PEARSON EDEXCEL A-LEVEL CHEMISTRY · 9CH0

CHEMISTRY



MARK SCHEME

TOPIC 1: ATOMIC STRUCTURE AND THE PERIODIC TABLE

SCORE	PERCENTAGE
/93	%

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mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which equation shows the third ionisation energy of aluminium?

(1)

☐ **A** $Al(g) \rightarrow Al^{3+}(g) + 3e^-$

☐ **B** $Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$

☐ **C** $Al^{3+}(g) + 3e^- \rightarrow Al(g)$

☐ **D** $Al^{3+}(g) + e^- \rightarrow Al^{2+}(g)$

(Total for question = 1 mark)

Mark Scheme

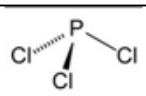
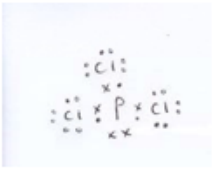
Q1.

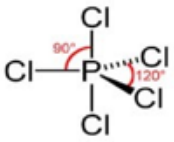
Question Number	Answer	Additional Guidance	Mark
	• correct expression (1) • evaluation of calculation and answer to 2 dp (1)	Example of calculation RAM= $\frac{(50.52 \times 78.918)+(49.48 \times 80.916)}{100}$ (= 79.9066104) = 79.91 ALLOW units of g mol^{-1} only Do not award units of % Correct answer without working scores (2)	(2)

Q2.

Question Number	Answer	Additional guidance	Mark
	A discussion that makes reference to the following points: • both elements / atoms have the last added electron in the d-subshell / d orbital (so are d-block elements) **(1)** • but neither forms a (stable) ion with an incomplete d-subshell / d orbital (so are not transition metals) **(1)** • Zn^{2+} is $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ (so d subshell is full) **(1)** • Sc^{3+} is $1s^2 2s^2 2p^6 3s^2 3p^6$ (so d subshell is empty) **(1)**	Do not award just 'contains d electrons' Allow 'transition elements form a (stable) ion with an incomplete d-subshell / d orbital' Allow $[Ar]3d^{10}$ Allow [Ar]	**(4)**

Q3.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to • **M1** PCl_3 is (trigonal) pyramidal (1) • **M2** has 3 bond pairs and 1 lone pair (around central P atom) (1) • **M3** electron pairs repel to positions of minimum repulsion / maximum separation (1)	Marking points 1 and 2 may be shown on diagrams (see below) Award M1 for correct name of shape even if diagram(s) incorrect Ignore lone pair – bond pair repulsions > bond pair – bond pair repulsions Answer must state or imply somewhere that (electron) pairs repel Do not award if specifically stated that 'bonds repel' or 'atoms repel' Ignore any references to bond angles even if incorrect	(3)
Example of diagram for award of M1 (a lone pair may also be shown on the P atom) 			
Example of diagram for award of M2 (must show 3 bond pairs and 1 lone pair) 			

Question Number	Answer	Additional Guidance	Mark
(ii)	• **M1** Diagram showing trigonal bipyramidal shape, with 3D emphasised by use of two wedges or one hatch and one wedge in the central plane (1) • **M2** 90˚ and 120˚ angles labelled (1) • **M3** trigonal bipyramidal (1)	 M2 dependent on correct M1 Ignore 180° Do not award M2 if any incorrect bond angle is shown M3 stand alone mark Both words required Award "trigonal bipyramid"	(3)

Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following points: • phosphorus can expand its octet / can expand its (outer) shell / can accommodate more than 8 electrons / can accommodate 10 electrons / has available (3d-) orbitals (for promotion of electrons) (1) • nitrogen does not have (2)d-orbitals / can only accommodate eight electrons (in its outer shell) (1)	**Comment** Award reference to P accommodating 18 electrons Ignore comparisons of size / radius of P and N atoms	(2)

Q4.

Question Number	Answer	Additional Guidance	Mark
	An answer that makes reference to the following points • (energy) released **(1)** • energy is required to overcome the (electrostatic) attraction from the nucleus for the electron **(1)**	Allow energy is required to remove an electron Allow (the removal of an electron) is endothermic	**(2)**

Q5.

