Questions

Q1.

(a) State what is meant by the term **molar volume of a gas**.

(1)

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(b) The following steps were carried out by a student to find the molar mass of a gas. The experiment was carried out at 20 °C and one atmosphere pressure. The dry gas was supplied in a plastic bag fitted with a self-sealing device. The student had a choice of two different gas syringes. The student decided to use a 50 cm^3 syringe.

Step **1.** The 50 cm^3 syringe was fitted with a needle and then emptied of air by pushing in the plunger to zero. The needle was sealed by pushing the needle into a rubber bung and the syringe and bung were then weighed on a balance.

Step **2.** The syringe was checked for leaks by pulling the plunger out by about 10 cm^3 for a few seconds before releasing it.

Step **3.** The rubber bung was removed from the needle which was then inserted through the self-sealing device in the plastic bag of the dry gas.

Step **4.** 50 cm^3 of the dry gas was withdrawn from the plastic bag into the syringe and the needle resealed with the same rubber bung used in step **1**.

Step **5.** The syringe and rubber bung were then reweighed on the balance.

Results

volume of gas used	50 cm^3
initial mass of empty syringe	107.563 g
final mass of syringe + gas	107.655 g

(i) The gas syringe has a total uncertainty of ±0.5 cm^3.
Each reading on the balance has an uncertainty of ±0.0005 g.
Calculate the percentage uncertainty in the measurement of the volume and mass of gas used in this procedure.

(2)

(ii) The student repeated the experiment with 100 cm^3 of the gas using a 100 cm^3 syringe.
The total uncertainty for this larger syringe was also ±0.5 cm^3.
Determine the effect, if any, on the volume and mass uncertainties.

(2)

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(iii) Calculate the molar mass of the gas used in the procedure outlined in part (b).
You may assume that one mole of gas occupies 24 000 cm^3 under these conditions.
Give your answer to an appropriate number of significant figures and include units in your answer.

(2)

(iv) Explain how the student would know if the syringe had a leak in step **2** and what effect this leak would have on the molar mass determined in part (b)(iii).

(2)

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(c) If the temperature had been less than 20 °C and the pressure remained at one atmosphere, deduce the effect, if any, on the molar mass calculated in part (b)(iii).

(2)

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(d) Give a reason why the gas should be dry.

(1)

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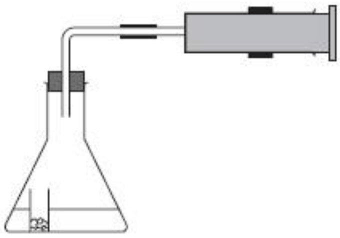
(Total for question = 12 marks)

Q2.

A student wanted to measure the volume of a gas and use the results to find the volume occupied by one mole of the gas. The following method was used.

- A sample of calcium carbonate was weighed out in a small plastic container.
- 20 cm^3 of hydrochloric acid of concentration 2.00 mol dm^{-3} was added to a conical flask. A small pinch of calcium carbonate was added to the acid.
- The container was placed in the conical flask and a gas syringe was connected to the top of the conical flask.
- The flask was carefully shaken so that the small plastic container fell over, allowing the acid and calcium carbonate to mix.

The apparatus set up is shown.



The student repeated the experiment five times using different masses of calcium carbonate on each occasion, with the concentration and volume of the hydrochloric acid constant.

Experiment number	Mass / g	Volume of CO_2 / cm^3
1	0.10	23
2	0.20	44
3	0.30	67
4	0.40	96
5	0.50	115

(a) (i) Write the equation for the reaction between calcium carbonate and hydrochloric acid. Include state symbols.

(2)

(ii) Calculate the molar mass of calcium carbonate.

(1)

.... g mol^{-1}

(iii) Show that, in each experiment, the hydrochloric acid is in excess.

(2)

(b) (i) Plot a graph of volume of carbon dioxide produced against mass of calcium carbonate on the grid. Include a line of best fit.

(2)

(ii) State how your graph supports the idea that the volume of gas produced depends directly on the mass of calcium carbonate added.

(1)

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(c) Calculate the volume, under these conditions, of one mole of carbon dioxide gas from these data. Give your answer in dm^3 to **two** significant figures.

(2)

(d) Give a reason why the student added a small pinch of calcium carbonate to the acid before starting the reaction.

(1)

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(Total for question = 11 marks)

Q3.

Ethanol, C_2H_5OH, is a member of the homologous series of alcohols.

Calculate the number of molecules in 55.2kg of ethanol.

[Avogadro Constant = 6.02×10^{23} mol^{-1}]

(2)

(Total for question = 2 marks)

Q4.

Sulfur is a bright yellow crystalline solid at room temperature.

Sulfur forms rings of 8 sulfur atoms so the formula of the yellow solid is S_8.

Compound **X** is an oxide of sulfur. A gaseous sample of 0.318 g of **X** occupied a volume of 132 cm^3 at a temperature of 420 K and pressure of 105 kPa.

The number of moles of a gas and the volume occupied by it can be found using the ideal gas equation

$$pV = nRT$$

Calculate the relative molecular mass of **X** and hence its molecular formula.
You must show **all** your working.

[R = 8.31 J mol^{-1} K^{-1}]

(5)

(Total for question = 5 marks)

Q5.

This question is about alkenes with the molecular formula C_5H_{10}.

A sample of pent-1-ene, with a mass of 1.33 g, is warmed to 60 °C in a sealed container.
The volume of the container is 500 cm^3.

Calculate the pressure inside the container.
Include units and give your answer to an appropriate number of significant figures.

[Gas constant (R) = 8.31 J mol^{-1} K^{-1}]

(4)

(Total for question = 4 marks)

Q6.

In an experiment, 1.000 g of a hydrocarbon, **A**, was burned completely in oxygen to produce 3.143 g of carbon dioxide and 1.284 g of water.

In a different experiment, the molar mass of the hydrocarbon, **A**, was found to be 84.0 g mol^{-1}.

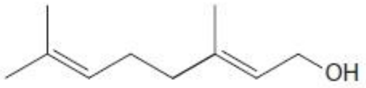
Calculate the empirical formula and the molecular formula of the hydrocarbon, **A**.

(4)

(Total for question = 4 marks)

Q7.

The characteristic smell of pine wood is due, partly, to the presence of a group of compounds called terpenes. One of the simpler terpenes is a compound called geraniol, which is an oily liquid at room temperature and pressure. The structure of geraniol is



Deduce the molecular formula of geraniol. Use your answer to calculate the molar mass of geraniol in g mol^{-1}.

(2)

(Total for question = 2 marks)

Q8.

Boron and aluminium are in the same group of the Periodic Table. Both form compounds with chlorine and with fluorine.

Aluminium also reacts directly with chlorine to form a compound, aluminium chloride, containing only aluminium and chlorine.

A 0.500 g sample of aluminium chloride was analysed and found to contain 0.101 g of aluminium.

Another 0.500 g sample was heated to 473 K. The gas produced occupied a volume of 73.6 cm^3 at a pressure of 1.00×10^2 kPa.

Determine the molecular formula of the gas.

You will need to use the equation $pV = nRT$ and $R = 8.31$ J mol^{-1} K^{-1}

(6)

(Total for question = 6 marks)

Q9.

A group of students analysed a hydrated salt with the formula $KH_3(C_2O_4)_y$. **z**H_2O where **y** and **z** are whole numbers.

The students carried out experiments to determine the values of **y** and **z**.

