Question Number	Answer	Mark
11	**The only correct answer is C** (20 cm^3) ***A** is incorrect because this is half the volume of butane that could be burned in 130 cm^3 oxygen* ***B** is incorrect because this is three quarters of the volume of butane that could be burned in 130 cm^3 oxygen* ***D** is incorrect because this is double the volume of butane that could be burned in 130 cm^3 oxygen*	**(1)**

Question Number	Answer	Mark
14	**The only correct answer is A** () ***B** is incorrect because hexane is not an oxidising agent* ***C** is incorrect because hexane is not corrosive* ***D** is incorrect because hexane is not toxic*	**(1)**

Question Number	Answer	Mark
15	**The only correct answer is B** (it decolourises bromine water) ***A** is not correct because it is an addition polymer* ***C** is not correct because it is non-biodegradable* ***D** is not correct because it has the empirical formula CH_2*	**(1)**

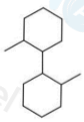
Question Number	Answer	Mark
6	**The only correct answer is B** (vaporisation, ionisation, deflection, detection) ***A** is incorrect because deflection is the third step not the first* ***C** is incorrect because ionisation is the second step not the first* ***D** is incorrect because deflection is the third step not the second*	**(1)**

Question Number	Answer	Mark
15	**The only correct answer is A** () ***B** is not correct because the symbols for oxidising and health hazard are shown* ***C** is not correct because the symbol for oxidising is shown* ***D** is not correct because the symbol for health hazard is shown*	**(1)**

Question Number	Answer	Mark
14(a)	**The only correct answer is A** () ***B*** *is incorrect because hydrogen peroxide is not concentrated enough to be toxic, nor is it flammable* ***C*** *is incorrect because hydrogen peroxide is not flammable* ***D*** *is incorrect because hydrogen peroxide is not concentrated enough to be toxic*	**(1)**

Question Number	Answer	Mark
14(b)	**The only correct answer is C** (II and III) ***A*** *is incorrect because using an alternative method that involves less hazardous materials would not work* ***B*** *is incorrect because working on a smaller scale has not been included* ***D*** *is incorrect because using an alternative method that involves less hazardous materials is not appropriate*	**(1)**

Question Number	Answer	Mark
15(a)	**The only correct answer is B** (C_nH_{2n-2}) ***A*** *is incorrect because this would be 2 hydrogens short of the general formula* ***C*** *is incorrect because this is the general formula of alkenes or cyclic alkanes, not cyclic alkenes* ***D*** *is incorrect because this is the general formula of alkanes*	**(1)**

Question Number	Answer	Mark
15(b)	**The only correct answer is D** () ***A*** *is incorrect because the two new bonds on each hexagon must be at either end of the double bond in cyclohexene* ***B*** *is incorrect because the two new bonds on each hexagon must be at either end of the double bond in cyclohexene* ***C*** *is incorrect because there should be two new single bonds on each hexagon*	**(1)**

Question Number	Answer	Mark
15(c)	**The only correct answer is D** (12.2 g) ***A*** *is incorrect because this is the value if the molecular masses are reversed and the yield inverted.* ***B*** *is incorrect because this is the value if the molecular masses are reversed and the yield is 100%* ***C*** *is incorrect because this is the mass needed if the yield is 100%*	**(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
7	**The only correct answer is C** (91.2) *A is not correct because this only takes into account the base peak* *B is not correct because this does not take into account the peak at 96* *D is not correct because this is the unweighted mean*	**(1)**

Question Number	Answer	Mark
16	**The only correct answer is C** (2-methylbut-2-ene) *A is incorrect because the name is not based on the longest carbon chain* *B is incorrect because the name is not based on the longest carbon chain* *D is incorrect because the numbering of the substituent group is incorrect*	**(1)** **Computer**

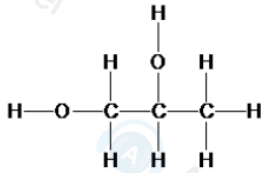
Question Number	Answer	Mark
13	**The only correct answer is D** (thermal decomposition) *A is incorrect because the alkane has not been burned* *B is incorrect because the alkane has not been hydrolysed* *C is incorrect because the alkane has not been neutralised*	**(1)**

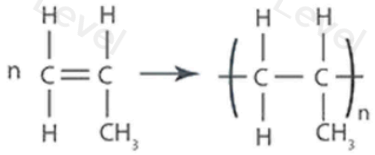
Question Number	Answer	Mark
18	**The only correct answer is D** ((i), (ii) and (iii)) *A is incorrect because all three are true* *B is incorrect because all three are true* *C is incorrect because all three are true*	**(1)**