Question Number	Answer	Mark
	The only correct answer is B (the mass of one atom of an isotope relative to one twelfth of the mass of an atom of the isotope carbon-12) **A** *is not correct because this is the relative atomic mass definition* **C** *is not correct because this is part of the relative atomic mass definition and because of the comparison of one atom to 12 g* **D** *is not correct because of the comparison of one atom to 12 g*	**(1)**

Q6.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	• bottom of meniscus between 23.8 and 23.9 (cm^3) **(1)** • meniscus curved downwards **(1)**	Example of diagram  Ignore shading below the meniscus Do not award M2 if there is shading above the meniscus	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	An explanation that makes reference to the following points: • 23.15 (cm^3) should be used as it is the mean of the concordant titres / titres 2 and 4 /23.10 and 23.20 (cm^3) **(1)** • 23.43 (cm^3) should not be used as it includes the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm^3) **(1)**	Allow other descriptions of concordant e.g. titres within 0.1 / 0.2 cm^3 Allow (23.1(0) + 23.2(0))/2 = 23.15 (cm^3) Allow only the concordant titres / titres 2 and 4 / 23.20 and 23.20 (cm^3) should be used / are used(in the mean) Allow the inaccurate / non-concordant / rough values / titres 1 and 3 / 23.85 and 23.55 (cm^3) should not be used / are used (in the mean)	**(2)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(iii)	• calculation of percentage uncertainty	Example of calculation $\frac{2 \times 0.05}{23.20} \times 100$ = (±)0.431 / 0.43 / 0.4 (%) Ignore SF including 1 SF Correct answer with no working scores (1)	**(1)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a) (iv)	• calculation of moles of MnO_4^- **(1)** • calculation of moles $C_2O_4^{2-}$ in 25.0 cm^3 **(1)** • calculation of moles $C_2O_4^{2-}$ in 1.00 dm^3 **(1)** • calculation of **y** to nearest whole number **(1)**	Example of calculation moles MnO_4^- = 23.15 x 0.0203/1000 = 0.00046995 / 4.6995 x 10^{-4} (mol) moles $C_2O_4^{2-}$ in 25.0 cm^3 = 4.6995 x 10^{-4} x 5/2 = 0.0011749 / 1.1749 x 10^{-3} (mol) TE on moles MnO_4^- moles $C_2O_4^{2-}$ in 1.00 dm^3 = 1.1749 x 10^{-3} x $\frac{1000}{25.0}$ = 0.046995 / 4.6995 x 10^{-2} (mol) TE on moles $C_2O_4^{2-}$ in 25.0 cm^3 Ratio moles salt : moles $C_2O_4^{2-}$ = 0.0235 : 0.046995 = 1 : 1.9998 **y** = 2 TE on moles $C_2O_4^{2-}$ in 1.00 dm^3 Alternative method for M3 and M4 moles salt in 25.0 cm^3 = 0.0235 x 25.0/1000 = 5.875 x 10^{-4} (1) Ratio moles salt : moles $C_2O_4^{2-}$ = 5.875 x 10^{-4} : 1.1749 x 10^{-3} = 1 : 1.9998 **y** = 2 TE on moles salt and $C_2O_4^{2-}$ in 25.0 cm^3 (1) Ignore SF in working except 1 SF Correct answer with no working scores (1) Allow M4 for correct answer using charges on ions	**(4)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	• calculation of mol of anhydrous salt **(1)** • calculation of mol H_2O **(1)** • calculation of ***z*** to nearest whole number **(1)**	<u>Example of calculation</u> mol anhydrous salt = 2.96/218.1 = 0.013572 / 1.3572 x 10^{-2} (mol) TE on M_r of anhydrous salt from value of **y** in (a)(iv) or an assumed value of ***y*** Allow 0.013578 from M_r 218 mol H_2O (= 0.45/18) = 0.025 / 2.5 x 10^{-2} (mol) Ratio mol salt : mol H_2O = 0.013572 : 0.025 = 1 : 1.842 **z** = 2 TE on moles anhydrous salt and moles H_2O Ignore SF in working except 1 SF Correct answer with some working scores (3) Penalise **y** and **z** not given to nearest whole number once only in (a)(iv) and (b)(i) Allow alternative correct methods	**(3)**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	An answer which includes the following points: Crystals jumped out of crucible • value of ***z*** increases **and** because it appears that more mass / mol / water is lost (than expected) **(1)** • (this can be prevented by) placing a lid on the crucible **or** **(1)** heat more gently / carefully Not all water of crystallisation lost • less mass / mol /water is lost (than expected) **(1)** • (this can be prevented by) heating to constant mass **or** description of heating to constant mass **(1)** • so this accounts for the lower value of ***z*** / value of ***z*** decreases **(1)**	Ignore just 'loss in mass / mol' Stand alone mark Allow just 'cover the crucible' Ignore use an electrical heater / larger crucible / evaporating basin / conical flask / test tube etc Do not award add anti-bumping granules Stand alone mark Ignore just 'heat for longer' Do not award the idea of repeating the experiment / using a drying agent Conditional on M3	(5)