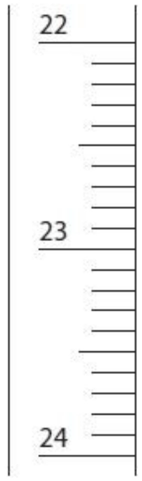
(a) **Experiment 1** – to determine the value of **y**

One student was provided with a 0.0235 mol dm^{-3} solution of the salt.
25.0 cm^3 portions of the salt solution were acidified with excess dilute sulfuric acid and heated to about 60 °C.
Each portion was titrated with 0.0203 mol dm^{-3} potassium manganate(VII).
The results of four titrations are shown in the table.

Titration number	1	2	3	4
Final burette reading / cm^3	23.85	47.20	24.05	48.10
Initial burette reading / cm^3	0.00	24.00	0.50	25.00
Titre / cm^3	23.85	23.20	23.55	23.10

(i) Complete the diagram to show the final burette reading in **Titration 1**.

(2)



(ii) Explain why this student should use a mean titre of 23.15 cm^3 and not 23.43 cm^3 in the calculation.

(2)

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(iii) The uncertainty in each burette reading is ±0.05 cm^3.
Calculate the percentage uncertainty in the titre volume of potassium manganate(VII) solution used in **Titration 2**.

(1)

(iv) The equation for the reaction is

$$2MnO_4^- + 5C_2O_4^{2-} + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

Deduce, by calculation, the value of **y**, to the nearest whole number, in the formula $KH_3(C_2O_4)_\mathbf{y}.\ \mathbf{z}H_2O$.
Use the mean titre of 23.15 cm^3 and other data from **Experiment 1**.
You **must** show your working.

(4)

(b) **Experiment 2 –** to determine the value of **z**

Another student wrote an account of the method for this experiment.

A crucible was weighed.

A sample of the hydrated salt was added to the crucible and it was reweighed.

The crucible and salt were heated to remove the water of crystallisation and then allowed to cool.

The crucible and contents were weighed again.

Results

Mass of crucible	= 19.56 g
Mass of crucible + $KH_3(C_2O_4)_\mathbf{y}.\mathbf{z}H_2O$	= 22.97 g
Mass of crucible + $KH_3(C_2O_4)_\mathbf{y}$	= 22.52 g

(i) Deduce, by calculation, the value of **z**, to the nearest whole number, in the formula $KH_3(C_2O_4)_\mathbf{y}.\ \mathbf{z}H_2O$.
You must use the data from **Experiment 2** and your value of **y** in (a)(iv).
You **must** show your working.

(3)

(ii) A third student carried out Experiment 2 and calculated a value of **z** that was lower than expected.

This student evaluated the experiment and gave two suggestions for **z** being lower.

Suggestion **1**

"Some of the crystals jumped out of the crucible while it was being heated."

Suggestion **2**

"It was difficult to tell when all the water of crystallisation had been lost."

Evaluate these two suggestions to decide whether they could account for the lower value of **z** obtained from the experimental results.

Include an explanation of the effect each suggestion would have on the calculated value of **z** and how the method could be improved to prevent these errors.

(5)

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(Total for question = 17 marks)

Q10.

Sulfur reacts with fluorine to form a number of different compounds.

One compound contains 45.79% sulfur and 54.21% fluorine by mass.
Calculate the empirical formula of this compound.

(2)

(Total for question = 2 marks)

Q11.

This question is about isotopes, mass spectra and hydrocarbons.

1.00 g of a **different** hydrocarbon, **W**, was burnt in oxygen.
Analysis of the combustion products showed that complete combustion produced 3.14 g of carbon dioxide and 1.29 g of water.

Water and carbon dioxide were the only products of combustion.

Calculate the **empirical** formula of hydrocarbon **W**.
You **must** show your working.

(4)

(Total for question = 4 marks)

Q12.

This question is about equilibrium systems.
Sulfur dioxide and oxygen form an equilibrium with sulfur trioxide.

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

The composition of an equilibrium mixture at 698 K and a total pressure of 2.40 atm is shown in the table.

Substance	$SO_2(g)$	$O_2(g)$	$SO_3(g)$
Number of moles /mol	0.0160	0.0120	0.772

(i) Calculate the value of K_p at this temperature.
Include units, if appropriate.

(5)

(ii) Calculate the number of sulfur dioxide molecules present in this equilibrium mixture.

(1)

(iii) Deduce, by referring to K_p, how the number of sulfur dioxide molecules will change if more oxygen is added to the equilibrium mixture.

(2)

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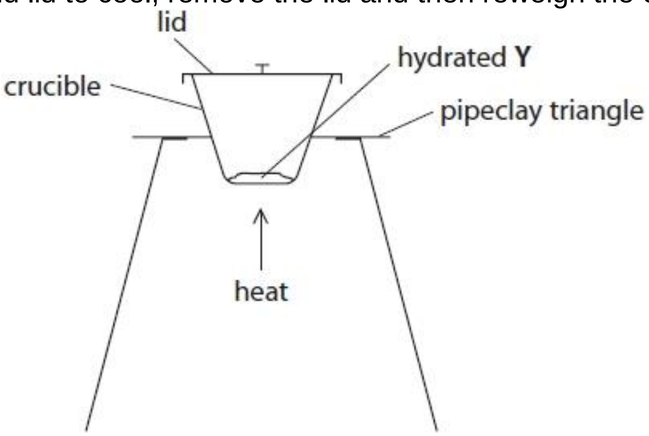
(Total for question = 8 marks)

Q13.

Y is identified as hydrated potassium carbonate, $K_2CO_3 \cdot nH_2O$.
Two of the students were asked to determine the number of moles of water of crystallisation, *n*, in **Y** using the procedure shown:

- weigh a sample of hydrated **Y** into a pre-weighed crucible
- place a lid loosely on the crucible and heat it for five minutes to remove the water of crystallisation
- allow the crucible and lid to cool, remove the lid and then reweigh the crucible with its contents.



(i) The first student carried out the experiment but forgot to use the lid.

Explain how this mistake would affect the calculated value of *n*.

(2)

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(ii) The second student carried out the experiment but heated the apparatus for only **one** minute.

Explain how this mistake would affect the calculated value of *n*.

(2)

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(iii) In an accurate experiment, **Y** is found to consist of 71.9% K_2CO_3 by mass.

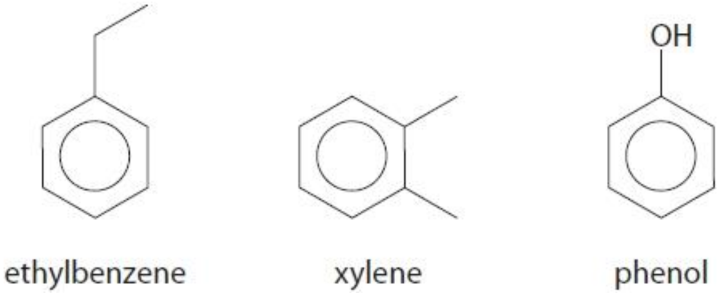
Calculate the value of *n*.

(3)

(Total for question = 7 marks)

Q14.

This question is about the arenes, ethylbenzene, xylene, and phenol, which can be identified in wine samples using gas chromatography.



A student carried out an experiment to determine the molar mass of xylene.

The student's sample of xylene vapour had a mass of 0.271 g.

At a temperature of 165 °C and a pressure of 118 kPa, this sample had a volume of 70.5 cm^3.