Question Number	Answer	Additional Guidance	Mark
22(a)(i)	• nickel / Ni	Allow platinum / Pt / palladium / Pd Allow Raney nickel	**(1)**

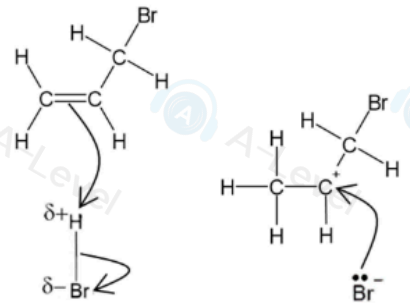
Question Number	Answer	Additional Guidance	Mark
22(a)(ii)	• 1,2-dichloropropane	Allow incorrect dashes / commas / spaces Allow minor spelling errors e.g. cloro Ignore formulae, even if incorrect Do not award propene	**(1)**

Question Number	Answer		Additional Guidance	Mark
22(a)(iii)	• steam	**(1)**	Allow $H_2O(g)$ but not H_2O or water alone	**(2)**
	• phosphoric((V)) acid / H_3PO_4	**(1)**	Allow acid **and** catalyst Do not award incorrect formulae e.g. H_3PO_3 or H_3PO_5	
	Or			
	• (concentrated) sulfuric acid / H_2SO_4	**(1)**	Do not award aqueous or dilute	
	• (followed by) water	**(1)**	NB Water must be second for M2	
			If a mixture of the options if given max 1 mark Ignore temperatures and pressures	

Question Number	Answer	Additional Guidance	Mark
22(a)(iv)	• correct displayed structure	 Allow CH_3 on one end Allow OH shown without the bond between Do not award connections to alcohol hydrogen, BOD on middle of OH	**(1)**

Question Number	Answer		Additional Guidance	Mark
22(b)(i)	• correct repeat unit including extension bonds • rest of equation	**(1)** **(1)**	 Allow multiple repeat units for M1, but must be balanced for M2 Allow any shape brackets Allow n anywhere on the left-hand side of propene Ignore brackets on left-hand side M2 dependent on M1 or a near-miss	**(2)**

Question Number	Answer		Additional Guidance	Mark
22(b)(ii)	An answer that makes reference to two of the following points: • many polymers are not biodegradable • not all plastics can be recycled • incineration/burning releases toxic gases	 **(1)** **(1)** **(1)**	 Allow (increase) landfill Allow polymers degrade very slowly / over a long time / many years Ignore "non-renewable" Allow plastics need to be separated to be recycled Allow named toxic gases Ignore harmful gases Ignore references to CO_2 / global warming etc. Ignore comments relating to wildlife and marine environments	**(2)**

Question Number	Answer	Additional Guidance	Mark
22(c)(i)	An answer that makes reference to: • dipole on H–Br • arrow from H–Br bond to $Br^{\delta-}$ • curly arrow from double bond to $H^{(\delta+)}$ • correct carbocation intermediate • arrow from lone pair on Br • arrow to C^{+} on intermediate • charge on bromide All marking points score 4 marks, 5/6 points score 3 marks, 3/4 points score 2, 2 points score 1 mark	Example of a mechanism:  Fishhook arrows only negate one of the 7 points Positive charge should be on the carbon not on a bond Final product, if given, should match the intermediate or negates 1 point	**(4)**

Question Number	Answer		Additional Guidance	Mark
22(c)(ii)	An explanation that makes reference to the following points:		Allow reverse arguments:	**(2)**
	• 1,2-dibromopropane is formed from the secondary carbocation (intermediate)	**(1)**	1,3-dibromopropane is formed from the primary carbocation (intermediate) Do not award "1,2-dibromopropane is a secondary carbocation" Apply list principle for correct/incorrect answers, i.e. if one correct answer is given but an incorrect answer is also stated then no mark is awarded.	
	• the secondary (carbocation) is more stable (than the primary carbocation)	**(1)**	the primary carbocation is less stable than the secondary carbocation Allow tertiary is more stable than the secondary/primary for M2 Ignore "secondary carbocation is stronger" Ignore Markovnikov even if incorrect Marks are independent	

(Total for Question 22 = 15 marks)

