Question Number	Answer	Mark
1	**The only correct answer is A** ($C_{10}H_8$) ***B*** *is incorrect because there are only 8 hydrogens, one on each of the carbons which are not linking the two rings* ***C*** *is incorrect because there are only 10 carbons and 8 hydrogen atoms* ***D*** *is incorrect because there are only 10 carbons and 8 hydrogen atoms*	**(1)**

Question Number	Answer	Mark
17	**The only correct answer is C** (water, carbon dioxide and sulfur dioxide) ***A*** *is not correct because no hydrogen can be produced* ***B*** *is not correct because no hydrogen chloride can be produced* ***D*** *is not correct because no hydrogen can be produced*	**(1)**

Question Number	Answer	Mark
10	**The only correct answer is C** ($Cu + 2AgNO_3 \rightarrow Cu(NO_3)_2 + 2Ag$) ***A*** *is incorrect because atom economy is 59.4%* ***B*** *is incorrect because atom economy is 65.8%* ***D*** *is incorrect because atom economy is 91.2%*	**(1)**

Question Number	Answer	Mark
13	**The only correct answer is A** (BF_3) ***B*** *is incorrect because there are four bonding pairs of electrons which repel equally* ***C*** *is incorrect because there are two bonding pairs of electrons which repel less strongly than the two lone pairs* ***D*** *is incorrect because there are three bonding pairs of electrons which repel less strongly than the lone pair*	**(1)** **Computer**

Question Number	Answer	Mark
8	**The only correct answer is C** (51%) ***A*** *is incorrect because this is the molecular mass of ethanol ÷ total mass of products × 100* ***B*** *is incorrect because this is the percentage by mass of carbon dioxide* ***D*** *is incorrect because this is the ratio of the mass of carbon dioxide to the mass of ethanol × 100*	**(1)**

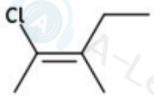
Question Number	Answer	Mark
8	**The only correct answer is D** (87%) ***A*** *is incorrect because this is the atom economy of water* ***B*** *is incorrect because this is the economy by moles rather than by mass* ***C*** *is incorrect because this is the value ignoring the stoichiometry (balancing) of the equation for the products*	**(1)**

Question Number	Answer	Mark
14	**The only correct answer is A** (R—O—O—R → 2R—O•) ***B** is incorrect because in this step a radical and a molecule form a radical so this is a propogation step* ***C** is incorrect because in this step two radicals from a molecule, so this is a termination step* ***D** is incorrect because in this step a radical and a molecule form a radical so this is a propogation step*	**(1)**

Question Number	Answer	Mark
11	**The only correct answer is A** (ionic soluble high poor) ***B** is incorrect because ionic compounds usually have high melting temperatures and do not conduct as a solid* ***C** is incorrect because metallic structures are insoluble in water and usually have high melting temperatures* ***D** is incorrect because metallic stuctures have good electrical conductivity*	**(1)**

Question Number	Answer	Mark
1	**The only correct answer is B** (3.6×10^{23}) ***A** is incorrect because this is the number of molecules of carbon dioxide in 8.8 g* ***C** is incorrect because this is the number of molecules of carbon dioxide in 88 g* ***D** is incorrect because this is the number of atoms of carbon dioxide in 88 g*	**(1)**

Question Number	Answer	Mark
2	**The only correct answer is C**  ***A** is incorrect because the 2s orbital should contain 2 electrons* ***B** is incorrect the 2s orbital should contain 2 electrons and each 2p orbital should have one electron before any are doubled up* ***D** is incorrect because each 2p orbital should have one electron before any are doubled up*	**(1)**

Question Number	Answer	Mark
20	**The only correct answer is D** () ***A** is incorrect because the chlorine on C1 and the methyl on C2 are highest priority so E-* ***B** is incorrect because the chlorine on C1 and the ethyl on C2 are highest priority so E-* ***C** is incorrect because the bromine on C1 and the chlorine on C2 are highest priority so E-*	**(1)**

Question Number	Answer	Mark
8	**The only correct answer is C** ($11.34\ g\ cm^{-3}$) *A is incorrect because they have divided the A_r by the number of moles* *B is incorrect they have used the atomic number not the mass number* *D is incorrect because this is the number of moles*	**(1)**