Q7.

Question Number	Answer	Additional Guidance	Mark
	• $(1s^2)2s^22p^63s^23p^1$	Allow numbers of electrons as subscripts or large numbers Allow p orbitals designated as x, y and z Ignore $1s^2$ repeated	(1)

Q8.

Question Number	Answer	Mark
	The only correct answer is C *A is not correct because this is only the number of electrons in the 3p orbitals of the chlorine atom* *B is not correct because this is only the number of electrons in the 3p orbitals of the chloride ion* *D is not correct because this is the total number of electrons in the chloride ion, not just those in the p orbitals*	**(1)**

Q9.

Question number	Answer	Additional guidance	Marks
(a)	D		**1**
(b)	B		**1**
(c)	D		**1**

Q10.

Question Number	Answer	Additional Guidance	Mark
	An answer that includes • (estimated value) between 1100 – 1380 (kJ mol^{-1})		**(1)**

Q11.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • **Nuclear charge** magnesium (atom) / Mg has more protons than sodium (atom) / Na **or** magnesium / Mg has a greater (effective) nuclear charge (than sodium / Na) **(1)** • **Shielding** (outer) electron in magnesium (atom) / Mg in the same (quantum) shell / energy level / sub-shell / orbital as in a sodium atom / Na **or** shielding in magnesium atom / Mg similar to / same as that in sodium atom / Na **(1)** • **Attraction** so the force of attraction between the nucleus and the (outer) electron is greater in magnesium (atom) / Mg (than in sodium atom / Na) **(1)**	Penalise reference to ion once only Ignore reference to atomic radius Allow correct E.C of both atoms Allow same number of (quantum) shells / energy levels in Mg and Na Allow the (outer) electron in Mg is held more tightly to the nucleus (than in Na) **Note** An answer that describes the trend across a period, without one reference to either sodium or magnesium, scores maximum (2) marks	**(3)**

Question Number	Answer	Additional Guidance	Mark
(ii)	• correct equation with state symbols	<u>Examples of equations</u> $Mg^{2+}(g) \rightarrow Mg^{3+}(g) + e^{(-)}$ $Mg^{2+}(g) - e^{(-)} \rightarrow Mg^{3+}(g)$ Ignore state symbol for the electron Do not allow ⇌	**(1)**

Q12.

Question Number	Answer	Mark
	The only correct answer is C (c) **A** *is not correct because it is carbon* **B** *is not correct because it is nitrogen* **D** *is not correct because it is aluminium*	**(1)**

Q13.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points • the outer electron in a sodium atom is closer to the nucleus (than that in potassium) **(1)** • (and) less shielding from inner electron shells **(1)** • these outweigh the greater nuclear charge / number of protons in potassium **(1)**	Accept reverse arguments throughout Allow sodium atoms are smaller (than potassium) Allow sodium has electron in 3s whereas potassium has electron in 4s Allow diagram to illustrate Do not award reference to ionic radius Do not award if reference given to both have a +1 charge/ same nuclear charge	**(3)**