Use the Ideal Gas Equation to calculate the molar mass, in g mol^{-1}, of this sample.

Give your answer to an appropriate number of significant figures.

You **must** show your working.

(4)

(Total for question = 4 marks)

Q15.

This question is about the identification of an alcohol, **X**.

(a) Alcohol **X** has the following percentage composition by mass:

carbon, C	= 68.2%
hydrogen, H	= 13.6%
oxygen, O	= 18.2%

The molecular ion peak in the mass spectrum for alcohol **X** occurs at *m*/*z* = 88.
Use all of these data to show that the molecular formula for alcohol **X** is $C_5H_{12}O$. Include your working.

(2)

(b) (i) When alcohol **X** is oxidised, a carboxylic acid is formed.

State what information this gives about alcohol **X**.

(1)

....

(ii) Draw the **displayed** formulae of the four possible structural isomers that could be alcohol **X**.

(3)

Alcohol 1	Alcohol 2
Alcohol 3	**Alcohol 4**

(iii) The mass spectrum of alcohol **X** has a major peak at m/z = 45.
Draw the structure of the species that could give this peak.

(1)

(iv) Alcohol **X** has a branched chain.
Identify alcohol **X**, explaining your reasoning.

(2)

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(Total for question = 9 marks)

Q16.

This question is about nitrogen and some nitrogen compounds.

A study of one brand of crisps found that each packet contained 0.420 g of nitrogen gas at a pressure of 120 kPa and a temperature of 20°C.

(i) Calculate the volume of nitrogen gas, in **cm^3**, in one packet of crisps.

[R = 8.31 J mol^{-1} K^{-1}]

(4)

(ii) Give a possible reason why nitrogen gas and not air is used in packets of crisps.

(1)

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(Total for question = 5 marks)

Q17.

This question is about organic compounds containing fluorine and chlorine.

The use of chlorofluorocarbons as refrigerants has ceased due to concerns about their effects on the ozone layer. One such compound is dichlorodifluoromethane.

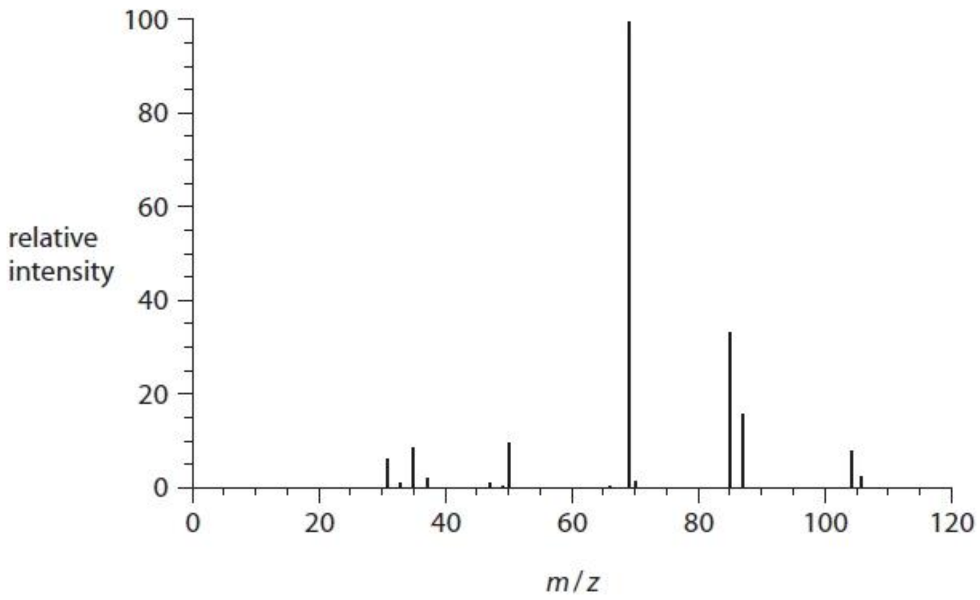
(i) A different refrigerant contains 34.0% chlorine and 54.5% fluorine by mass, with the remainder carbon.

Calculate the empirical formula of this compound.

(3)

(ii) Use the mass spectrum to show that the empirical and the molecular formulae of this compound are the same.

(1)



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(iii) Suggest the species responsible for the peak at $m / z = 69$.

(1)

(Total for question = 5 marks)

Q18.

This question is about sodium carbonate.

Sodium carbonate forms a number of hydrates with the general formula $Na_2CO_3.xH_2O$.

A 250 cm^3 standard solution of one of these hydrates contained 10.0 g of the compound.

In an experiment, the M_r of a **different** hydrated sodium carbonate was found to be 286 g mol^{-1}.

(i) Calculate the relative formula mass of anhydrous sodium carbonate, Na_2CO_3 .

(1)

(ii) Calculate the number of molecules of water of crystallisation, *x*, for this hydrated sodium carbonate, $Na_2CO_3.xH_2O$.

(1)

(Total for question = 2 marks)

Q19.

This question is about extracting benzoic acid from a mixture of benzoic acid, C_6H_5COOH, and phenol, C_6H_5OH.

The following steps were carried out.

Step **1** A suitable mass of the mixture was placed in a separating funnel and some ether added. The funnel was shaken to dissolve the mixture.

Step **2** Aqueous sodium hydrogencarbonate was added to the separating funnel, and the contents shaken.

Step **3** Once the reaction was complete, the two layers were allowed to separate.

Step **4** The lower aqueous layer was removed and placed in a beaker.

Step **5** The ether layer in the separating funnel was washed with deionised water and the washings added to the beaker.

Step **6** Hydrochloric acid was added to the aqueous solution in the beaker to precipitate the benzoic acid.

Step **7** The impure benzoic acid was filtered under reduced pressure.

Step **8** The impure benzoic acid was purified by recrystallisation.

Step **9** The melting temperature of the purified benzoic acid was measured and compared with the literature value of 122 °C.

Benzoic acid can be purified in Step **8** because of its high solubility in hot water and low solubility in cold water.

Calculate the maximum number of benzoic acid molecules that can dissolve in 50.0 cm^3 of cold water if the solubility is 1.70 g per 1000 cm^3.

(3)

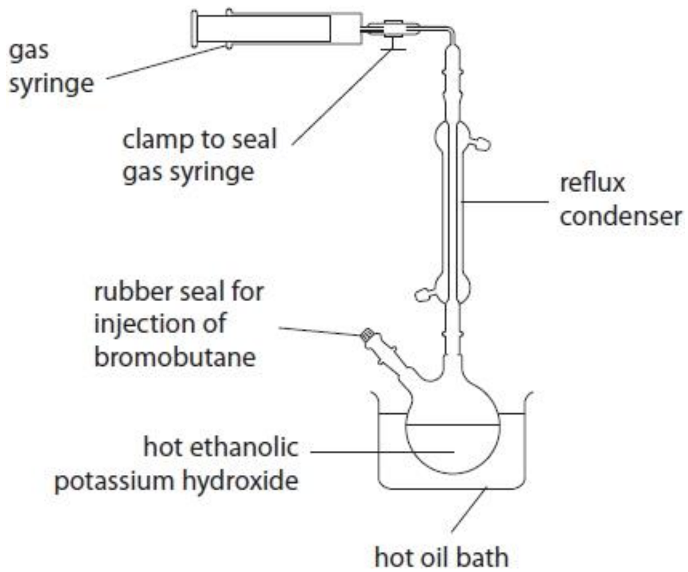
(Total for question = 3 marks)

Q20.