Question Number	Answer	Additional Guidance	Mark
21(a)	An explanation that makes reference to the following points: • graphite has a giant covalent structure / many (strong) covalent bonds within the layers/ **each** carbon atom is covalently bonded to 3 other carbon atoms **(1)** • (which gives it) a high melting temperature /requires a lot of energy to break/melt **(1)** • it has delocalised electron(s) (between the layers) **and** which allows it to conduct electricity / carry charge/ can move when a potential difference is applied **(1)**	Ignore references to intermolecular forces, shape Allow free electrons Do not award conduction by ions	**(3)** **Expert**

Question Number	Answer	Additional Guidance	Mark
21(b)(i)	• calculation of moles of aluminium in 1 kg **(1)** • deduction of aluminium to oxygen/ CO_2 ratio **(1)** • amount of CO_2 produced **(1)** • volume CO_2 produced **(1)**	Example of calculation 1000 ÷ 27 = 37.037 (mol) 2 : 1.5 or 4 : 3 37.037 × ¾ = 27.778 (mol) 27.778 × 24 = 667 (dm^3) Correct answer with some working scores 4 If units given, they must be correct Ignore SF except 1 SF	**(4)** **Expert**

Question Number	Answer	Additional Guidance	Mark
21b(ii)	An explanation that makes reference to the following points:: • less mining (of bauxite/ore/aluminium)/ less transport of raw materials **(1)** • the electrolysis of aluminium oxide is reduced / less new aluminium produced **(1)** • recycling involves melting the metal which uses less energy (than electrolysis) **(1)**	Ignore references to alternative storage e.g. plastics Allow less raw materials used Accept reduces need for electrolysis/ extraction Accept less fossil fuels burned to produce energy for electrolysis Ignore less need to produce cans Ignore space is saved /landfill Ignore references to reduction in carbon dioxide produced Ignore references to incineration Do not award no heat/energy is needed (for recycling)	**(3)** **Expert**

(Total for Question 21 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
19(a)(i)	An answer that makes reference to the following point: • (vaporised atoms are ionised by) bombarding / striking/ hitting/firing with (high speed / high energy) electron(s)	Allow molecules for atoms Allow electron gun / electron beam / Allow $X + e^- \rightarrow X^+ + 2e^-$ Ignore electron current, voltage Ignore incorrect ionisation equation	(1) Expert

Question Number	Answer	Additional Guidance	Mark
19(a)(ii)	An answer that makes reference to the following point: • (ions are accelerated by) an **electric** field / voltage/ potential difference / (series of negatively) charged plates	Ignore references to link between mass of ion and acceleration/speed Do not award references to (electro)magnetic field Do not award positively charged plates	(1) Graduate

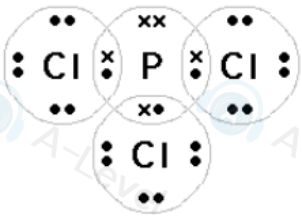
Question Number	Answer	Additional Guidance	Mark
19(a)(iii)	An explanation that makes reference to the following points: • (atoms/isotopes) have the same/identical electronic configurations / isoelectronic (1) • (isotopes/atom/ions) have different masses/ different m/z (with same charge) (1)	Allow the same number of (outer) electrons Accept heavier isotopes are deflected less / lighter isotopes are deflected more Ignore reference to just neutrons Ignore reference to protons Ignore comments linking deflection to charge	(2) Expert

Question Number	Answer	Additional Guidance	Mark
19(b)(i)	An explanation that makes reference to the following points: • (weighted) mean / average mass of atom(s) (of an element) (1) • divided by/compared to 1/12 (mass) of a ^{12}C (atom) /carbon 12 (atom) (1)	Accept $\frac{\text{(weighted) mean mass of an atom}}{\frac{1}{12}\text{ of the (mass) of a carbon 12 atom}}$ for both marks Do not award molecules for atoms	(2) Expert

Question Number	Answer	Additional Guidance	Mark
19(b)(ii)	• calculation of weighted mean / average (1) • answer to 4 SF (1)	Example of calculation $\frac{(75.53 \times 35) + (24.47 \times 37)}{100}$ (26.436 +9.0539 = 35.489) 35.49 Correct answer with no working scores 2 TE on arithmetical errors in M1 provided answer between 35 and 37	(2) Expert

