Question Number	Answer	Mark
17	**The only correct answer is A** (*E*-1-bromo-2-methylbut-1-ene) ***B*** is incorrect because the highest priority groups are on opposite sides of the double bond ***C*** is incorrect because the longest carbon chain has four atoms ***D*** is incorrect because the longest carbon chain has four atoms and the highest priority groups are on opposite sides of the double bond	**(1)** Computer

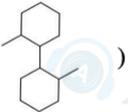| Question Number	Answer	Mark
5	**The only correct answer is C** (x = 2, y = 7, z = 4) ***A*** is incorrect because x must be 2 to match the 4 P in P_4O_{10} ***B*** is incorrect because z must be 4 to give 8 H to match the H in $2P_2H_4$ ***D*** is incorrect because x must be 2 to match the 4 P in P_4O_{10}	**(1)**

Question Number	Answer	Mark
13	**The only correct answer is C** (green solution and effervescence) ***A*** is not correct because the solution is not colourless and effervescence is not included ***B*** is not correct because a colourless solution is not formed ***D*** is not correct because effervescence is not included	**(1)** Computer

Question Number	Answer	Mark
3	**The only correct answer is A** (a molecule of ethene, $^{12}C_2\,^1H_4$) ***B*** is incorrect because it contains 16 neutrons ***C*** is incorrect because it contains 16 neutrons ***D*** is incorrect because it contains 16 neutrons	**(1)**

Question Number	Answer	Mark
12	**The only correct answer is A** (small ↔ large) ***B*** is incorrect because the ion needs a large charge ***C*** is incorrect because the ion needs a small radius and a large charge ***D*** is incorrect because the ion needs a small radius	**(1)**

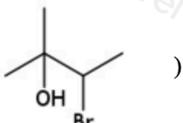| Question Number	Answer	Mark
14	**The only correct answer is A** (R—O—O—R → 2R—O•) ***B*** is incorrect because in this step a radical and a molecule form a radical so this is a propogation step ***C*** is incorrect because in this step two radicals from a molecule, so this is a termination step ***D*** 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
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
4	**The only correct answer is A** (argon) *B is incorrect because this would have a mass of 176 mg* *C is incorrect because this would have a mass of 16 mg* *D is incorrect because neon is monatomic not diatomic*	**(1)**

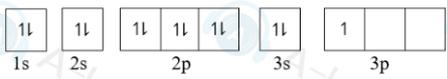| Question Number	Answer	Mark
9	**The only correct answer is B** ($CH_4 + H_2O \rightarrow 3H_2 + CO$) *A is incorrect because atom economy is 11.1%* *C is incorrect because atom economy is 4.35%* *D is incorrect because atom economy is 12.0%*	**(1)**

Question Number	Answer	Mark
17	The only correct answer is A ( )	(1)
	B is incorrect because this is the minor product of the addition of BrOH to 2-methylbut-2-ene	
	C is incorrect because this is the major product of the addition of BrOH to 2-methylbut-1-ene	
	D is incorrect because this is the minor product of the addition of BrOH to 2-methylbut-1-ene	

Question Number	Answer	Mark
13	The only correct answer is A (BF_3)	(1)
	B is incorrect because there are four bonding pairs of electrons which repel equally	Computer
	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	

Question Number	Answer	Mark
8	The only correct answer is D (87%)	(1)
	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	

Question Number	Answer	Mark
3	The only correct answer is C (2.408×10^{22})	(1)
	A is incorrect because this is the number of H_2SO_4 molecules in 0.0100 mol	
	B is incorrect because this is the number of oxygen molecules required to give this many oxygen atoms	
	D is incorrect because this is the number of atoms in 0.0100 mol of H_2SO_4	

Question Number	Answer	Mark
10	The only correct answer is D (250 cm^3 of 0.09 mol dm^{-3} $(NH_4)_2SO_4(aq)$)	(1)
	A is incorrect because there are 0.09 mol of ions	Computer
	B is incorrect because there are 0.09 mol of ions	
	C is incorrect because there are 0.09 mol of ions	

Question Number	Answer	Additional Guidance	Mark
21(a)(i)	An answer that makes reference to the following point: • $1s^22s^22p^63s^23p^1$	Allow Allow double headed arrows Ignore $[Ne]3s^2\,3p^1$ Ignore 2,8,3	**(1)**

Question Number	Answer	Additional Guidance	Mark
21(a)(ii)	An answer that makes reference to the following points: • they have the same number of / 3 outershell electrons **(1)** • they have different numbers of shells of electrons / boron has two shells, aluminium 3 shells and thallium 6 shells **(1)**	Ignore reference to d-electrons in thallium Allow all $(n)\,s^2\,p^1$ Allow electron configurations Allow number of shells increase down the group Ignore different number of sub-shells	**(2)**

