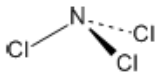
Atomic Structure and the Periodic Table - Mark Scheme

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)

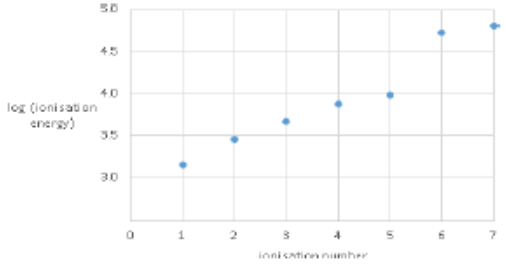
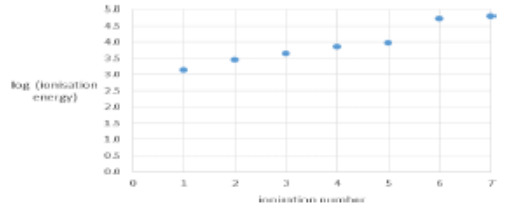
Question number	Answer	Additional guidance	Mark
(b)	• calculation of mol of C, H and Cl **(1)** • calculation of empirical formula **(1)** • calculation of molecular formula **(1)**	Example of calculation: C : H : Cl mol $\frac{3.09}{12} : \frac{0.26}{1} : \frac{9.15}{35.5}$ = 0.2575 : 0.26 : 0.2577 (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)

Question number	Answer	Additional guidance	Mark
(c)(ii)	• number of bonding pairs **and** number of lone pairs • shape • bond angle	Example of table: Number of bonding pairs of electrons on nitrogen: 3 Number of lone pairs on electrons on nitrogen: 1 Shape of molecule: trigonal pyramidal Bond angle: 107° **Shape:** Allow 3-dimensional drawing e.g.  There must be at least 1 dotted/dashed line or wedge for 3-d Allow just 'pyramidal' Allow pyramid for pyramidal Do not award tetrahedral **Bond angle:** Allow any number in the range 106-108° Ignore missing °	(3)

Q2.

Question number	Answer	Additional guidance	Mark
(a)(i)	• two correct values	(6) (53 268) 4.73 (7) (64 362) 4.81 Both numbers correct and must be to 2 d.p.	(1)

Question number	Answer	Additional guidance	Mark
(a)(ii)	• axes correct way round **and** linear scale points covering at least half the grid horizontally **(1)** • both axes labelled **(1)** • points plotted correctly **(1)**	Example of graph:  Allow  **Labels**: Allow log(IE / kJ mol^{-1}) Do not award log(IE) / kJ mol^{-1} **Points**: TE on values in table for 6th and 7th log(IE) Allow ±1 small square Allow points joined by lines / bar chart Ignore lines drawn from x axis to each point Do not award a best fit straight line Do not award lines joined to the origin	(3)

Question number	Answer	Additional guidance	Mark
(a)(iii)	An answer that makes reference to the following: • the range of numbers / 1402 to 64362 is too large (to fit on a graph / axis) **or** logarithms make it easier to plot the numbers	Allow: A (very) long y axis would be needed The difference between the ionisation energies is too large So the numbers will fit on the graph Allow logs give smaller (range of) numbers	(1)

Question number	Answer	Additional guidance	Mark
(a)(iv)	An explanation that makes reference to the following points: • the (large) jump (between ionisations 5 and 6) shows the start of a new (quantum) shell **(1)** • there are two electrons that are harder to remove and they are closer to the nucleus **(1)** • there are five electrons that are easier to remove and they are further from the nucleus **(1)**	Penalise use of orbitals instead of shells once only Allow any answer relating the jump / large increase to two (quantum) shells Allow jump linked to **1s** and **2s** sub-shells Do not award jump between incorrect numbers Allow there are two electrons in the inner (quantum) shell Allow there are five electrons in the outer (quantum) shell / five valence electrons	**(3)**

Question number	Answer	Additional guidance	Mark
(a)(v)	An explanation that makes reference to the following points: **Oxygen** • oxygen (atom) loses a paired electron (from a 2p orbital / 2p sub-shell) **or** electron is lost from a full (2p) orbital **(1)** **Nitrogen** • nitrogen (atom) loses an electron from a singly-occupied orbital **or** loses an electron from a half-filled subshell **(1)** **Repulsion** • there is (more) repulsion between **paired** electrons (than between electrons in different orbitals so less energy is required to remove the electron in oxygen) **(1)**	Penalise mention of incorrect orbital e.g. 3p once only Ignore any reference to nuclear charge / numbers of protons / shielding / atomic radius Allow M1 and M2 from diagrams showing electrons in boxes Allow oxygen has a pair of electrons in a (2)p orbital **or** there is spin pairing in oxygen in a (2)p orbital Allow nitrogen has no paired electrons in the (2)p sub-shell / (2)p orbitals **or** nitrogen only has 1 electron in each (2)p orbital / has 3 unpaired (2)p electrons / has a half-filled (2)p sub-shell / has half-filled (2)p orbitals Do not award just 'nitrogen has a half-filled p orbital'	**(3)**

Question number	Answer	Additional guidance	Mark
(b)(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)