Q14.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• any 2 correct (1) • all 3 correct (2)	Example of table 1st IE: (590) 4s; 2nd IE: (1145) 4s; 3rd IE: (4912) 3p Accept $3p_x$ / $3p_y$ / $3p_z$ for 3rd IE Ignore any superscript numbers by 4s and 3p Allow (1) for just 's, s, p' or 's, s, p' with one or more incorrect numbers in front	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• correct equation	Examples of equations $Ca^{2+}(g) \rightarrow Ca^{3+}(g) + e^{(-)}$ **or** $Ca^{2+}(g) - e^{(-)} \rightarrow Ca^{3+}(g)$ Correct state symbols are required Ignore any state symbol for the electron	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following points: • (there is a much larger difference between the 2nd and 3rd ionisation energies because the) 3rd electron is lost from a shell / energy level / sub- shell / (3p) orbital closer to the nucleus **or** the 3rd electron is lost from a shell / energy level / sub-shell / (3p) orbital of lower energy **(1)** • (there is a smaller difference between the 1st and 2nd ionisation energies because the) 1st and 2nd electrons removed from the same shell / energy level / sub- level / orbital **or** the first two electrons experience similar shielding (from the inner electrons) **or** there is only a small change in electron-electron repulsion as the first two electrons are removed **(1)**	Ignore electron is lost from a full (sub-)shell / a full (sub-)shell is more stable Ignore just '3rd electron lost is more strongly attracted to the nucleus' Allow the same amount of shielding Allow the 3rd electron (to be lost) experiences less shielding (from inner electrons)	**(2)**

Q15.

Question Number	Answer	Additional Guidance	Mark
	• N^{3-} / O^{2-} / F^- / Na^+ / Al^{3+}	Do not award Ne, C^{4-}, Si^{4+}	**(1)**

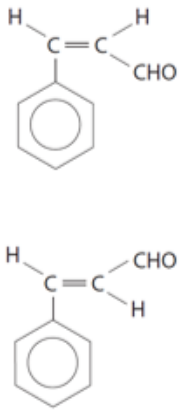
Q16.

Question Number	Answer	Additional Guidance	Mark
	• all 4 ion formulae **(1)** • all 4 *m/z* values **(1)** **or** • any two *m/z* values with corresponding ion formulae **(1)** • the other two *m/z* values with corresponding ion formulae **(1)**	Example of answer: ions *m/z* $P(^{35}Cl)_3^+$ 136 $P(^{35}Cl)_2{}^{37}Cl^+$ 138 $P^{35}Cl(^{37}Cl)_2^+$ 140 $P(^{37}Cl)_3^+$ 142 Allow any other unambiguous way of representing the formulae e.g. with brackets or in words Positive charge only needs to be shown on one of the ions Ignore mass number on P	**(2)**

Q17.

Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • identification of oxygen / O **(1)** • identification of isotopes corresponding to any 3 *m/z* values **(1)** • Conditional on M2 awarded identification of isotopes corresponding to other 2 *m/z* values **(1)**	Isotopes in ions at each *m/z* value: (32 –) $^{16}O=^{16}O^+$ / $^{16}O_2{}^+$ (33 –) $^{16}O=^{17}O^+$ (34 –) $^{16}O=^{18}O^+$ **and** $^{17}O=^{17}O^+$ / $^{17}O_2{}^+$ (35 –) $^{17}O=^{18}O^+$ (36 –) $^{18}O=^{18}O^+$ / $^{18}O_2{}^+$ Allow single bonds Allow any other unambiguous ways of showing the masses of the isotopes for each *m/z* value e.g. 16+16, $_2O^{16}$ Allow use of X / another symbol e.g. Cl instead of O for M2 and M3 Ignore missing charges as given in question Penalise negative charge once only	**(3)**

Q18.

Question Number	Answer	Additional guidance	Mark
(b)(i)	• contains C=C/alkene		1
(b)(ii)	• contains carbonyl group/ aldehyde or ketone	C=O alone	1
(b)(iii)	• aldehyde/ -CHO		1
(c)(i)	• 77 $C_6H_5^+$ (1) • 103 $C_8H_7^+$ (1)	Must show a charge but only penalise omission once Allow structural, displayed or skeletal formulae	2
(c)(ii)	 	Allow non-displayed benzene C-Hs	2
(c)(iii)	• The peak is due to the presence of an atom of a (^{13}C) isotope	Allow reference to other named isotope of H or O	1

Q19.

