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)**	<u>example of calculation</u> 0.5 cm^3 in 50 cm^3 % uncertainty = $\frac{0.5}{50} \times 100 = 1\%$ mass of gas = 107.655 – 107.563 = 0.092 g uncertainty = 0.0005 x 2 0.001 g in 0.092 g % uncertainty = $\frac{0.001}{0.092} \times 100$ = 1/1.1/1.09/1.08696 % Ignore uncertainties added together Do not award calculation of uncertainty in each mass <u>reading</u> (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)**	example of calculation 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)**

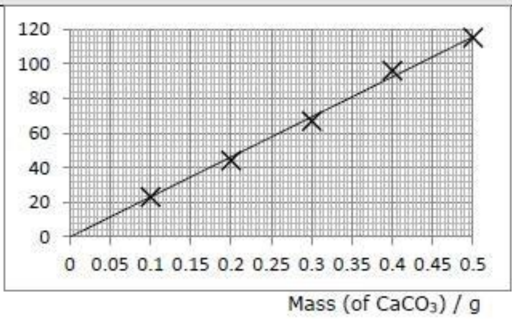
Question Number	Acceptable Answer	Additional Guidance	Mark
(d)	an answer that makes reference to the following point: water (vapour) would decrease/affect molar mass OR gas is now a mixture so would decrease/affect molar mass	Ignore gas may dissolve in water Do not award water may react with gas in syringe 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	<u>Example of calculation</u> 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)**	<u>Example of calculation</u> 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  	**(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 x 10^{23} = 7.224 x 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 x 10^{23} scores 1 (used 55.2 g) 7.224 x 10^{20} scores 1 (used 0.0552 g)	**(2)**

Q4.

Question Number	Answer	Additional Guidance	Mark
	• rearrangement of the ideal gas equation (1) • conversion of volume into m^3 and conversion of pressure into pascals (1) • calculation of number of moles (1) • calculation of molar mass (1) • deduction of formula of **X** (1)	<u>Example of calculation</u> $n = \frac{pV}{RT}$ $V = 0.000132$ (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)**	<u>example of calculation</u> 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)**	Example of calculation 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)** rearrange $pV = nRT$ and finds number of moles **(1)** finds molecular mass **(1)** finds molecular formula **(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} $n = \dfrac{100000 \times (73.6/1000000)}{8.31 \times 473} = 0.001872$ or 1.872473×10^{-3} (mol) $M_r = \dfrac{0.500}{1.872473 \times 10^{-3}} = 267.03$ $\dfrac{267.03}{27.0 + (35.5 \times 3)} = 2$ 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)**	<u>Example of diagram</u>  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 / 1.3572×10^{-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 / 2.5×10^{-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
		Example of calculation:	(2)
	• evaluation of the number of moles of S and F (1)	n(S) = (45.79 ÷ 32.1) = 1.426 n(F) = (54.21 ÷ 19.0) = 2.853	
	• evaluation of ratio 1 : 2 and empirical formula (1)	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	

Q11.

Question Number	Acceptable Answer		Additional Guidance	Mark
	An answer that makes reference to the following points:		Example of calculation	(4)
	• calculation of moles of carbon/carbon dioxide	(1)	Moles of carbon dioxide = 3.14 ÷ 44 = 0.071364 (mol) Moles of carbon = 0.071364 (mol)	
	• calculation of moles of water	(1)	Moles of water = 1.29 ÷ 18 = 0.071667 (mol)	
	• calculation of moles of hydrogen	(1)	Moles of hydrogen = 0.071667 x 2 = 0.14333 (mol)	
	• calculation of empirical formula	(1)	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	

Q12.

Question Number	Answer	Additional Guidance	Mark
(i)	• **(M1)** calculation of mole fractions **(1)**	<u>Example of calculation</u> 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	**(5)**
	• **(M2)** calculation of partial pressures **(1)**	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	
	• **(M3)** expression of K_p **(1)**	$K_p = \frac{(P_{SO_3})^2}{(P_{SO_2})^2 \times P_{O_2}}$ Do not award square brackets	
	• **(M4)** calculation of value of K_p **(1)**	$K_p = \frac{2.316^2}{0.048^2 \times 0.036}$ = 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	
	• **(M5)** units **(1)**	atm^{-1}	
		Correct final answer without working scores	(5)

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of the number of molecules	<u>Example of calculation</u> 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) $\frac{138.2}{71.9} \times 28.1 = 54$ (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>

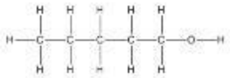
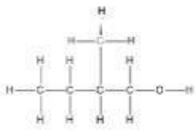
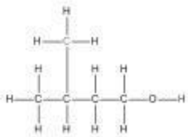
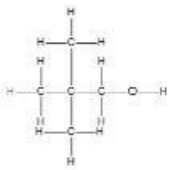
Q14.

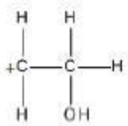
Question Number	Answer	Additional Guidance	Mark
	• **M1** conversion of pressure and temperature (1) • **M2** conversion of volume units (1) • **M3** rearrangement of gas equation and calculation of n (1) • **M4** calculation of the molar mass with the final answer given to **2 or 3 SF** (1)	Example 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)**

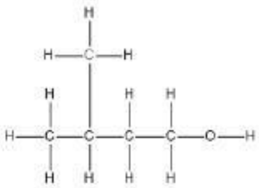
Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)	• calculation of empirical formula **(1)** • uses molecular ion to prove molecular formula **(1)** **or** • calculation of percentage of each element in compound all 3 correct scores **(2)** any 2 correct scores **(1)** **or** • calculation of the number of atoms of each element directly all 3 correct scores **(2)** any 2 correct scores **(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 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** % 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** 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	**(2)**

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)

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(iv)	•  **(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)**	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)	**(2)**

Q16.

Question Number	Answer	Additional Guidance	Mark
(i)	• 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)**	<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)	**(4)**

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)** • division of all percentages by atomic mass **(1)** • find simplest ratio and give empirical formula **(1)**	Example of calculation: 100 – (34.0 + 54.5) = 11.5% Cl 34.0 / 35.5 = 0.95775 F 54.5 / 19.0 = 2.8684 C 11.5 / 12.0 = 0.95833 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.	**(3)**

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=$(1.70 \times 0.05=)0.0850$ (g) n=$(0.0850 \div 122=)$ $6.967 \ldots \times 10^{-4}$ (mol) n=$(1.70 \div 122 =)$ 0.01393... (mol) n=$(0.01393\ldots \times 0.05 =)$ $6.967 \ldots \times 10^{-4}$ (mol) N= $(6.967 \ldots \times 10^{-4} \times 6.02 \times 10^{23}=)$ $=4.19 \times 10^{20}$ / 4.2×10^{20} Ignore sf except 1sf Penalise excessive (6+) SF Allow use of 6.0×10^{23} to give 4.18×10^{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)**	<u>Example of calculation</u> $\frac{24}{22}$ = 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)	<u>Example of calculation vs1</u> 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} <u>Example of calculation vs2</u> 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} <u>Example of calculation vs3</u> 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 x 10^5 / 500 000 Pa $V = \frac{nRT}{P}$ V = 1 x 8.31 x 333/500 000 = 5.53446 x 10^{-3} = 0.0055 m^3/5.5 x 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)**