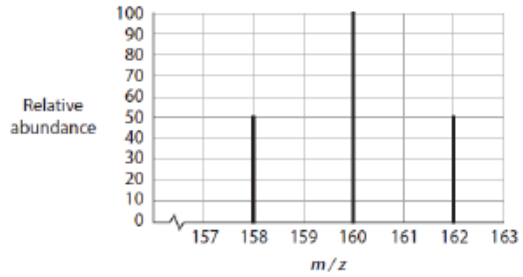
Question number	Answer	Additional guidance	Mark
(b)(ii)	• calculation of moles of nitrogen atoms • calculation of number of nitrogen atoms	Example of calculation: mol $N_2 = \frac{5.60}{28} = 0.20$ **and** mol N atoms = 0.20 x 2 = 0.40 **or** $\frac{5.60}{14} = 0.40$ number of N atoms = $0.40 \times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

Question number	Answer	Additional guidance	Mark
(b)(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
(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)	 • lines at 158 and 160 and 162 (1) • relative abundances 50:100:50 (1)	Allow relative abundances in any ratio 1:2:1, e.g. 25:50:25	2

Question number	Answer	Additional guidance	Mark
(b)(iii)	• 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 = $\frac{200}{1 \times 10^6} = 2.00 \times 10^{-4}\ m^3$ 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

Q4.

Question number	Answer	Mark
	D 	1

Q5.

Question number	Answer	Mark
	B 2 electrons in a 2p orbital, 18 electrons in the third quantum shell	1

Q6.

Question number	Answer	Mark
	The only correct answer is D (1000) ***A*** *is incorrect because this is less than the first ionisation energy of sodium and phosphorus has 4 more protons* ***B*** *is incorrect because this is less than the first ionisation energy of aluminium and phosphorus has 2 more protons* ***C*** *is incorrect because this is less than the first ionisation energy of silicon and phosphorus has 1 more proton*	(1)

Q7.

Question number	Answer	Mark
	The only correct answer is D  ***A*** *is incorrect because the 1s and 2s electrons should be paired* ***B*** *is incorrect because the 2s electrons should be paired* ***C*** *is incorrect because the 2p electrons should not be paired*	**(1)**

Q8.

Question number	Answer	Mark
	The only correct answer is B (Group 3) ***A*** *is incorrect because the biggest jump is after the third ionisation energy not after the second* ***C*** *is incorrect because the biggest jump is not after the fourth ionisation energy* ***D*** *is incorrect because the biggest jump is not after the fifth ionisation energy*	**(1)**

Q9.

Question number	Answer	Mark
	The only correct answer is D (3p subshell 6, third quantum shell 18) ***A*** *is incorrect because 2 is the number of electrons in a 3p orbital and the 3d electrons have been omitted from the third quantum shell* ***B*** *is incorrect because 2 is the number of electrons in a 3p orbital* ***C*** *is incorrect because the 3d electrons have been omitted from the third quantum shell*	**(1)**

Q10.

Question number	Answer	Mark
	The only correct answer is B (8 neutrons and 10 electrons) ***A*** *is incorrect because in a negative ion the number of electrons should be more than the number of protons* ***C*** *is incorrect because the numbers of neutrons and electrons are incorrect* ***D*** *is incorrect because oxygen has 8 neutrons and hydrogen has 0*	**(1)**

Q11.

Question number	Answer	Mark
	The only correct answer is B (28.2) **A** *is incorrect because this is the mass number of the most abundant isotope* **C** *is incorrect because this is the average of the mass numbers without considering their abundances* **D** *is incorrect because the percentages have been mixed up*	**(1)**

Q12.

Question number	Answer	Additional guidance	Mark
(a)	• correct species in equation (1) • correct state symbols (1)	Examples of equation: $N(g) \rightarrow N^+(g) + e^{(-)}$ or $N(g) - e^{(-)} \rightarrow N^+(g)$	**2**

Question number	Answer	Additional guidance	Mark
(b)	An explanation that makes reference to the following points: • general increase across a period/atomic numbers 3-10 due to increase in nuclear charge (1) • the (outer) electrons are added to the same quantum shell or the shielding is the same. (1) Irregularities: • atom with atomic number 5 has lower IE than atom with atomic number 4 as the (2)p electron is better shielded than the (2)s electron (so requires less energy to be removed) (1) • atom with atomic number 8 has lower IE than atom with atomic number 7 as there is repulsion between the pair of electrons in the 2(p) orbital (so less energy is required to remove one of them). (1)	Allow increase in effective nuclear charge Accept reverse arguments Accept names for atomic numbers Allow the 2p sub-shell is further from the nucleus than the 2s orbital Allow a half-filled p sub shell is more stable	**4**

Question number	Answer	Additional guidance	Mark
(c)	An explanation that makes reference to the following points: • (decrease down a group due to) (there is an increase in nuclear charge from 3 to 11 but this is offset by) the outer electron is in a higher quantum shell/higher energy level (1) • therefore further from the nucleus/better shielded. (1)		**2**

Q13.

Question number	Answer	Mark
	B $^{56}Fe^{2+}$	1

Q14.

Question number	Answer	Mark
(a)	A R and U	1

Question number	Answer	Mark
(b)	C Y	1

Question number	Answer	Mark
(c)	C U^{2+} and T^{2-}	1

Q15.

Question number	Answer	Mark
	A P^{3-}	1

Q16.

Question number	Answer	Mark
	C 20.18	1