

F321

Question			Expected Answers	Marks	Additional Guidance
1	a	i	(atoms of the) same element OR same atomic no. OR no. of protons AND with different numbers of neutrons OR different masses ✓	1	IGNORE 'same number of electrons' DO NOT ALLOW 'different numbers of electrons' DO NOT ALLOW 'different relative atomic masses' DO NOT ALLOW 'elements with different numbers of neutrons' without mention of same protons OR same atomic number
		ii	same (number of) electrons (in the outer shell) OR same electron configuration OR structure ✓	1	DO NOT ALLOW different number of protons IGNORE 'same number of protons' IGNORE 'they are both carbon' OR 'they are both the same element'
		iii	mass of the isotope compared to 1/12th OR mass of the atom compared to 1/12th ✓ (the mass of a) carbon-12 OR ^{12}C (atom) ✓	2	IGNORE reference to average OR weighted mean (i.e. correct definition of relative atomic mass will score both marks) ALLOW mass of a mole of the isotope/atom with 1/12th the mass of a mole OR 12 g of ✓ carbon-12 ✓ ALLOW 2 marks for: 'mass of the isotope OR mass of the atom compared to ^{12}C atom given a mass of 12.0' i.e. 'given a mass of 12' communicates the same idea as 1/12th.'

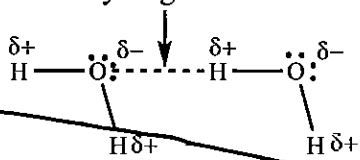

Question	Expected Answers	Marks	Additional Guidance
			<p>ALLOW 12C OR C12</p> <p>ALLOW FOR 2 MARKS: $\frac{\text{mass of the isotope}}{\text{mass of 1/12th mass of carbon - 12}}$ i.e. fraction is equivalent to 'compared to'</p> <p>ALLOW 1 MARK FOR a mix of mass of atom and mass of mole of atoms, i.e.: 'mass of the isotope/mass of an atom compared with 1/12th the mass of a mole OR 12 g of carbon-12.'</p>
b	<p>giant covalent (lattice) ✓</p> <p>layers ✓</p> <p>Each of the three properties below must be linked to explanation <i>good conductor</i> - because it has mobile electrons OR delocalised electrons OR electrons can move ✓</p> <p><i>high melting / boiling point</i> - because strong OR covalent bonds have to be broken ✓</p> <p><i>soft</i> - because there are van der Waals' forces OR</p>	5	<p>Use annotations with ticks, crosses etc. for this part.</p> <p>All five marking points are independent</p> <p>ALLOW giant atomic OR giant molecular OR macromolecular</p> <p>ALLOW planes OR sheets Allow diagram showing at least two layers</p> <p>Electron(s) must be spelt correctly ONCE</p> <p>DO NOT ALLOW 'strong ionic bonds' OR strong metallic bonds.</p>

F321 Atoms, Bonds and Groups

Question			Expected Answers	Marks	Additional Guidance												
1	(a)	(i)	<table border="1"> <thead> <tr> <th></th> <th>protons</th> <th>neutrons</th> <th>electrons</th> </tr> </thead> <tbody> <tr> <td>²⁴Mg</td> <td>12</td> <td>12</td> <td>12</td> </tr> <tr> <td>²⁵Mg</td> <td>12</td> <td>13</td> <td>12</td> </tr> </tbody> </table> <p>²⁴Mg line correct ✓ ²⁵Mg line correct ✓</p>		protons	neutrons	electrons	²⁴ Mg	12	12	12	²⁵ Mg	12	13	12	2	mark by row
	protons	neutrons	electrons														
²⁴ Mg	12	12	12														
²⁵ Mg	12	13	12														
		(ii)	$\frac{24 \times 78.60 + 25 \times 10.11 + 26 \times 11.29}{100}$ <p>OR 18.8640 + 2.5275 + 2.9354</p> <p>OR 24.3269 ✓</p> <p>A_r = 24.33 (to 4 sig figs) ✓</p>	2	<p>ALLOW two marks for A_r = 24.33 with no working out</p> <p>ALLOW one mark for ecf from incorrect sum provided final answer is between 24 and 26 and is to 4 significant figures, e.g. 24.3235 * gives ecf of 24.32 ✓</p>												
		(iii)	<p>The (weighted) mean mass of an atom OR (weighted) average mass of an atom ✓</p> <p>relative to 1/12th (the mass) ✓</p> <p>of (one atom of) ¹²C ✓</p>	3	<p>ALLOW The (weighted) mean mass OR (weighted) average mass of an atom OR average atomic mass ✓ compared with (the mass of) carbon-12 ✓ which is 12 ✓</p> <p>For 1st marking point, ALLOW mean mass of the isotopes OR average mass of the isotopes Do NOT ALLOW the singular: isotope</p> <p>ALLOW mass of one mole of atoms ✓ compared to 1/12th ✓ (the mass) of one mole / 12 g of carbon-12 ✓</p>												