Bromobutanes react with hot ethanolic potassium hydroxide solution to produce gaseous butenes.

$$C_4H_9Br + OH^- \rightarrow C_4H_8 + Br^- + H_2O$$

Apparatus



Procedure

- 0.0080 mol of liquid 1-bromobutane was injected into a round bottom flask containing hot ethanolic potassium hydroxide.
- After the reaction, the syringe was sealed using a clamp.
- The syringe was then removed from the apparatus and allowed to cool to room temperature (298 K).

Result

The final volume of but-1-ene collected was 22.0 cm^3.

Before cooling, the volume of but-1-ene in the gas syringe was 24.0 cm^3.

Calculate the temperature of the gas in the syringe before it cooled.

[Assume no loss from the gas syringe during cooling, and a constant pressure]

(2)

(Total for question = 2 marks)

Q21.

Ice has a density of 0.92 g cm^{-3} and water has a density of 1.00 g cm^{-3}.

Calculate how many **more** molecules there are in 5.00 cm^3 of water compared to 5.00 cm^3 of ice.

(3)

(Total for question = 3 marks)

Q22.

This question is about the molar volume of gases.

(i) Calculate the volume of one mole of an ideal gas, **A**, at 60 °C and 500 kPa pressure.

Give your answer to two significant figures and include units.
[The ideal gas equation is $pV = nRT$. Gas constant (R) = 8.31 J K^{-1} mol^{-1}]

(3)

(ii) At room temperature and pressure (r.t.p) another gas **B**, with formula XH_3, has a density of 1.42 g dm^{-3}.

Calculate the molar mass of the gas XH_3 and deduce the identity of the element X.
[The molar volume of gas **B** = 24 000 cm^3 mol^{-1} at r.t.p.]

(2)

(Total for question = 5 marks)

Q23.

Traditionally, high-flying aircraft and Formula 1 racing cars have had their tyres inflated with nitrogen gas instead of air. Recently, this practice has been extended to some other cars.

A car tyre is filled with nitrogen gas to a volume of 8.98 dm^3 and a pressure of 207 kPa at 20 °C.

(i) Using the Ideal Gas Equation, calculate the mass of nitrogen gas, in grams, present in the car tyre under these conditions. Give your answer to an appropriate number of significant figures.

(3)

(ii) During a car journey, the tyres become warm. Use the Ideal Gas Equation to deduce the effect that this has on the pressure in the tyres.

(1)

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(Total for question = 4 marks)

Mark Scheme

Q1.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a)	an answer that makes reference to the following point: volume/space occupied by one mole of a gas at a specified temperature and pressure/rtp/stp/standard conditions	temp and pressure need not be s.t.p. or r.t.p. ignore just reference to 22.4 or 24 dm^3 Ignore units of volume, if given.	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	(% volume uncertainty =)1% **(1)** (% mass uncertainty =) 1/1.1/1.09/1.08696 % **(1)**	example of calculation 0.5 cm^3 in 50 cm^3 % uncertainty = $\frac{0.5}{50}$ x 100 = 1% mass of gas = 107.655 – 107.563 = 0.092 g uncertainty = 0.0005 x 2 0.001 g in 0.092 g % uncertainty = $\frac{0.001}{0.092}$ x 100 = 1/1.1/1.09/1.08696 % Ignore uncertainties added together Do not award calculation of uncertainty in each mass reading (often added together +1) eg 0.0004644 + 0.0004648 + 1 = 1.000928	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(ii)	an answer that makes reference to the following points: halves the % volume uncertainty /0.5 cm^3 in 100 cm^3 = 0.5% **(1)** (volume of gas is doubled so mass of gas doubles), % mass uncertainty (also) halves. **(1)**	TE for answer to (b)(i) ÷ 2 TE for answer to (b)(i) ÷ 2 Allow 1 mark for both uncertainties decrease	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iii)	• mass of gas and expression for molar mass **(1)** • molar mass to 2 or 3 SF and correct units **(1)**	<u>example of calculation</u> mass of gas = 107.655 – 107.563 = 0.092 g and molar mass = 0.092 x 24000 /50 = 44.16 Allow any other correct alternative calculation TE from M1 to M2 for incorrect mass only **44.2/44 g mol^{-1}** Correct answer to 2/3 SF with/without working gets 2 marks	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(iv)	an explanation that makes reference to the following points: • plunger does not return (to zero/original position) when released **(1)** • molar mass will decrease **because** 'air' has a lower molar mass (than 44/carbon dioxide) **(1)**	Mark independently There must be some reference to air	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following points: • the calculated molar mass would be greater **(1)** • at a lower temperature there would be more molecules/moles/mass in the same volume /density is greater. **(1)**	Points to be marked independently Standalone mark Do not award for answers that refer to smaller volume Ignore smaller molar volume Ignore particles/molecules/atoms closer together	**(2)**

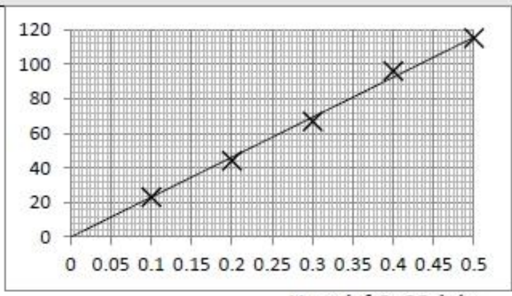
Question Number	Acceptable Answer	Additional Guidance	Mark
(d)	an answer that makes reference to the following point: water (vapour) would decrease/affect molar mass OR gas is now a mixture so would decrease/affect molar mass	Ignore gas may dissolve in water Do not award water may react with gas in syringe Do not award wet gas is heavier Ignore answers that refer to molar volume	**(1)**

Q2.

Question Number	Acceptable Answer	Additional Guidance	Mark
(a) (i)	$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$ Balanced equation **(1)** State symbols **(1)**	Accept $CaCO_3(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2O(l) + CO_2(g)$ 2nd mark dependent on first or near miss. Reject $H_2CO_3(aq)$ in equation, but allow state symbol mark if otherwise correct.	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(a) (ii)	Finds molar mass of calcium carbonate	Example of calculation Mr of calcium carbonate = 40.1 + 12 + (16 x 3) =100.1 (g mol^{-1}) Allow = 40 + 12 + (16 x 3) = 100 (g mol^{-1}) Accept answer with no working	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(a) (iii)	• calculate moles of calcium carbonate in 0.50 g **(1)** • moles of hydrochloric acid in 20 cm^3 AND Show the hydrochloric acid is in excess with appreciation of 2:1 ratio in equation for reaction **(1)**	Example of calculation moles of calcium carbonate = 0.50/100.1 = 0.004995 = 0.0050 (mol) moles of hydrochloric acid in 20 cm^3 = 20/1000 x 2 = 0.040 (mol) 0.04 (moles of hydrochloric acid) reacts with 0.02 (moles of calcium carbonate) therefore the acid is in (a four times) excess. OR 0.0050 (moles of calcium carbonate) reacts with 0.010 (moles of hydrochloric acid) therefore the acid is in (a four times) excess Ignore calculations using other masses of calcium carbonate	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(i)	Points plotted accurately AND axes labelled **(1)** Points plotted must cover more than half of graph paper AND Reasonable straight line of best fit which may extend to the origin **(1)** Allow ecf on reasonable line on incorrectly plotted points.	Do not award for reversed axes Volume (of CO_2) / cm^3  Mass (of $CaCO_3$) / g	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(b)(ii)	Straight line through the origin (therefore volume is directly proportional to mass)	Allow 'There is a positive correlation.'	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(c)	Either • finds gradient from graph **(1)** • molar volume given to 2 s.f. with units **(1)** OR • moles of calcium carbonate **(1)** • molar Volume **(1)**	Example calculation Gradient = $\frac{\text{volume}}{\text{mass}}$ = 231 (cm^3 per gram) Allow correctly calculated values in the range = 210 to 250 (Molar Volume = Gradient x Mr) Molar Volume = 231 x 100.1(or x 100) = 23 (dm^3) (must be 2 s.f) Answer to 2 s.f. (and units) Allow TE from any gradient OR Data may be used from any experiment number eg using data from Experiment 5 Moles of calcium carbonate = 0.50/100.1 = 0.0050 Molar Volume = 115/0.005 = 23 (dm^3) Allow data from a point on the line calculated using route 2	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(d)	To saturate the solution with CO_2 / to stop the CO_2 formed from dissolving		**(1)**

