 3.79 × 10^{-3} to 3.8 × 10^{-3}

$M_r = m/n = .304/3.79 \times 10^{-3} = 80.1$ **(1)**

range 80 – 80.3
min 2 s.f. conseq

If 'V' wrong lose M2; 'p' wrong lose M3; 'inverted' lose M3 and M4

[5]

Q32.

(a) $L = \dfrac{1.0078}{1.6734 \times 10^{-24}}$ **(1)** or $\dfrac{\text{mass of 1 mol}}{\text{mass of 1 atom}}$

must show working

$= 6.0225 \times 10^{23}$ **(1)**

Ignore wrong units
NB answer only scores 1

2

(b) equal **(1)**

Or same or 1:1

1

(c) PV = nRT (or $n = \dfrac{PV}{RT}$) **(1)**

$= \dfrac{98000 \times 0.0352}{8.31 \times 298}$ **(1)**

= 1.39 **(1)**

Allow 1.390 to 1.395
ignore units even if incorrect
answer = 1.4 loses last mark

3

Q33.

(a) (i) Avogadro's number/constant of molecules/particles/species / 6×10^{23}

[Not 'atoms']

1

Or same number of particles as (there are atoms)

[Not molecules]

in 12.(00)g of ^{12}C

1

(ii) *Moles O_2 = $\dfrac{0.350}{32}$ (= 1.09×10^{-2} mol)*

1

$= 29 (\times 1.09 \times 10^{-2})$

[Accept answers via 4 separate mole calculations]

1

= 0.316 – 0.317 mol [answer to 3 + sf]

[Mark conseq on errors in M1/M2] *(1)*

1

(iii) Moles of nitroglycerine = 4 × 1.09 × 10^{-2} (= 0.0438 mol)

[Mark conseq on their moles of O_2]

1

M_r of nitroglycerine = 227 or number string

1

Moles of nitroglycerine = 227 × 0.0438 = 9.90 – 9.93(g)

[answer to 3+ sf]

[If string OK but final answer wrong then allow M6 but AE for M7]

[Mark conseq on error in M_r] *[Penalise wrong units]*

[Penalise sig. fig. errors once only in whole question]

(b) pV = nRT **or** pV = $\frac{mRT}{V}$ **or** p = $\frac{nRT}{V}$

1

$$p = \frac{nRT}{V} = \frac{0.873 \times 8.31 \times 1100}{1.00 \times 10^{-3}}$$

1

= 7980093 **or** 7980 **or** 7.98

[ignore s.f.]

1

units = Pa **or** kPa **or** MPa (as appropriate)

[If error in conversion from Pa, treat as a contradiction of the units mark]

[If transfer error, mark conseq but penalise M2]

[If data from outside of above used, penalise M2 and M3]

[If pV expression incorrectly rearranged, penalise M2 and M3]

[if T = 1373 K used, penalise M2]

1

[11]