Question Number	Answer	Mark
13	**The only correct answer is B** (PCl_3F_2) *A is incorrect because this is not symmetrical so must have a dipole* *C is incorrect because this is not symmetrical as the central equatorial chlorines are asymmetrical so must have a dipole* *D is incorrect because this is not symmetrical so must have a dipole*	**(1)**

Question Number	Answer	Mark
8	**The only correct answer is D** (buckminsterfullerene C_{60}) *A is incorrect because silver has a giant metallic lattice* *B is incorrect because sodium chloride has a giant ionic lattice* *C is incorrect because carbon has giant covalent lattice*	**(1)**

Question Number	Answer	Mark
2	**The only correct answer is B** (Mg^{2+}) *A is incorrect because the fluoride anion has fewer protons than magnesium* *C is incorrect because the sodium cation has fewer protons than magnesium* *D is incorrect because the oxide ion has fewer protons than magnesium*	**(1)** **Computer**

Question Number	Answer	Mark
10	**The only correct answer is D** (sulfur molecules have more electrons than phosphorus molecules) *A is incorrect because there is no electronegativity difference so no dipole in sulfur or phosphorus* *B is incorrect because the covalent bonds do not break during melting, only intermolecular forces between simple molecular structures are broken* *C is incorrect because sulfur has a simple molecular structure, S_8*	**(1)**

Question Number	Answer	Mark
3(a)	**The only correct answer is B** ($C_{10}H_{16}$) ***A*** *is not correct because there are 6 too few hydrogen atoms* ***C*** *is not correct because there are 2 extra hydrogen atoms* ***D*** *is not correct because there are 6 extra hydrogen atoms*	**(1)** **Computer**

Question Number	Answer	Mark
3(b)	**The only correct answer is D** (CH_2) ***A*** *is not correct because the wrong formula of limonene was used* ***B*** *is not correct because this is the empirical formula of* $C_{10}H_{18}$ ***C*** *is not correct because this is the empirical formula of* $C_{10}H_{16}$	**(1)** **Computer**

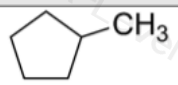
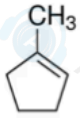
Question Number	Answer	Additional Guidance	Mark
19(a)(i)	• Expression for weighted mean for energy density **(1)** • calculation of energy density of sample to 2 or 3 SF **(1)**	example of calculation $\frac{(92.2 \times 46.5) + (29.7 \times 7.80)}{100}$ OR (92.2% × 46.5) + (7.8% × 29.7) = 45.190 = 45 / 45.2 (MJ kg^{-1}) Allow 45000 kJ kg^{-1} / 45200 kJ kg^{-1} Correct answer with or without working scores 2 marks	**(2)**

Question Number	Answer	Additional Guidance	Mark
19(a)(ii)	• calculation of mass of sample	example of calculation 0.729 × 1500 = 1093.5 / 1094 / 1090 / 1100 (g) Do not award 1093 (g)	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(a)(iii)	• calculation of energy released **and** correct units	example of calculation 1093.5 ÷ 1000 = 1.0935 45.190 × 1.0935 = 49.415 MJ Accept 49415 kJ Accept 4.9415× 10^7 J OR 1093.5 ÷ 1000 = 1.0935 38.1 × 1.0935 = 41.662 MJ Accept 41662 kJ Accept 4.1662 × 10^7 J Allow TE from (i) and (ii) Allow use of rounded values from (i) and (ii) Ignore SF except 1 SF Ignore negative signs Correct answer with no working scores the mark Comment – if a value is given in (a)(i), candidates can still use 38.1 to access the mark here	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(b)	An answer that makes reference to three of the following points: • (increased amount of) ethanol used could be bioethanol / ethanol sourced from plants **(1)** • from fermentation (of sugars / glucose using yeast) **(1)** • reducing CO_2 emissions (overall) / (some) CO_2 released in combustion offset by CO_2 used in photosynthesis **(1)** • less impact on global warming / climate change **(1)** • **uses less** of a finite resource (which can then be used in other processes e.g. manufacture of pharmaceuticals) **(1)** • less pollution from sulfur impurities / less SO_2 emissions **(1)**	Allow ethanol can be made from a renewable resource Ignore esterification of vegetable oils (biodiesel) Allow fermentation is a low energy process Allow bioethanol is (nearly) carbon neutral / has a lower carbon footprint Ignore 'crude oil is non-renewable' Comment – allow reverse arguments in context of E5	**(3)**

