Formulae, Equations and Amounts of Substance - Mark Scheme

Q1.

Question number	Answer	Additional guidance	Mark
(a)	An explanation that makes reference to the following points: • (I) is incorrect because the solutions are aqueous **or** ions are (in the) aqueous (state) the state symbols should be (aq) instead of (I) • silver ions should have one positive charge / Ag^+ **or** silver chloride is AgCl	Allow silver nitrate and sodium chloride are aqueous Do not award if incorrect state symbol for one of the species in the equation e.g. Ag is (s) / AgCl is (aq) Ignore just the charge on the silver ion is incorrect / the formula of silver chloride is incorrect	(2)

Question number	Answer	Additional guidance	Mark
(b)	• calculation of mol of C, H and Cl **(1)** • calculation of empirical formula **(1)** • calculation of molecular formula **(1)**	Example of calculation: C : H : Cl mol $\frac{3.09}{12} : \frac{0.26}{1} : \frac{9.15}{35.5}$ = 0.2575 : 0.26 : 0.2577 (ratio 1 : 1 : 1) Empirical formula is CHCl molar mass CHCl = 12 + 1 + 35.5 = 48.5 $\frac{\text{molar mass } (CHCl)_n}{\text{molar mass CHCl}} = \frac{97}{48.5} = 2$ Molecular formula is $C_2H_2Cl_2$ Allow symbols in any order Do not award 2CHCl Ignore SF in mol and ratio Correct molecular formula with some working scores (3) **Alternative method** scores (3) no. C atoms = $\frac{3.09 \times 97}{12.5 \times 12} = 2 / 1.9982$ no. H atoms = $\frac{0.26 \times 97}{12.5 \times 1} = 2(.0176)$ no. Cl atoms = $\frac{9.15 \times 97}{12.5 \times 35.5} = 2$	(3)

Question number	Answer	Additional guidance	Mark
(c)(i)	• all 4 ion formulae • all 4 (corresponding) *m* / *z* values	Example of answer: ions *m* / *z* $N(^{35}Cl)_3^+$ 119 $N(^{35}Cl)_2{}^{37}Cl^+$ 121 $N^{35}Cl(^{37}Cl)_2^+$ 123 $N(^{37}Cl)_3^+$ 125 Allow any other unambiguous way of representing the formulae e.g. in words Allow (1) for any two *m* / *z* values with corresponding ion formulae Ignore missing / incorrect charge on ion Ignore mass number on N Ignore bonds or + between Cl atoms / order of atoms e.g. $N\text{-}^{35}Cl\text{-}^{35}Cl\text{-}^{35}Cl$	(2)

Q2.

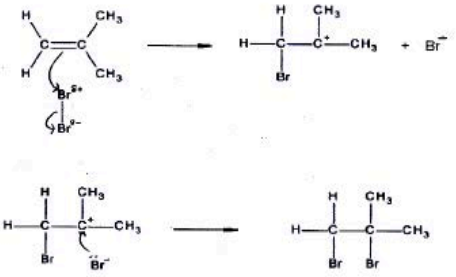
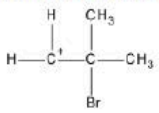
Question number	Answer	Additional guidance	Mark
(a)(i)	• dot-and-cross diagram	Example of dot-and-cross diagram:  Allow overlapping circles Allow all dots / all crosses Allow dots and crosses in any order in the triple bond Allow the dots and crosses side-by-side in the triple bond e.g. x o x o x o Allow the non-bonded electrons on each N shown separately Ignore inner shell electrons, even if incorrect Ignore lines as bonds e.g. x x x o o o	(1)

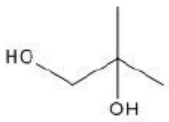
Question number	Answer	Additional guidance	Mark
(a)(ii)	• calculation of moles of nitrogen atoms • calculation of number of nitrogen atoms	Example of calculation: mol $N_2 = \frac{5.60}{28} = 0.20$ **and** mol N atoms = 0.20 x 2 = 0.40 **or** $\frac{5.60}{14} = 0.40$ number of N atoms = $0.40 \times 6.02 \times 10^{23}$ $= 2.408 \times 10^{23} / 2.41 \times 10^{23} / 2.4 \times 10^{23}$ TE on moles of nitrogen Ignore SF except 1SF Correct answer with no working scores (2)	(2)

Question number	Answer	Additional guidance	Mark
(a)(iii)	• conversion of volume to m^3 **(1)** • conversion of temperature to K **(1)** • rearrangement of ideal gas equation **(1)** • evaluation to give n **(1)**	Example of calculation: volume of $N_2 = \frac{108}{1 \times 10^6} = 1.08 \times 10^{-4}$ m^3 temperature = 25 + 273 = 298 K $n = \frac{pV}{RT}$ **or** $n = \frac{1.36 \times 10^5 \times 1.08 \times 10^{-4}}{8.31 \times 298}$ TE on volume and temperature $n = 5.9312 \times 10^{-3}$ / 0.0059312 (mol) Conditional on correctly rearranged equation in M3 Ignore SF except 1SF Correct answer with no working scores full marks	**(4)**

Q3.