Question Number	Answer	Additional Guidance	Mark
21(a)(iii)	An answer that makes reference to the following points: • all three will be the same shape (because they have the same number of outer shell electrons to form bonds with chlorine) **(1)** • trigonal planar **(1)** • because there are three bonding pairs of electrons and no lone pairs of electrons which are at maximum separation / minimum repulsion **(1)**	**M2 and M3 may be scored for any one molecule identified as trigonal planar** Allow any of the three stated as trigonal planar Allow triangular planar / planar triangle Allow this explanation for any one of the three. No TE from incorrect shape	(3)

Question Number	Answer	Additional Guidance	Mark
21(b)(i)	• calculation of moles of aluminium chloride **(1)** • rearrangement of $pV = nRT$ **(1)** • calculation of number of moles **and** number of moles are the same (so consistent with Al_2Cl_6) **(1)** OR • Calculation of M_r or moles **(1)** • Use of PV=nRT correctly rearranged for n or V **(1)** • Evaluated answer **and** comparison with Al_2Cl_6 data **(1)**	Example of calculation: $5.00 \div 267 = 0.018727 / 1.8727 \times 10^{-2}$ (mol) $= 0.0187 / 1.87 \times 10^{-2} / 0.019 / 1.9 \times 10^{-2}$ n = $pV \div RT$. May be seen in the expression in M3 $(0.000700 \times 101000) \div (8.31 \times 455) = 0.018699 / 1.8699 \times 10^{-2}$ $= 0.0187 / 1.87 \times 10^{-2} / 0.019 / 1.9 \times 10^{-2}$ Allow alternative method Ignore SF except 1 SF $V = nRT/p$ Ignore SF except 1 SF	(3)

Question Number	Answer	Additional Guidance	Mark
21(b)(ii)	An answer that makes reference to the following point: • 3 covalent bonds, one dot, one cross, between each Al and 3 Cl atoms **(1)** • 2 dative covalent bonds with two crosses between one Al and one Cl **(1)** • 3 lone pairs of electrons on the terminal Cl atoms, two pairs on the bridging Cl atoms **(1)**	Example of diagram If all dots or all crosses are used allow M2 and M3 for the correct numbers of electrons marked as dots or crosses. No TE anywhere	**(3)**

Question Number	Answer	Additional Guidance	Mark
21(c)	 • a diagram of the $TlCl_4^{3-}$ ion including one lone pair of electrons on Tl **(1)** • an estimated bond angle of $\leq 120°$ shown between the two equatorial Cls **(1)** • at least one estimated bond angle of $\leq 90°$ shown between two Cl (an axial and an equatorial Cl) **(1)**	Examples of diagrams Allow diagrams without dots and wedges Ignore absence of charge (as in the diagrams below) Ignore estimated bond angles, even if incorrect for M1. Ignore 180° No TE on M2 or M3 for incorrect shape	**(3)**

(Total for Question 21 = 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 $1000 \div 27 = 37.037$ (mol) $2 : 1.5$ or $4 : 3$ $37.037 \times \frac{3}{4} = 27.778$ (mol) $27.778 \times 24 = 667$ (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

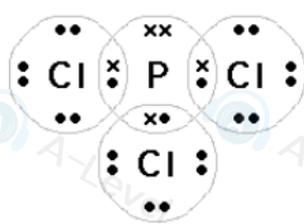| Question Number	Answer		Additional Guidance	Mark
19(a)(ii)	An answer that makes reference to the following point: • (ions are accelerated by) an **electric** field / voltage/ potential difference / (series of negatively) charged plates		Ignore references to link between mass of ion and acceleration/speed 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)**	Allow the same number of (outer) electrons	**(2)** Expert
	• (isotopes/atom/ions) have different masses/ different m/z (with same charge)	**(1)**	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	

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)**	Accept $\dfrac{\text{(weighted) mean mass of an atom}}{\frac{1}{12} \text{ of the (mass) of a carbon 12 atom}}$ for both marks Do not award molecules for atoms	**(2)** Expert
	• divided by/compared to 1/12 (mass) of a ^{12}C (atom) /carbon 12 (atom)	**(1)**		

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

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

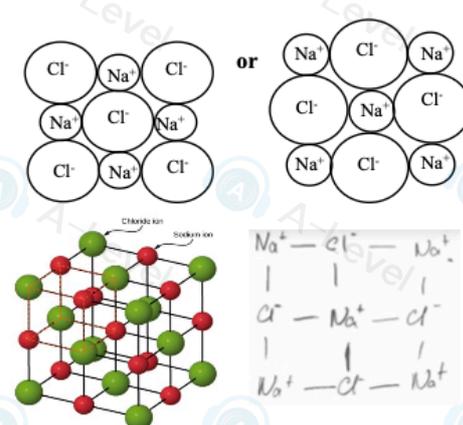| Question Number	Answer	Additional Guidance	Mark
19(d)(i)	An answer that makes reference to the following points: • 3 shared pairs of electrons (1) • all other electrons correct (1)	Example of diagram Electrons can be shown as all dots / crosses	(2) Expert