Question Number	Answer	Additional Guidance	Mark
19(c)(i)	An answer that makes reference to the following point: $C_6H_{14} \rightarrow C_6H_{12} + H_2$	Allow other types of correct formulae Allow $C_6H_{14} \rightarrow C_6H_{10} + 2H_2$ Allow multiples Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(c)(ii)		Allow skeletal, displayed or hybrid formulae mark for (c)(ii) could be evident in c(i) Allow methylcyclopentenes if C_6H_{10} is given in (c)(i) e.g.  No TE from (c)(i)	**(1)**

Question Number	Answer	Additional Guidance	Mark
19(d)(i)	An explanation that makes reference to the following points: • (to provide enough energy) to break Cl-Cl **bond(s)** / for homolytic fission of chlorine **(1)** • to form chlorine radicals / to form $Cl^{\bullet}$ **(1)**	Allow $Cl_2 \rightarrow 2Cl^{\bullet}$ for M2 Accept (to form chlorine radicals) without breaking the C-H bonds (in hexane) Do not award ions Do not award chloride radicals Comment  Scores M1 for LHS and M2 for RHS	**(2)**

Question Number	Answer	Additional Guidance	Mark
19(d)(ii)	An answer that makes reference to the following points: • equation for propagation step **(1)** • equation for termination step **(1)**	$Cl^{\bullet} + C_6H_{14} \rightarrow {}^{\bullet}C_6H_{13} + HCl$ $({}^{\bullet}C_6H_{13} + Cl_2 \rightarrow Cl^{\bullet} + C_6H_{13}Cl)$ $2{}^{\bullet}C_6H_{13} \rightarrow C_{12}H_{26}$ Allow $C_6H_{13}^{\bullet}$ for hexyl radical Do not award if additional termination equations are shown Penalise omission of unpaired electron once only Comment – if $C_{12}H_{26}$ used as the reactant alkane allow TE for M2 $2C_{12}H_{25}^{\bullet} \rightarrow C_{24}H_{50}$	**(2)**

(Total for Question 19 = 13 marks)

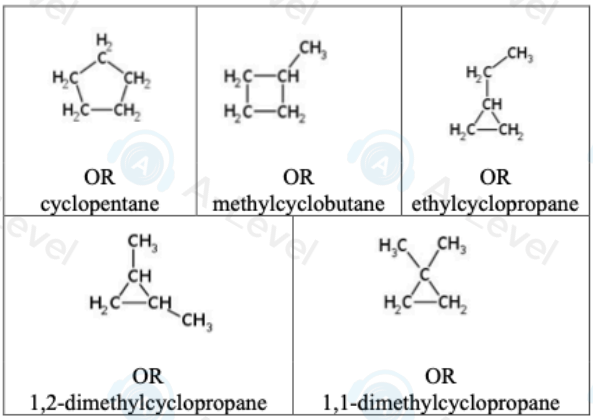
Question Number	Answer	Additional Guidance	Mark
24(a)(i) Clip all	• rearrangement of $pV = nRT$ **(1)** • conversion of dm^3 to m^3 **(1)** • substitution in correctly rearranged expression **(1)** • calculation of value of n **(1)**	Example of calculation $n = pV \div RT$ $V = 0.00179 / 1.79 \times 10^{-3}$ $n = (110\,000 \times 0.00179) \div (8.31 \times 473)$ Allow TE in M3 from incorrect conversion from dm^3 to m^3 $n = 0.0501$ (mol) / 5.01×10^{-2} (mol) / 0.050094 (mol) / 5.0094×10^{-2} (mol) / 0.05 (mol) / 5×10^{-2} (mol) Allow TE for M4 from incorrect values shown in a correctly rearranged expression Ignore SF throughout Correct answer with some working scores 4	**(4)**