Question number	Answer	Additional guidance	Mark
3(a)	• CH_2	Allow H_2C Ignore C_nH_{2n} / C_4H_8 Do not award C_3H_6	**(1)**

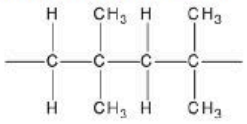
Question number	Answer	Additional guidance	Mark
3(b)	• dipole on bromine molecule **and** final product **(1)** • curly arrow from C=C to Br **and** curly arrow from Br-Br to, or just beyond, Br **(1)** • intermediate **(1)** • lone pair on Br^- **and** curly arrow from lone pair to positive charge **(1)**	Example of mechanism:  Allow intermediate with positive charge on other carbon atom  Allow full marks for using formula 2 / any combination of structural and displayed formula Penalise half arrow heads once only Do not award δ+ on intermediate in M3 Do not award δ- on Br in M4	**(4)**

Question number	Answer	Additional guidance	Mark
3(c)(i)	• skeletal formula	Example of skeletal formula:  Ignore bond lengths and bond angles Do not allow O-H-C horizontally	(1)

Question number	Answer	Additional guidance	Mark
3(c)(ii)	• (From)purple (to) colourless	Both colours needed for the mark Allow pink or violet for purple Ignore clear	(1)

Question number	Answer	Additional guidance	Mark
3(c)(iii)	• hydrogen bromide / HBr	Ignore state symbols (g) / (l) / (aq) / (s) Do not award bromine	(1)

Question number	Answer	Additional guidance	Mark
3(c)(iv)	An explanation that makes reference to the following points: • (2-bromo-2-methylpropane is formed from a) tertiary carbocation / tertiary intermediate **(1)** • (tertiary carbocation / intermediate) is more stable than primary (carbocation) **or** a tertiary carbocation is the **most** stable **(1)**	Allow a description of a tertiary carbocation Do not award secondary carbocation for M1 Allow primary carbocation is less stable than tertiary Allow secondary carbocation is more stable than primary, if secondary carbocation identified in M1 Ignore just 'tertiary carbocation is more stable' Ignore any explanation of why one cation is more stable than another Ignore any reference to Markovnikov's rule Do not award tertiary **product** is more stable (than primary)	(2)

Question number	Answer	Additional guidance	Mark
3(d)	• 4 carbon atoms linked by single bonds **and** both extension bonds **(1)** • rest of structure correct **(1)**	Example of repeat units:  Allow any combination of structural and displayed formulae or skeletal formulae Do not award 1, or more than 2, repeat units / 2 separate repeat units in M1 Penalise one or both extension bonds missing in M1 only M2 is conditional on M1 **or** 1 or more than 2 repeat units / 2 separate repeat units Allow both methyl groups on carbons one and three or two and three or one and four Ignore any brackets and any 'n's or numbers Ignore bond lengths and bond angles Ignore connectivity of CH_3 groups	**(2)**

Question number	Answer	Additional guidance	Mark
3(e)	• calculation / working of mol of alcohol **(1)** • calculation / working of mol of alkene if 58.2% **(1)** • calculation / working of mass of alkene **(1)** • answer given to 2 or 3 SF **(1)** **Alternative method for M2 and M3** • calculation / working of theoretical mass of alkene **(1)** • calculation / working of actual mass of alkene **(1)**	Example of calculation: mol alcohol used = $\frac{6.85}{74}$ = 0.092568 / 9.2568 x 10^{-2} mol alkene if 58.2% = 0.092568 x $\frac{58.2}{100}$ = 0.053874 / 5.3874 x 10^{-2} TE on mol alcohol mass alkene = 0.053874 x 56 = 3.017 (g) TE on mol alkene answer to 2 or 3 SF = 3.0 / 3.02 (g) Conditional on working involving 74 and 56 Correct answer to 2 or 3SF with or without working scores (4) **Alternative method for M2 and M3** mass alkene if 100% = 0.092568 x 56 = 5.1838 (g) TE on mol alcohol mass alkene if 58.2% = 5.1838 x $\frac{58.2}{100}$ = 3.017 (g) TE on theoretical mass	**(4)**

Q4.