Q3.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• calculation of no. mol of ethanol **(1)** • calculation of no. molecules of ethanol **(1)**	<u>Example of calculation</u> no. mol of ethanol = 55.2 x 1000 / 46 = 1200 no. molecules ethanol = 1200 x 6.02×10^{23} = 7.224×10^{26} TE on no. of mol of ethanol Correct answer with or without working scores both marks Ignore SF except 1 SF Ignore units **Comment:** common incorrect answers: 7.224×10^{23} scores 1 (used 55.2 g) 7.224×10^{20} scores 1 (used 0.0552 g)	**(2)**

Q4.

Question Number	Answer		Additional Guidance	Mark
	• rearrangement of the ideal gas equation • conversion of volume into m^3 and conversion of pressure into pascals • calculation of number of moles • calculation of molar mass • deduction of formula of **X**	(1) (1) (1) (1) (1)	Example of calculation $n = \frac{pV}{RT}$ $V = 0.000132$ (m^3) and $p = 105000$ (Pa) $n = \frac{105\,000 \times 0.000132}{8.31 \times 420} = 0.0039711$ (mol) $M_r = \frac{m}{n} = \frac{0.318}{0.0039711} = 80.078/\ 80.1$ ($g mol^{-1}$) Ignore SF SO_3 Allow S_2O Allow TE at each stage Correct answer with at least MP2, MP3 or MP4 correct scores (5)	(5)

Q5.

Question Number	Answer	Additional Guidance	Mark
	• calculation of moles of pent-1-ene (1) • conversion of volume and temperature (1) • rearrangement of ideal gas equation and calculation of p (1) • final answer to 2 or 3 SF and units (1)	<u>Example of calculation</u> 1.33 / 70 = 0.019 (mol) 500 x 10^{-6} m^3 and 333 K Allow conversion of volume to 0.5 dm^3 if units for M3 and / or M4 shown as kPa $P = (nRT) / V$ = (0.019 x 8.31 x 333) / 500 x 10^{-6} = 105154.74 = 105000 Pa / 1.05 x 10^5 Pa / 1.1 x 10^5 Pa Allow N m^{-2} for Pa Allow 105 kPa Allow TE at each stage Penalise rounding to 1SF in M1 but then allow TE Correct answer with units and no working scores (4)	**(4)**

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• moles of CO_2/moles of C **(1)** • moles of H **(1)** • empirical formula **(1)** • calculates molecular formula C_6H_{12} **(1)**	example of calculation moles of CO_2 = 3.143/44 (= 0.07143/0.071) = moles of C moles of H_2O = 1.284/18 (= 0.07133) moles of H = 2 x moles of H_2O = 0.1427 C:H = 0.07143:0.1427 = 1:2 hence C_1H_2 or CH_2 allow TE from first and/or second mark point(s) Allow any workable calculation Ignore SF in intermediate stages of calculation Award 3 marks for correct C:H ratio, with or without working. 84/14 = 6 6 x CH_2 = C_6H_{12} Mark independently of M1, M2, M3	**(4)**

Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	$C_{10}H_{18}O$ **(1)** 154 (g mol^{-1}) **(1)**	Ignore $C_{10}H_{17}OH$ no TE on incorrect molecular formula except for $C_{10}H_{17}OH$	**(2)**

Q8.

Question Number	Acceptable Answer	Additional Guidance	Mark
	Determine empirical formula finds mass of Cl AND finds moles of aluminium and chlorine **(1)** determines ratio and hence empirical formula is $AlCl_3$ **(1)**	<u>Example of calculation</u> 0.500 - 0.101 = 0.399(g) AND 0.101/27.0 = 0.00374074 / 3.74… x 10^{-3} AND 0.399/35.5 = 0.01123944 / 1.12… x 10^{-2} $\frac{0.01123944}{0.00374074}$ = 3.005 Could use (0.101/0.5) x 100 = 20.2% 20.2/27.0 = 0.74814815 AND 79.8/35.5 = 2.2478873 $\frac{2.2478873}{0.74814815}$ = 3.005	**(6)**

	Determine molecular mass		
	converts p into Pa / N m^{-2} and V into m^3 **(1)**	$p = 1.00 \times 10^2 \times 10^3 = 100\,000 / 1 \times 10^5$ AND $V = 73.6 / 1\,000\,000$ or 7.36×10^{-5}	
	rearrange $pV = nRT$ and finds number of moles **(1)**	$n = \dfrac{100000 \times (73.6/1000000)}{8.31 \times 473} = 0.001872$ or 1.872473×10^{-3} (mol)	
	finds molecular mass **(1)**	$M_r = \dfrac{0.500}{1.872473 \times 10^{-3}} = 267.03$	
	finds molecular formula **(1)**	$\dfrac{267.03}{27.0 + (35.5 \times 3)} = 2$ so Al_2Cl_6	
		COMMENT MP 3-5 and identity of Al_2Cl_6 without incorrect working scores 6 marks	