Question Number	Answer	Mark
	The only correct answer is C (Y) **A** *is not correct because there is a steady increase in ionisation energies* **B** *is not correct because there is a steady increase in ionisation energies* **D** *is not correct because there is a large increase after the first ionisation energy, so Z is a Group 1 element*	**(1)**

Q20.

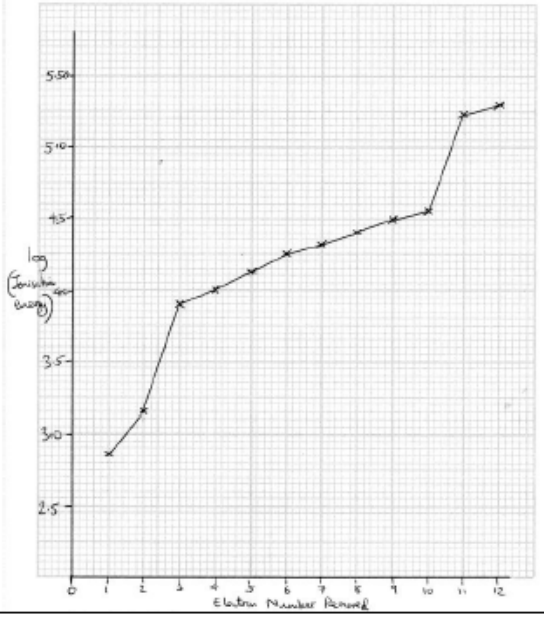
Question Number	Answer	Additional Guidance	Mark
	An answer that includes • species in suitable equation **(1)** • state symbols **(1)**	<u>Example of equation</u> $O^{+}(g) \rightarrow O^{2+}(g) + e^{(-)}$ ALLOW $O^{+}(g) - e^{(-)} \rightarrow O^{2+}(g)$ Ignore state symbols on electron Do not allow multiples for M1 M2 dependent on M1 or near miss	**(2)**

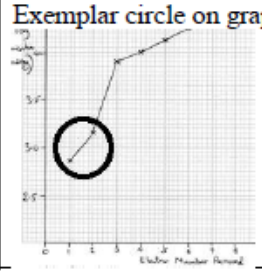
Q21.

Question Number	Answer	Additional Guidance	Mark
(i)	• completed table	4.26 and 5.28	**(1)**

Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that includes • the range of numbers / 738 to 189 371 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 (some of) the numbers are too large the difference between the ionisation energies is too large so the numbers will fit on the graph logs give smaller (range of) numbers Ignore simpler to read Do not award reference to averages	**(1)**

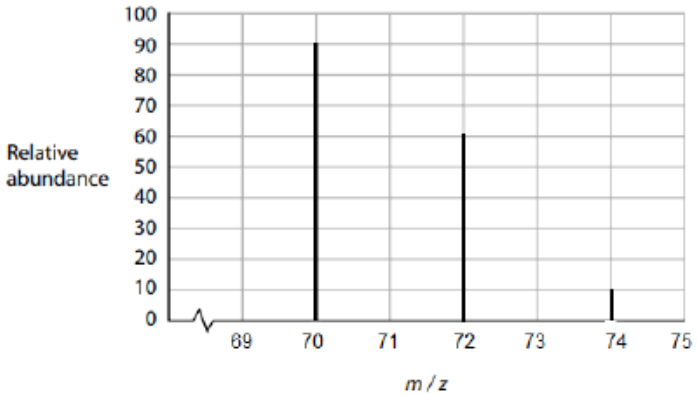
Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that includes one of the following points • the same number of protons is attracting a decreasing number of electrons **or** electron is removed from an increasingly positively charged ion **or** electron removed is closer to the nucleus **or** the electron removed is experiencing less electron-electron repulsion	Do not award each electron is removed from shells closer to the nucleus	(1)

Question Number	Answer	Additional Guidance	Mark
(iv)	An answer that includes a suitable graph • labelled axes (1) • suitable scale (1) • plotting of points and lines joining points (1)	Do not award if any units given on y axis Plotted points must cover at least ½ the graph paper on each axis Allow ±½ square Do not award line going from point 1 to the origin Ignore plotting of electron 6 and 12 Exemplar graph  	(3)

Question Number	Answer	Additional Guidance	Mark
(v)	An answer that includes • circle around the first two points/circles around individual points	Exemplar circle on graph 	(1)

Q22.