Question number	Answer	Additional guidance	Mark
(a)	• $[Ar]3d^{10}4s^24p^5$	Allow $4s^23d^{10}4p^5$ Ignore $1s^22s^22p^63s^23p^6$ for (Ar) written out but do not allow incorrect electronic configuration for Ar	1

Question number	Answer					Additional guidance	Mark
(b)(i)						1 mark for each row correct	2
	Species	Protons	Neutrons	Electrons			
	^{79}Br	35	44	35	(1)		
	$^{81}Br^-$	35	46	36	(1)		

Question number	Answer	Additional guidance	Mark
(b)(ii)	• calculation of amount (mol) of Br_2 (1) • calculation of molecules of Br_2 (1)	Example of calculation: Amount of Br_2 = $\frac{2.00}{160}$ = 0.0125 (mol) Molecules of Br_2 = $0.0125 \times 6.02 \times 10^{23}$ = 7.525×10^{21} or Amount of Br_2 = $\frac{2.00}{(2 \times 79.9)}$ = 0.012516 (mol) Molecules of Br_2 = $0.012516 \times 6.02 \times 10^{23}$ = 7.5344×10^{21} TE on amount Br_2 Correct answer with no working scores both marks Ignore SF except 1 SF	2

Question number	Answer	Additional guidance	Mark
(c)	• conversion of volume to m^3 (1) • conversion of temperature to K (1) • rearrangement of expression (1) • evaluation to give n (1)	Example of calculation: Volume of bromine = $\frac{200}{1 \times 10^6}$ = 2.00×10^{-4} m^3 77+273 = 350 $1.51 \times 10^5 \times 2.00 \times 10^{-4} = n \times 8.31 \times 350$ TE on volume bromine $n = \frac{1.51 \times 10^5 \times 2.00 \times 10^{-4}}{8.31 \times 350}$ $n = 1.03834 \times 10^{-2}$ Ignore SF except 1SF Correct answer with no working scores full marks	4

Q5.

Question number	Answer	Mark
	C 30.0	1

Q6.

Question number	Answer	Mark
	C 0.20	1

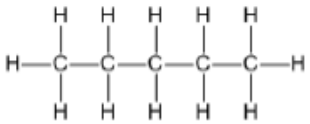
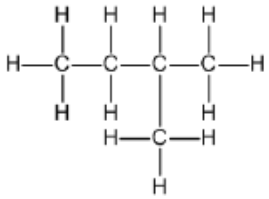
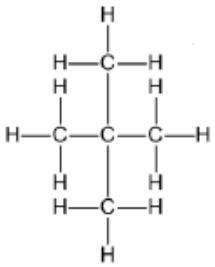
Q7.

Question number	Answer	Mark
	B C_5H_{12}	1

Q8.

Question number	Answer	Mark
	B (C_4H_7Cl)	1

Q9.

Question number	Answer		Additional guidance	Mark
(a)	• 	(1)	Allow CH_3 in branches	3
	• 	(1)	Allow 2 marks for 3 correct structural or skeletal formulae or any combination of these	
	• 	(1)		

Question number	Answer	Additional guidance	Mark
(b)	• 2,4-dimethylhexane	Ignore punctuation errors	1

Question number	Answer		Additional guidance	Mark
(c)	• molecular formula: C_5H_{12}	(1)		2
	• boiling temperature 25 - 40 °C	(1)	Allow any temperature or range within the given range	

Question number	Answer	Additional guidance	Mark
(d)(i)	• $C_3H_8 + 3½O_2 \rightarrow C + CO + CO_2 + 4H_2O$	Allow multiples Ignore state symbols, even if incorrect	1

Question number	Answer		Additional guidance	Mark
(d)(ii)	An explanation that makes reference to the following points:			2
	• (carbon monoxide) reacts with haemoglobin (in the blood)	(1)	Allow forms carboxyhaemoglobin	
	• preventing it from carrying oxygen (around the body).	(1)		

Question number	Answer		Additional guidance	Mark
(e)(i)	• $C_3H_8 + Cl\bullet \rightarrow C_3H_7\bullet + HCl$	(1)	Allow equations in either order Penalise missing • once only	2
	• $C_3H_7\bullet + Cl_2 \rightarrow C_3H_7Cl + Cl\bullet$	(1)		

Question number	Answer	Additional guidance	Mark
(e)(ii)	• the products are 1-chloropropane and 2-chloropropane	Allow any unambiguous formulae Ignore molecular formulae	1

Question number	Answer	Additional guidance	Mark
(e)(iii)	• the chlorine free radical can remove a hydrogen from either the end carbon atoms or the central carbon atom		1