Question Number	Answer	Additional Guidance	Mark
19(c)(i)	An answer that makes reference to the following points: • 101 $^{31}P^{35}Cl^{35}Cl^{+}$ / $^{31}P^{35}Cl_2{}^{+}$ • 103 $^{31}P^{35}Cl^{37}Cl^{+}$ / $^{31}P^{37}Cl^{35}Cl^{+}$ • 105 $^{31}P^{37}Cl^{37}Cl^{+}$ / $^{31}P^{37}Cl_2{}^{+}$	All three correct scores 2 Two correct scores 1 Allow omission of 31 on P Allow atoms in any order Allow isotope mass after symbol e.g. Cl^{35} Ignore any bonds shown between atoms Penalise omission of / incorrect charge once only Penalise omission of P once only	(2) Graduate

Question Number	Answer	Additional Guidance	Mark
19(c)(ii)	An explanation that makes reference to the following points: • so the ratios for the three ions are (101) ¾ × ¾ = 9/16 (= 0.5625) (103) ¼ × ¾ × 2 = 6/16 (= 0.375) (105) ¼ × ¼ = 1/16 (= 0.0625)	All three correct scores 2 Two correct scores 1 Allow (101) 3 ×3 = 9 (103) 1× 3 × 2 = 6 (105) 1 ×1 = 1 Allow use of original isotopic percentages i.e. 75.53% for ^{35}Cl etc	(2) Expert

Question Number	Answer	Additional Guidance	Mark
19(d)(i)	An answer that makes reference to the following points: • 3 shared pairs of electrons (1) • all other electrons correct (1)	Example of diagram  Electrons can be shown as all dots / crosses	(2) Expert

Question Number	Answer	Additional Guidance	Mark
19(d)(ii)	An explanation that makes reference to the following points: • drawn or stated (trigonal) pyramidal shape (1) • minimum repulsion between electron pairs (1) • lone pairs repel more than bonded pairs / lp-bp repulsion is greater than bp-bp repulsion (1)	Ignore reference to bond angle even if incorrect Allow maximum separation between electron pairs Do not award lp-lp repulsion is greater than bp-lp/bp-bp repulsion TE on incorrect dot-and-cross diagram from (d)(i) for M1 and M2 only	(3) Expert

(Total for Question 19 = 17 marks)

Question Number	Answer	Additional Guidance	Mark
23(a)(i)	• calculation of abundance of 5th isotope **(1)** • expression for relative atomic mass **(1)** • calculation of x given to 2SF **(1)**	Example of calculation 100 – 20.5 – 7.8 – 36.5 – 7.8 = 27.4 (%) $72.6 = \frac{(70 \times 20.5) + (73 \times 7.8) + (74 \times 36.5) + (76 \times 7.8) + (x \times 27.4)}{100}$ OR $72.6 = \frac{1435 + 569.4 + 2701 + 592.8 + (x \times 27.4)}{100}$ OR $72.6 = \frac{5298.2 + (x \times 27.4)}{100}$ Allow TE from M1 $x = \frac{7260 - 5298.2}{27.4} = 1961.8 \div 27.4 = 71.59 = 72$ Allow TE from M2 provided final answer is between 68 – 78 Correct answer with some working scores 3 Correct answer with no working scores 1	**(3)**

Question Number	Answer	Additional Guidance	Mark
23(a)(ii)	An answer that makes reference to the following point: • the number of protons **and** neutrons / nucleons must be an integer / whole number	Ignore the values in the table with the least significant figures have 2 SF	**(1)**

Question Number	Answer	Additional Guidance	Mark
23(b)	An answer that makes reference to the following points: Similarity • (the atoms) have the same total / sum of the numbers of protons and of neutrons **(1)** Difference • (an atom of) germanium(-76) has 2 fewer protons / (an atom of) selenium(-76) has 2 more protons • (an atom of) germanium(-76) has 2 more neutrons / (an atom of) selenium(-76) has 2 fewer neutrons **(1)** • (an atom of) germanium(-76) has 2 fewer electrons / (an atom of) selenium(-76) has 2 more electrons **(1)**	M2, M3 and M4 must be quantitative Allow the atoms have the same mass number Allow germanium has 32 protons and selenium has 34 protons Allow germanium has 44 neutrons and selenium has 42 neutrons Allow germanium has 32 electrons and selenium has 34 electrons Allow germanium has 4 outer-shell electrons and selenium has 6 outer-shell electrons If none of M2, M3 and M4 have been awarded allow 1 mark for **two** of the following: • germanium has more neutrons • germanium has fewer protons • selenium has more electrons Allow reverse argument(s)	**(4)**

(Total for Question 23 = 8 marks)