Question Number	Answer	Additional Guidance	Mark
24(a)(ii)	• calculation of M_r of X	Example of calculation $M_r = 3.5 \div 0.0500 = 70$ Accept 69.869 Allow TE on incorrect moles in (a)(i) provided answer >1	**(1)**

Question Number	Answer	Additional Guidance	Mark
24(a)(iii)	• calculation of moles of carbon **and** moles of hydrogen **(1)** • calculation of ratio **and** gives empirical formula **(1)**	Example of calculation $85.7 \div 12 = 7.1417$ **and** $14.3 \div 1 = 14.3$ $14.3 \div 7.1417 = 2.0023$ CH_2 Ignore SF throughout Correct answer with no working scores (2)	**(2)**

Question Number	Answer	Additional Guidance	Mark
24(a)(iv)	• molecular formula	Example of calculation ans(a)(ii) ÷ ans(a)(iii) $70 \div 14 = 5$ C_5H_{10} Allow TE on (a)(ii) and (a)(iii) Answer with no working scores 1	**(1)**

Question Number	Answer	Additional Guidance	Mark
24(b)	An answer that makes reference to the following point: • no (C=C) double bonds are present / molecule is not unsaturated / molecule is not an alkene / only single bonds are present / molecule is saturated / molecule is an alkane	Allow it is a cycloalkane Ignore it does not contain oxygen	**(1)**

Question Number	Answer	Additional Guidance	Mark
24(c)	An answer that makes reference to the following points: • one possible structural isomer **(1)** • a second structural isomer **(1)**	 OR cyclopentane OR methylcyclobutane OR ethylcyclopropane OR 1,2-dimethylcyclopropane OR 1,1-dimethylcyclopropane Allow any type of displayed or skeletal formulae Allow 1-methylcyclobutane and 1-ethylcyclopropane If name and formula are given, both must be correct Allow TE on formula from (a)(iv) If answer in (b) is alkene, then allow 1 mark for two correct alkenes using formula in (a)(iv)	**(2)**

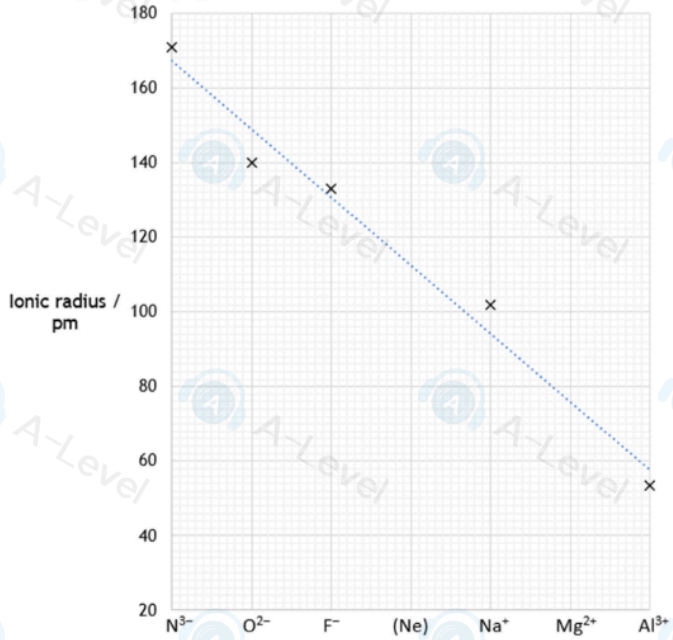
(Total for Question 24 = 11 marks)

Question Number	Answer	Additional Guidance	Mark
22(a)	An answer that makes reference to the following point: • to show that the electrons have opposite **spin**	Allow different **spin** Allow **spin** in different / opposite direction Award **spin** +½ and −½ Do not award spin/rotate around the nucleus in opposite direction Do not award references to attraction / positive charges	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(b)	An explanation that makes reference to the following points: • some of the electrons are in an s sub-shell / orbital **and** some electrons are in the p sub-shell / orbital **(1)** • (they don't have the same energy because) electrons in p sub-shell / orbital have higher energy **(1)**	Do not award s / p shell Accept reverse argument Allow mention of singular p orbital Do not award s / p shell Penalise use of s / p shell once only	**(2)**