Question Number	Answer	Additional Guidance	Mark
(i)	• all numbers for ^{35}Cl correct (1) • all numbers for $^{37}Cl^-$ correct (1)	Example of table Particle / Protons / Neutrons / Electrons ^{35}Cl atom: 17 / 18 / 17 $^{37}Cl^-$ ion: 17 / 20 / 18 If no other mark is awarded, allow (1) for any four numbers correct	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	• lines at 70 and 72 and 74 (1) • relative abundances 9:6:1 (1)	Example of spectrum  Allow any abundances in an approximate 9:6:1 ratio e.g. 56:37-38:6 as %, or 75 : 50 : 8	(2)

Q23.

Question Number	Answer	Mark
	The only correct answer is D ***A*** *is not correct because there are no peaks for bromine molecules* ***B*** *is not correct because the peak for the ^{79}Br-$^{81}Br^+$ molecular ion is missing* ***C*** *is not correct because the peak for the ^{79}Br-$^{81}Br^+$ molecular ion is not twice the height of the other molecular ion peaks*	**(1)**

Q24.

Question Number	Acceptable Answer		Additional Guidance	Mark
	• 1s orbital – 2 electrons • 2p subshell – 6 electrons • third quantum shell – 18 electrons	**(1)** **(1)** **(1)**	Example of table Region / Maximum number of electrons the 1s orbital: 2 the 2p subshell: 6 the third quantam shell: 18 Allow $1s^2$ for 2 Allow $2p^6$ for 6 Ignore $3s^23p^63d^{10}$ for the third number Do not award more than one number written in the box e.g. 8 or 18 in the third box	**(3)**

Q25.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• ^6Li – 3 protons **and** 3 neutrons **and** 3 electrons **(1)** • $^7Li^+$ – 3 protons **and** 4 neutrons **and** 2 electrons **(1)**	Example of table Particle / Protons / Neutrons / Electrons ^6Li: 3 / 3 / 3 $^7Li^+$: 3 / 4 / 2 If no other mark is scored, allow (1) for any 4 correct numbers Ignore + or - signs	**(2)**

Q26.

Question Number	Answer	Mark
	The only correct answer is B ***A*** *is not correct because incorrect electrons* ***C*** *is not correct because incorrect protons, neutrons and electrons* ***D*** *is not correct because incorrect protons and neutrons*	**(1)**

Q27.

Question Number	Answer	Mark
	The only correct answer is A ***B*** *is not correct because oxygen atoms do not have this number of protons* ***C*** *is not correct because oxygen atoms do not have this number of protons* ***D*** *is not correct because oxygen atoms do not have this number of protons*	**(1)**

Q28.

Question number	Acceptable Answer	Additional Guidance	Marks
(i)	An explanation that makes reference to the following points: • the outermost electron of the magnesium atom is in a quantum shell of lower energy (than that of the strontium atom) \ the outermost electron is in the 3s rather than the 5s (orbital) (1) • the outermost electron of the magnesium atom is closer to the nucleus so is more strongly attracted **OR** the outermost electron(s) of the magnesium atom experiences less shielding (that that of the strontium atom) so is more strongly attracted (1)	Ignore any mention of (effective) nuclear charge	**2**

Question number	Acceptable Answer	Additional Guidance	Marks
(ii)	An explanation that makes reference to the following points: **<u>EITHER</u>** • greater proton to electron ratio so greater attraction **/**electron is being removed from a positively charged particle (1) • remaining electron is closer to the nucleus (1) **<u>OR</u>** • after the first electron is removed the remaining electron experiences less repulsion (1) • therefore it has a lower energy (than before) (1)		**2**

Question number	Acceptable Answer	Additional Guidance	Marks
(iii)	An explanation that makes reference to the following points: • the third electron is removed from a different (quantum) shell / removed from the second (quantum) shell as opposed to the third (1) • of lower energy / closer to the nucleus **OR** • less shielding of the 2p electron (1)		**2**

Q29.

Question Number	Answer	Mark
	The only correct answer is B $(Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-)$ **A** *is not correct because it is the equation for the first three ionisation energies* **C** *is not correct because an ion is gaining electrons* **D** *is not correct because an ion is gaining an electron*	**(1)**