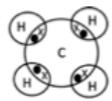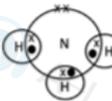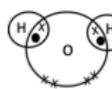| Question Number	Answer	Additional Guidance	Mark
19(d)(ii)	An explanation that makes reference to the following points: • drawn or stated (trigonal) pyramidal shape (1) • minimum repulsion between electron pairs (1) • lone pairs repel more than bonded pairs / lp-bp repulsion is greater than bp-bp repulsion (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)	An answer that makes reference to the following point: • (electrostatic force of) **attraction** between oppositely charged ions	Allow attraction between cations / positively charged metal ions and anions	**(1)**

Question Number	Answer	Additional Guidance	Mark
23(a)(ii)	An explanation that makes reference to the following points: • magnesium **ions** have a higher charge. **(1)** • magnesium ions have a smaller radius. **(1)**	Allow ORA about sodium ions Allow Mg^{2+} and Na^+ Allow magnesium has a smaller ionic radius / magnesium ions are smaller If no other mark awarded allow one mark for Mg^{2+} / magnesium ion has a greater charge density Penalise any mention of covalent bonding or intermolecular forces once only.	**(2)**

Question Number	Answer		Additional Guidance	Mark
23(a)(iii)	An answer that makes reference to the following points:		**Mark independently**	**(2)**
	•	(1)	Allow eight electrons on outer shell instead of no electrons or no circle Allow single sodium ion Do not award Na^+_2	
	•	(1)	Allow transferred electrons in any pattern Do not award all dots or all crosses for the oxide ion Ignore omission of square brackets	

Question Number	Answer		Additional Guidance	Mark
23(a)(iv)	An answer that makes reference to the following points:			**(2)**
	• At least 9 correctly labelled sodium **and** chloride ions	(1)		
	• The correct structure of alternating sodium / positive and chloride / negative (ions) either in rows or 3D lattice	(1)		
			Ignore size of ions Do not award M1 if suggestion that sodium chloride is not NaCl	

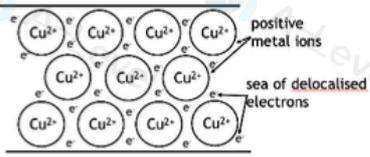| Question Number	Answer	Additional Guidance	Mark
23(b)(i)	An answer that makes reference to the following point: • (electrostatic force of) **attraction** between the **shared pair** of electrons and the nuclei (of two atoms)		(1)

Question Number	Answer		Additional Guidance	Mark
23(b)(ii)	An answer that makes reference to the following points: • structure of methane	(1)		(3)
	• structure of ammonia	(1)		
	• structure of water	(1)		

Question Number	Answer		Additional Guidance	Mark
23(b)(iii)	An answer that makes reference to the following points: • shape and bond angle for methane	(1)		(3)
	• shape and bond angle for ammonia	(1)		
	• shape and bond angle for water	(1)		

molecule	shape	bond angle
methane	tetrahedral	109.5°
ammonia	(trigonal) pyramidal	107°
water	non-linear / bent / V-shaped	104.5°

If no other mark scored 1 mark for either three correct bond angles or three correct shapes

Question Number	Answer		Additional Guidance	Mark
23(b)(iv)	An answer that makes reference to the following points: (Both ammonia and water have four pairs of electrons around the central atom) • ammonia has one lone pair and water has two lone pairs	(1)	Allow water has an extra lone pair	(2)
	• lone pairs (of electrons) repel more than bonded pairs.	(1)	Ignore bond angles even if incorrect.	

Question Number	Answer	Additional Guidance	Mark
23(b)(v)	An answer that makes reference to the following points: • ethene is a simple molecule • ethene has weak intermolecular forces • poly(ethene) is a polymer • poly(ethene) strong intermolecular forces All four bullet points scores 2 Two or three bullet points scores 1	Allow London / van der Waals / dispersion forces for intermolecular forces Ignore monomer Do not award reference to breaking covalent bonds Allow poly(ethene) is a macromolecule / giant molecule for polymer Do not award reference to breaking covalent bonds	(2)

Question Number	Answer	Additional Guidance	Mark
23(c)(i)	An answer that makes reference to the following point: • **electrostatic** (force of) **attraction** between the positive / metal ions and the (sea of delocalised) electrons.		(1)

Question Number	Answer		Additional Guidance	Mark
23(c)(ii)	An explanation that makes reference to the following points: • **delocalised** electrons are able to move / flow (through the lattice and carry a charge) • diagram showing lattice of Cu^{2+} ions and (sea of) electrons interspersed within the structure – approximately twice as many electrons as ions	(1) (1)	Delocalised electrons may be labelled in the diagram Do not award ions move	(2)

(Total for Question 23 = 21 marks)