Question Number	Answer	Additional Guidance	Mark
22(c)	An explanation that makes reference to the following points: • sphere / spherical **(1)**	Allow ball Do not award just circle / round Ignore diagrams	**(1)**

(Total for Question 22 = 4 marks)

Question Number	Answer	Additional Guidance	Mark
24(a)(i)	• axis labelled with unit **and** allowing the data to fill over half of y-axis **(1)** • 5 **points** in the table correctly plotted to within half a small square **(1)**	An example of the graph:  A scale of 30pm per large square does not score M1 Non-linear axes negate M1 **and** M2 – but an axis break is allowed NB trend line does not need to be present for M1 or M2 Ignore x-axis label even if incorrect Ignore point for Neon even if not on the line	**(2)**

Question Number	Answer	Additional Guidance	Mark
24(a)(ii)	• appropriate straight best fit line on graph **(1)** • value for Mg radius (read from graph) **(1)**	At least one point above and below the line Allow a line connecting N^{3-}, F^-, Al^{3+} Allow 70 – 80 (pm) Marks are independent	**(2)**

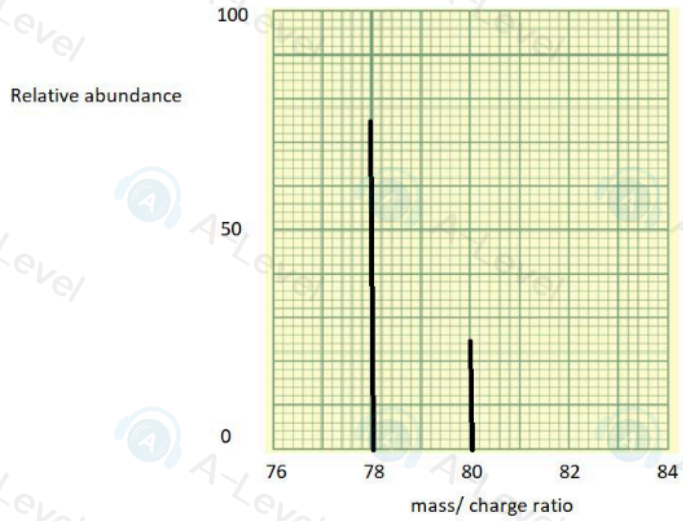
Question Number	Answer	Additional Guidance	Mark
24(a)(iii)	An explanation that makes reference to the following points: • (ionic) radius decreases (with (increasing) atomic number) **(1)** • because there are more protons (in the nucleus) **(1)** • and the ions are isoelectronic **(1)**	Must be a trend not a comparison for M1 Ignore "across the period" Do not award atomic radius Allow nuclear charge increases Ignore mass to charge ratio Ignore atomic number Ignore electrostatic force between electrons and nucleus is increasing (if no mention of protons) Accept there is no variation in shell/shielding / all have 10 electrons / the same number of electrons / same electronic configuration	**(3)**

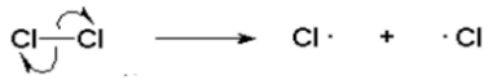
Question Number	Answer	Additional Guidance	Mark
24(b)(i)	An answer that makes reference to the following point: • **giant ionic** lattice	Allow crystal for lattice Allow giant ionic structure Do not award linear shape Do not award references to covalency or molecules Allow this answer given in 24(b)(ii) provided this is not negated by the 24(b)(i) answer	**(1)**

Question Number	Answer	Additional Guidance	Mark
24(b)(ii)	A description that makes reference to the following points: • sodium fluoride does not conduct electricity when **solid** **(1)** • sodium fluoride does conduct when in aqueous solution / molten **(1)** • because the ions cannot move (in a solid) **and** the ions are free to move when the substance is in solution / molten **(1)**	Allow poor conductor / insulator Ignore carry charge Allow because the ions are in fixed positions Do not award M3 if there is reference to sodium fluoride having delocalised electrons Must mention solutions **and** molten to gain all three marks	**(3)**