Q9.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	• bottom of meniscus between 23.8 and 23.9 (cm^3) **(1)** • meniscus curved downwards **(1)**	Example of diagram  Ignore shading below the meniscus Do not award M2 if there is shading above the meniscus	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	An explanation that makes reference to the following points: • 23.15 (cm^3) should be used as it is the mean of the concordant titres / titres 2 and 4 /23.10 and 23.20 (cm^3) **(1)** • 23.43 (cm^3) should not be used as it includes the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm^3) **(1)**	Allow other descriptions of concordant e.g. titres within 0.1 / 0.2 cm^3 Allow (23.1(0) + 23.2(0))/2 = 23.15 (cm^3) Allow only the concordant titres / titres 2 and 4 / 23.20 and 23.20 (cm^3) should be used / are used(in the mean) Allow the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm^3) should not be used / are used (in the mean)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(iii)	• calculation of percentage uncertainty	Example of calculation $\frac{2 \times 0.05}{23.20} \times 100$ = (±)0.431 / 0.43 / 0.4 (%) Ignore SF including 1 SF Correct answer with no working scores (1)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a) (iv)	• calculation of moles of MnO_4^- **(1)** • calculation of moles $C_2O_4^{2-}$ in 25.0 cm^3 **(1)** • calculation of moles $C_2O_4^{2-}$ in 1.00 dm^3 **(1)** • calculation of **y** to nearest whole number **(1)**	Example of calculation moles MnO_4^- = 23.15 x 0.0203/1000 = 0.00046995 / 4.6995 x 10^{-4} (mol) moles $C_2O_4^{2-}$ in 25.0 cm^3 = 4.6995 x 10^{-4} x 5/2 = 0.0011749 / 1.1749 x 10^{-3} (mol) TE on moles MnO_4^- moles $C_2O_4^{2-}$ in 1.00 dm^3 = 1.1749 x 10^{-3} x $\frac{1000}{25.0}$ = 0.046995 / 4.6995 x 10^{-2} (mol) TE on moles $C_2O_4^{2-}$ in 25.0 cm^3 Ratio moles salt : moles $C_2O_4^{2-}$ = 0.0235 : 0.046995 = 1 : 1.9998 **y** = 2 TE on moles $C_2O_4^{2-}$ in 1.00 dm^3 Alternative method for M3 and M4 moles salt in 25.0 cm^3 = 0.0235 x 25.0/1000 = 5.875 x 10^{-4} (1) Ratio moles salt : moles $C_2O_4^{2-}$ = 5.875 x 10^{-4} : 1.1749 x 10^{-3} = 1 : 1.9998 **y** = 2 TE on moles salt and $C_2O_4^{2-}$ in 25.0 cm^3 (1) Ignore SF in working except 1 SF Correct answer with no working scores (1) Allow M4 for correct answer using charges on ions	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• calculation of mol of anhydrous salt **(1)** • calculation of mol H_2O **(1)** • calculation of ***z*** to nearest whole number **(1)**	<u>Example of calculation</u> mol anhydrous salt = 2.96/218.1 = 0.013572 / 1.3572 x 10^{-2} (mol) TE on M_r of anhydrous salt from value of **y** in (a)(iv) or an assumed value of ***y*** Allow 0.013578 from M_r 218 mol H_2O (= 0.45/18) = 0.025 / 2.5 x 10^{-2} (mol) Ratio mol salt : mol H_2O = 0.013572 : 0.025 = 1 : 1.842 **z** = 2 TE on moles anhydrous salt and moles H_2O Ignore SF in working except 1 SF Correct answer with some working scores (3) Penalise **y** and **z** not given to nearest whole number once only in (a)(iv) and (b)(i) Allow alternative correct methods	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	An answer which includes the following points: Crystals jumped out of crucible • value of ***z*** increases **and** because it appears that more mass / mol / water is lost (than expected) **(1)**	Ignore just 'loss in mass / mol'	**(5)**
	• (this can be prevented by) placing a lid on the crucible **or** heat more gently / carefully **(1)**	Stand alone mark Allow just 'cover the crucible' Ignore use an electrical heater / larger crucible / evaporating basin / conical flask / test tube etc Do not award add anti-bumping granules	
	Not all water of crystallisation lost • less mass / mol /water is lost (than expected) **(1)**		
	• (this can be prevented by) heating to constant mass **or** description of heating to constant mass **(1)**	Stand alone mark Ignore just 'heat for longer' Do not award the idea of repeating the experiment / using a drying agent	
	• so this accounts for the lower value of ***z*** / value of ***z*** decreases **(1)**	Conditional on M3	

Q10.

Question Number	Acceptable Answers	Additional Guidance	Mark
	• evaluation of the number of moles of S and F **(1)** • evaluation of ratio 1 : 2 and empirical formula **(1)**	Example of calculation: n(S) = (45.79 ÷ 32.1) = 1.426 n(F) = (54.21 ÷ 19.0) = 2.853 Ratio = (1.426 : 2.853) = 1:2 Empirical formula SF_2 Allow use of S = 32 (1.431) Correct answer with no working scores 2 marks Ignore any units Use of atomic numbers/ incorrect atomic mass scores 0 overall	**(2)**

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • calculation of moles of carbon/carbon dioxide **(1)** • calculation of moles of water **(1)** • calculation of moles of hydrogen **(1)** • calculation of empirical formula **(1)**	Example of calculation Moles of carbon dioxide = 3.14 ÷ 44 = 0.071364 (mol) Moles of carbon = 0.071364 (mol) Moles of water = 1.29 ÷ 18 = 0.071667 (mol) Moles of hydrogen = 0.071667 x 2 = 0.14333 (mol) Ratio of moles C:H = 0.071364:0.14333 = 1:2.(001) Empirical formula = CH_2 TE on M4 for lost M3 (no x2), so CH TE on moles of C and H	**(4)**

Q12.

Question Number	Answer	Additional Guidance	Mark
(i)	• **(M1)** calculation of mole fractions **(1)** • **(M2)** calculation of partial pressures **(1)** • **(M3)** expression of K_p **(1)** • **(M4)** calculation of value of K_p **(1)** • **(M5)** units **(1)**	Example of calculation X_{SO_2} = 0.0160 ÷ 0.8 = 0.02(0) X_{O_2} = 0.0120 ÷ 0.8 =0.015 X_{SO_3} = 0.772 ÷ 0.8 =0.965 P_{SO_2} = 0.02(0) x 2.40 = 0.048 P_{O_2} = 0.015 x 2.40 = 0.036 P_{SO_3} = 0.965 x 2.40 =2.316 $K_p = \frac{(P_{SO_3})^2}{(P_{SO_2})^2 \times P_{O_2}}$ Do not award square brackets $K_p = \frac{2.316^2}{0.048^2 \times 0.036} =$ K_p= 64668.4…./6.46684.. x 10^4 K_p= 65000/6.5 x 10^4/64700/6.47 x 10^4 Ignore SF except 1 atm^{-1} Correct final answer without working scores	**(5)** (5)

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of the number of molecules	Example of calculation N=(n x L = 0.0160 x 6.02 x 10^{23}) = 9.632 x 10^{21} Ignore SF except 1SF Do not award if any units are given	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following points: • to ensure that K_p stays the same/ quotient stays the same **or** only temperature changes the value of K_p **(1)** • the number of (sulfur dioxide) molecules decreases **Either** because the equilibrium shifts to the right or because one of the denominators (oxygen) has increased so the other denominator (sulfur dioxide) has to decrease **(1)**	Standalone marks Allow concentration changes have no effect on the value of K_p Allow 'moles' for molecules	**(2)**

Q13.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • (not using a lid means) some of salt **Y** could be lost from crucible during heating **(1)** • (mass loss greater than expected), so *n* / amount of water (of crystallisation) greater (than expected) **(1)**	Allow solid / product / crystals for 'salt' Allow 'salt spits / jumps out' / 'salt escapes' from crucible Ignore gas escapes Do not award 'salt evaporates' M2 dependent on M1 or salt evaporates	**(2)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An explanation that makes reference to the following points: • (heating for only 1 minute may mean) not all the water (of crystallisation) has been removed **(1)** • (mass loss less than expected), so *n* / amount of water (of crystallisation) less (than expected) **(1)**	Allow evaporated / boiled off for removed Allow (only) partial dehydration Ignore incomplete reaction M2 dependent on M1 or incomplete reaction	**(2)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(iii)</td><td>•

• calculation of moles of K_2CO_3 (1)

• calculation of moles of H_2O (1)

deduction of n (1)</td><td><u>Example of calculation</u>
<table>
<tr><th></th><th>K_2CO_3</th><th>H_2O</th></tr>
<tr><td>Moles =</td><td>71.9 / (138.2) = 0.52026</td><td>(100 - 71.9) / 18 = 1.56111</td></tr>
<tr><td>Ratio =</td><td>= 0.52026 / 0.52026 = 1</td><td>= 1.56111 / 0.52026 = 3</td></tr>
<tr><td>n =</td><td>3</td><td></td></tr>
</table>
Accept use of 0.719 / 0.281 in M1
Allow TE from **M1**
Allow use of 138 for M_r of K_2CO_3 – gives 0.52101
Ignore SF including 1SF in M1 and M2
M3 must be 1 SF