Question number	Answer	Additional guidance	Mark
(e)(iv)	• two propyl (free) radicals react together or • $C_3H_7\bullet + C_3H_7\bullet \rightarrow C_6H_{14}$	Ignore just '(two free) radicals react together' Do not allow molecules/ions	1

Question number	Answer	Additional guidance	Mark
(e)(v)	• structure (1) • corresponding name (1)	Examples of structures and names: $CH_3CH_2CHCl_2$ 1,1-dichloropropane $CH_3CHClCH_2Cl$ 1,2-dichloropropane $CH_3CCl_2CH_3$ 2,2-dichloropropane $CH_2ClCH_2CH_2Cl$ 1,3-dichloropropane Allow displayed, structural or skeletal formulae or any combination of these	2

Q10.

Question number	Answer	Mark
	The only correct answer is A ($Ca + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2$) **B** *is incorrect because the formulae of nitric acid and calcium nitrate are incorrect* **C** *is incorrect because the formula of nitric acid is incorrect* **D** *is incorrect because the formula of calcium nitrate is incorrect*	(1)

Q11.

Question number	Answer	Mark
	The only correct answer is B (0.424 g) **A** *is incorrect because this is the answer using a molar mass of 83 g mol^{-1} from $NaCO_3$* **C** *is incorrect because this is the answer just using the volume and a concentration of 1 mol dm^{-3}* **D** *is incorrect because this is the answer just using the concentration and not the volume*	(1)

Q12.

Question number	Answer	Mark
	The only correct answer is A (6.0×10^{-2} g) ***B*** *is incorrect because* 12×10^{-6} *has been multiplied by 5 instead of 5000* ***C*** *is incorrect because* 12×10^{-6} *has been divided by 5 instead of multiplied by 5000* ***D*** *is incorrect because* 12×10^{-6} *has been divided by 5000 instead of multiplied*	**(1)**

Q13.

Question number	Answer	Mark
	The only correct answer is A ($0.36\ dm^3$) ***B*** *is incorrect because the 2:1 mole ratio has not been used* ***C*** *is incorrect because the mole ratio has been used as 1:2 instead of 2:1* ***D*** *is incorrect because the mass has not been converted to moles*	**(1)**

Q14.

Question number	Answer	Mark
	D 1.2 dm^3 of nitrogen, N_2, and 1.2 g of magnesium, Mg	1

Q15.

Question number	Answer	Additional guidance	Mark
(a)(i)	• correct balanced ionic equation with state symbols	Examples of equation: $MgO(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2O(l)$ or $MgO(s) + 2H_3O^+(aq) \rightarrow Mg^{2+}(aq) + 2H_2O(l)$	1

Question number	Answer		Additional guidance	Mark
(a)(ii)	• calculation of moles of MgO	(1)	Example of calculation: moles MgO = $\frac{2.45}{40.3}$ = 0.060794	3
	• calculation of moles of HCl	(1)	moles HCl = 2 × 0.060794 = 0.121588	
	• calculation of volume of HCl	(1)	volume HCl = 0.121588 × $\frac{1000}{2.00}$ = 60.794 cm^3 Ignore SF except 1 SF Allow use of A_r(Mg) = 24 (61.25 cm^3) Correct answer with no working scores full marks	

Question number	Answer		Additional guidance	Mark
(b)	Either • calculation of moles of $MgCO_3$	(1)	Example of calculation: moles $MgCO_3$ = $\frac{2.25}{84.3}$ = 0.02669	2
	• calculation of mass of $MgCl_2$	(1)	mass $MgCl_2$ = 0.02669 × 95.3 = 2.5436 (g)	
	or		or	
	• use of both molar masses	(1)	84.3 g $MgCO_3$ makes 95.3 g $MgCl_2$	
	• calculation of mass of $MgCl_2$	(1)	so 2.25 g $MgCO_3$ makes $\frac{95.3}{84.3}$ × 2.25 = 2.5436 (g) $MgCl_2$ Ignore SF except 1 SF Allow use of A_r(Mg) = 24 (2.5446 g) Correct answer with no working scores full marks	

Question number	Answer	Additional guidance	Mark
(c)	An explanation that makes reference to the following points: • (in the reaction with magnesium oxide) there are fewer waste products/no carbon dioxide is released/water is the only waste product (1) • so the molar mass of all products is lower/the denominator of the equation for atom economy is lower (1) or • 1 mol of magnesium compound produces 1 mol of magnesium chloride (1) • but the M_r of magnesium carbonate is greater than the M_r of magnesium oxide/carbon dioxide is an additional waste product from magnesium carbonate. (1)	Ignore calculations Allow reverse arguments	2