Question Number	Answer	Additional Guidance	Mark
24(b)(iii)	An explanation that makes reference to the following points: • the fluoride ion has a single charge **and** a small (ionic) radius / size **(1)** • so the electron cloud is difficult to **distort** **(1)**	Allow opposite argument i.e. ions that are large and bigger charges are easy to polarise, but you can't polarise fluoride due to its size and charge for M1 Allow small/low charge Allow small size Ignore low size Do not award M1 for atomic radius Ignore comments about electronegativity Allow "it is difficult to **distort**" Marks are independent	**(2)**

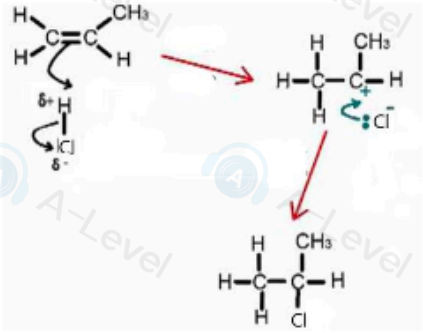
(Total for Question 24 = 13 marks)

Question Number	Answer	Additional Guidance	Mark
19(a)	A description that makes reference to the following points: • two peaks at 78 and 80 **(1)** • peak at 78, 3 x higher than peak at 80 **(1)** 	If there are more than 2 peaks score 0 Allow within 1small square If the peaks are wrong but the lower mass/ charge one is 3x higher than the other, M2 can be scored as a TE. Ignore any labels on the peaks	**(2)**

Question Number	Answer	Additional Guidance	Mark
19(b)(i)	An answer that makes reference to the following points:  • diagram showing curly half-arrows forming 2 free radicals **(1)** • uv (radiation / light) or sunlight **(1)**	Both arrows can come from the same side of the bond Ignore just light	**(2)**

Question Number	Answer	Additional Guidance	Mark
19(b)(ii)	An answer that makes reference to the following points: • homolytic: each atom gets one electron/ the electron pair splits evenly **(1)** • free radical: species with an unpaired electron **(1)**	Allow equal splitting of the electrons (in the bond) Allow atom/ element Allow lone electron Ignore free electron	**(2)**

Question Number	Answer	Additional Guidance	Mark
19(b)(iii)	An answer that makes reference to the following point: • multiple substitutions can occur/ more than one (organic) product	Allow more products formed//more waste products Allow termination products Allow side products/reactions Allow further reactions Ignore chain reaction Ignore poor yield/atom economy Ignore forms impurities Ignore references to HCl being formed/toxic	(1)

Question Number	Answer	Additional Guidance	Mark
19(c)(i)	An answer that makes reference to the following points: • 1 dipole on H–Cl • 2 curly arrow from H–Cl bond to Clδ– • 3 curly arrow from double bond to H(δ+) • 4 correct carbocation intermediate • 5 curly arrow from lone pair on Cl • 6 arrow to C+ on intermediate • 7 charge on chloride ion All 7 marking points score 4 marks, 5/6 points score 3 marks, 3/4 points score 2, 2 points score 1 mark	 Arrows must start from the covalent bond or lone pair From the H—Cl bond it must go to the Cl or beyond. From the C=C bond it must go to the H or in the space. From the lone pair on the Cl it must go to the C+ on the intermediate. If wrong alkene used just penalise 1 marking point. If primary carbocation is formed just penalise marking point 4 If half curly arrows used penalise 1 marking point If HBr/HI used penalise 1 marking point	(4)

Question Number	Answer	Additional Guidance	Mark
19(c)(ii)	An answer that makes reference to the following points: • (the formation of 1-chloropropane goes via a) primary carbocation **(1)** • (which is) less stable than the secondary carbocation (formed when of 2-chloropropane is produced) **(1)**	Do not award 1-chloropropane is a primary carbocation or 2-chloropropane is a secondary carbocation but only penalise once, Allow the correct comparison between a tertiary and primary or secondary carbocation for 1 mark Allow reverse argument	**(2)**

(Total for Question 19 = 13 marks)