Accept alternative methods e.g.
$\frac{138.2}{138.2 + 18n} = 0.719$ (1)
$38.8342 = 12.942n$ (1) so $n = 3$ (1) **or**
M_r of hydrated salt = $\frac{138.2}{0.719}$ = 192.2 (1)
mass of water = 192.2 – 138.2 = 54 (1) n = 54/18 = 3 (1) **or**
138.2 = 71.9% so 28.1% **is water** (1) $\frac{138.2}{71.9}$ x 28.1 = 54 (1)
n = 54/18 = 3 (1)

Correct answer with no working scores (1)
Correct answer with some correct working scores (3)</td><td>(3)</td></tr>
</table>

Edexcel Chemistry A-level - Moles, Mass and Formulae

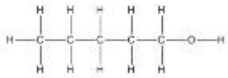
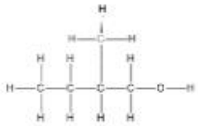
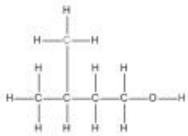
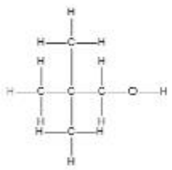
Q14.

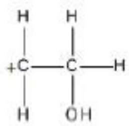
Question Number	Answer	Additional Guidance	Mark
	• **M1** conversion of pressure and temperature (1) • **M2** conversion of volume units (1) • **M3** rearrangement of gas equation and calculation of n (1) • **M4** calculation of the molar mass with the final answer given to **2 or 3 SF** (1)	Example of calculation 118 000 (Nm^{-2}) and 438 (K) 70.5×10^{-6} / 7.05×10^{-5} (m^3) $n = \frac{pV}{RT}$ $n = \frac{(118000 \times 70.5 \times 10^{-6})}{(8.31 \times 438)}$ $n = 2.2855777 \times 10^{-3}$ (mol) $\frac{0.271}{2.2855777 \times 10^{-3}}$ = 118.5696 = 119 / 120 ($g\ mol^{-1}$) If use $M_r = \frac{mRT}{pV}$ (since $n = \frac{m}{M_r}$) can score both **M3 and M4** $M_r = \frac{0.271 \times 8.31 \times 438}{118\ 000 \times 70.5 \times 10^{-6}}$ M_r = 118.5695 M_r = 119 / 120 ($g\ mol^{-1}$) Award TE at each stage Ignore units even incorrect	**(4)**

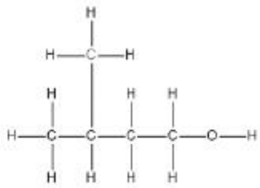
Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• calculation of empirical formula **(1)**	Example of calculation C : H : O $\frac{68.2}{12}$ $\frac{13.6}{1}$ $\frac{18.2}{16}$ = 5.68 13.6 1.14 = 5 12 1	**(2)**
	• uses molecular ion to prove molecular formula **(1)**	Use of 88 to show molecular formula is $C_5H_{12}O$ e.g. M_r is (5x12) + (12x1) + 16 = 88 or states that M_r of empirical formula is 88	
	or • calculation of percentage of each element in compound all 3 correct scores **(2)** any 2 correct scores **(1)**	**or** % C = $\frac{5 \times 12 \times 100}{88}$ = 68.2 % H = $\frac{12 \times 1 \times 100}{88}$ = 13.6 % O = $\frac{1 \times 16 \times 100}{88}$ = 18.2	
	or • calculation of the number of atoms of each element directly all 3 correct scores **(2)** any 2 correct scores **(1)**	**or** C atoms = $\frac{68.2 \times 88}{100 \times 12}$ = 5 H atoms = $\frac{13.6 \times 88}{100 \times 1}$ = 12 O atoms = $\frac{18.2 \times 88}{100 \times 16}$ = 1	

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• (**X** is a) primary/ 1° (alcohol)		**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	   	Allow alcohols in any order Allow CH_3 / OH Allow slip of 1 H missing from 1 alcohol / 1 C-C bond missing Ignore names, even if incorrect Penalise O-H-C- / -C-H-O at end of molecule once only If no other mark is given, allow (2) for 4 correct skeletal / structural formulae or any combination of these or (1) for 3 correct Allow (2) for displayed formulae of pentan-2-ol, pentan-3-ol and 3-methylbutan-2-ol if secondary alcohol in (b)(i), or (1) for any two of those	**(3)**
	• 4 correct **(3)** • 3 correct **(2)** • 2 correct **(1)**	If no other mark awarded and if (b)(i) is blank or incorrect, allow (2) for any 4 different alcohols with formula $C_5H_{12}O$, (1) for 3 alcohols	

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iii)	• 	Allow structural formula or any combination of displayed and structural formula Allow + anywhere on structure or outside of a formula in a bracket Do not allow $C_2H_5O^+$/$C_2H_4OH^+$ Do not allow missing charge Allow CH_3C^+HOH if secondary alcohol identified in (b)(i)	**(1)**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(b)(iv)</td><td>• 
(1)
• because this is the only alcohol with a branched chain <u>and</u> forms $CH_2OHCH_2^+$ / $C_2H_4OH^+$ / peak at 45 / fragment identified in (b)(iii)
(1)</td><td>Allow any type of identification, including name 3-methylbutan-1-ol

Ignore incorrect name with correct structure

Conditional on correct identification
Ignore missing charge on fragment

Allow reasons why the others are not correct e.g. not pentan-1-ol as it is not branched <u>and</u> not 2-methylbutan-1-ol or 2,2-dimethylpropan-1-ol as they do not form $CH_2OHCH_2^+$

If secondary alcohol identified in (b)(i):
Allow 3-methylbutan-2-ol (1) as it is the only alcohol with a branched chain that forms CH_3C^+HOH (1)</td><td>(2)</td></tr>
</table>

Q16.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(i)</td><td>• evaluation of number of moles of nitrogen (1)

• conversion of pressure and temperature to correct units (1)

• rearrangement of ideal gas equation so $V = nRT \div P$ and evaluation of volume
(1)

• answer converted into cm^3
(1)</td><td><u>Example of calculation</u>:

n = 0.42 ÷ 28 = 0.015 (mol)

120 kPa = 120 000 Pa, 20°C = 293 K

$V = \frac{0.015 \times 8.31 \times 293}{120\,000}$
$= 3.0435 \times 10^{-4}$ (m^3)

$= 3.0435 \times 10^{-4} \times 10^6$
= 304 (cm^3)

Ignore SF except 1SF
TE throughout

Correct answer without working scores (4)</td><td>(4)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to • prevents oxidation (of the crisps)	Allow answers such as 'keep the crisps fresh' or 'prevents the crisps from going off/stale' Allow reference to 'crisps not reacting with nitrogen but will with air' Ignore reference to gas prevents crisps from getting squashed/broken Ignore nitrogen is less reactive than air/oxygen or nitrogen is inert Ignore reference to effects of moisture	(1)

Q17.

Question Number	Answer		Additional Guidance	Mark
(i)	• calculate percentage of carbon	**(1)**	Example of calculation: 100 – (34.0 + 54.5) = 11.5%	**(3)**
	• division of all percentages by atomic mass	**(1)**	Cl 34.0 / 35.5 = 0.95775 F 54.5 / 19.0 = 2.8684 C 11.5 / 12.0 = 0.95833	
	• find simplest ratio and give empirical formula	**(1)**	Cl (0.95775 / 0.95775 = 2.9949) = 1 F (2.8684 / 0.95775 = 2.9949) = 3 C (0.95833 / 0.95775 = 2.9949) = 1 So CF_3Cl / $CClF_3$ Allow any order Correct answer with no working scores (3) Ignore significant figures throughout.	

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • molecular ion peak at 104 / 106 (which matches the mass of the empirical formula)	Do not award statements stating that the molecular ion peak is at 105 or at 104.5, unless this is a calculated average.	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	• correct ion	CF_3^+ Do not award CF_3 with no plus.	**(1)**

Q18.

Question Number	Answer	Additional Guidance	Mark
(i)	• calculation of M_r of Na_2CO_3	Example of calculation $= (2 \times 23) + 12 + (3 \times 16) = 106$ Correct answer with no working scores (1)	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of mass of water in 1 mole of $Na_2CO_3{\cdot}xH_2O$ and calculation of x.	Example of calculation $= \frac{286 - 106}{18} = 10$ Correct answer with no working scores (1) Ignore SF Allow TE on incorrect M_r from 2(c)(i)	(1)

Q19.

Question Number	Answer	Additional Guidance	Mark
	Method 1 • **(M1)** mass of benzoic acid in 50 cm^3 **(1)** • **(M2)** no. of moles of benzoic acid in 50 cm^3 **(1)** OR Method 2 • **(M1)** moles of benzoic acid in 1000 cm^3 **(1)** • **(M2)** no. of moles of benzoic acid in 50 cm^3 **(1)** then • **(M3)** evaluation of the number of molecules of benzoic acid in 50 cm^3 **(1)**	Example of calculation m=(1.70 x 0.05=)0.0850 (g) n=(0.0850 ÷ 122=) 6.967 ... x 10^{-4} (mol) n=(1.70 ÷ 122 =) 0.01393... (mol) n=(0.01393... x 0.05 =) 6.967 ... x 10^{-4} (mol) N= (6.967 ...x 10^{-4} x 6.02 x 10^{23}=) =4.19 x 10^{20} / 4.2 x 10^{20} Ignore sf except 1sf Penalise excessive (6+) SF Allow use of 6.0 x 10^{23} to give 4.18 x 10^{20} for (3) Correct final answer without working scores (3) TE throughout	**(3)**

Q20.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• calculation of ratio of volumes before and after cooling **(1)** • calculation of temperature of warm syringe **(1)**	Example of calculation $\frac{24}{22}$ = 1.091 / 1.0909... 1.0909 x 298 = 325 **K** / 325.09090909 **K** / 52°C Use of pV = nRT giving 325 K scores 2 Correct answer with no working scores 2 If candidate assumes P = 100000 / 101000 and uses pV = nRT to find T = 315 / 318 K award 1. Ignore SF except 1 SF	**(2)**

Q21.

Question Number	Answer	Additional Guidance	Mark
	An answer that give evidence of the following:	Multiple correct methods are possible which process the data in different sequences. The correct final answer is 1.34×10^{22} / 1.338×10^{22} which can be awarded (3) regardless of working If this answer is not given then look for evidence of each of the given mathematical processes and give one mark for each	**(3)**
	• use of **both** densities to get two masses **and** division by 18 to give moles **(1)**	The use of both densities must be carried out **first** Note that the use of 5 for the mass of water implies the use of a density of 1.00 g cm^{-3}	
	• subtraction to give either mass or moles or number of molecules **(1)**	Depending on the method used this can be done at the beginning, the middle or at the end of the calculation but **must** be of (water – ice)	
	• multiplication by Avogadro constant to give number of molecules **(1)**	This must be evidenced **after** moles have been calculated Allow TE throughout Ignore SF except 1SF for the final answer Allow use of 6×10^{23} which gives 1.33×10^{22} for (3) Correct answer without working scores (3) Do not allow a number of molecules <1	

	Marking points Subtraction (1) Use of both densities and division by 18 to give moles (1) Multiplication by Avogadro constant (1) **or** Multiplication by Avogadro constant (1) Use of both densities and division by 18 to give moles (1) Subtraction (1) **or** Use of both densities and division by 18 to give moles (1) Subtraction (1) Multiplication by Avogadro constant (1)	Example of calculation vs1 m(water) = (5 x 1.00) − (5 x 0.92) = 0.40 (g) n(H_2O) = (0.40 ÷ 18) = 0.022222 / 2.2222 x 10^{-2} (mol) N = (2.2222 x 10^{-2} x 6.02 x 10^{23}) =1.34 x 10^{22} / 1.338 x 10^{22} Example of calculation vs2 N(water molecules) = ((5x 1) ÷ 18) x 6.02 x 10^{23} = 1.667 x 10^{23} N(ice molecules) = ((5 x 0.92) ÷ 18) x 6.02 x 10^{23} = 1.533 x 10^{23} N(Extra) = 1.667 x 10^{23} – 1.533 x 10^{23} = 1.34 x 10^{22} Example of calculation vs3 n(water) = ((1.00 x 5.00) ÷ 18) = 0.27778 (mol) n(ice) = ((0.92 x 5.00) ÷ 18) = 0.25556 (mol) Difference in mol = (0.27778 − 0.25556) = 0.022222(mol) Extra molecules = 0.022222 x 6.02 x 10^{23} = 1.34 x 10^{22}	

Q22.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• converts temperature to Kelvin and pressure to Nm^{-2} (Pa) **(1)** • rearranging ideal gas equation and substituting **their** values **(1)** • evaluates answer to 2 SF and includes units **(1)**	Examples of calculation 60 °C = 333 K 500 kPa = 5×10^5 / 500 000 Pa $V = \frac{nRT}{P}$ $V = 1 \times 8.31 \times 333/500\,000$ $= 5.53446 \times 10^{-3}$ $= 0.0055\ m^3 / 5.5 \times 10^{-3}\ m^3$ / 5.5 dm^3 / 5500 cm^3 allow TE answers to 2 SF only correct answer with no working scores 3 marks correct answer with incorrect working scores 2 marks max.	**(3)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• calculates M_r to 2 or more SF **(1)** • identifies element X **(1)**	Example of calculation: molar mass = mass in 24000 cm^3 = 1.42 x 24000/1000 = 34 (.08) (g mol^{-1}) ignore SF except 1 SF (X + (3 x 1)) = 34 X = 31 so P / phosphorus just 'phosphorus' with no working scores M2 only	**(2)**

Q23.

Question Number	Answer	Additional Guidance	Mark
(i)	• conversion of pressure, volume and temperature to correct units **(1)** • rearrangement of ideal gas equation so n=PV ÷ RT and calculation of n **(1)** • conversion of answer into mass to 2/3 SF **(1)**	Example of calculation: 207kPa = 207 000 Pa 8.98 dm^3 = 0.00898 m^3, 20°C = 293 K $n = \frac{207\,000 \times 0.00898}{8.31 \times 293} =$ = 0.7634... = 0.7634.... x 28 = 21.37647.. = 21.4 / 21 (g) Correct answer with no working scores 3 TE on both parts of the calculation	**(3)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• The temperature increase will result in an increase in pressure because p is (directly) proportional to T (at constant volume and moles of gas)	Allow $p \propto T$ Reference to p=nRT/V	**(1)**