Question			Expected Answers	Marks	Additional Guidance
4	(a)	(i)	the energy required to remove one electron ✓ from each atom in one mole ✓ of gaseous atoms ✓	3	<p>ALLOW 3 marks for: the energy required to remove one mole of electrons ✓ from one mole of atoms ✓ atoms in the gaseous state ✓</p> <p>If no definition, ALLOW one mark for the equation below, including state symbols. $X(g) \rightarrow X^+(g) + e^-$ / $X(g) - e^- \rightarrow X^+(g)$ ALLOW e for electron IGNORE state symbol for electron</p>
	(b)	(i)	<p>outer electrons closer to nucleus OR radii decreases ✓</p> <p>nuclear charge increases OR protons increase ✓</p> <p>electrons added to the same shell OR screening OR shielding remains the same ✓</p>	3	<p>IGNORE 'atomic number increases' IGNORE 'nucleus gets bigger' 'charge increases' is not sufficient ALLOW 'effective nuclear charge increases' OR 'shielded nuclear charge increases'</p> <p>ALLOW shielding is similar</p>
		(ii)	<p>atomic radii increase OR there are more shells ✓</p> <p>there is more shielding OR more screening ✓</p>	3	<p>ALLOW electrons in higher energy level ALLOW electrons are further from the nucleus DO NOT ALLOW more orbitals OR more sub-shells DO NOT ALLOW different shell or new shell</p> <p>There must be a clear comparison: e.g. 'more shielding', 'increased shielding'. i.e. DO NOT ALLOW just 'shielding'. ALLOW 'more electron repulsion from inner shells'</p>

Question		Expected Answers	Marks	Additional Guidance
		the nuclear attraction decreases OR Increased shielding / distance outweigh the increased nuclear charge ✓		Nuclear OR proton(s) OR nucleus spelt correctly ONCE ALLOW 'nuclear pull' IGNORE any reference to 'effective nuclear charge'
(c)	(i)	$O^+(g) \longrightarrow O^{2+}(g) + e^-$ ✓	1	answer must have state symbols ALLOW e for electron ALLOW $O^+(g) - e^- \rightarrow O^{2+}(g)$ DO NOT ALLOW $O^+(g) + e^- \longrightarrow O^{2+}(g) + 2e^-$ IGNORE state symbol for electron
	(ii)	the O^+ ion, is smaller than the O atom OR the electron repulsion/shielding is smaller OR the proton : electron ratio in the 2+ ion is greater than in the 1+ ion ✓	1	ALLOW the outer electrons in an O^+ ion are closer to the nucleus than an O atom DO NOT ALLOW 'removed from next shell down'
		Total	11	

Question	Expected Answers	Marks	Additional Guidance
5 (a) (i)	number of protons (in the nucleus) ✓	1	ALLOW proton number ALLOW number of protons in an atom IGNORE reference to electrons
	(ii) $(1s^2)2s^22p^63s^23p^63d^24s^2$ ✓	1	ALLOW $1s^2$ written twice ALLOW subscripts ALLOW $4s^2$ before $3d^2$
	(iii) Mn / manganese and d ✓	1	ALLOW D
(b) (i)	<p style="text-align: center;">Hydrogen bond</p>  <p>Shape of water with at least one H with $\delta+$ and at least one O with $\delta-$ ✓</p> <p>H-bond between H in one water molecule and a lone pair of an O in another water molecule ✓</p> <p>hydrogen bond labelled OR H_2O has hydrogen bonding ✓</p>	3	<p>all marks can be awarded from a labelled diagram</p> <p>If HO_2 shown then DO NOT ALLOW 1st mark Dipole could be described in words so it does not need to be part of diagram.</p> <p>At least one hydrogen bond must clearly hit a lone pair Lone pair interaction could be described in words so it does not need to be part of diagram.</p> <p>DO NOT ALLOW hydrogen bonding if described in context of intramolecular bonding, <i>ie</i></p> 
	(ii) no hydrogen bonding OR weaker intermolecular forces ✓	1	<p>DO NOT ALLOW 'weaker' / 'weak' hydrogen bonding</p> <p>ALLOW weaker van der Waals' forces ALLOW weaker dipole-dipole interactions DO NOT ALLOW 'weak intermolecular forces' (<i>ie</i> comparison essential here) DO NOT ALLOW 'no intermolecular forces'</p>

Question	Expected Answers	Marks	Additional Guidance
b	<p>nuclear charge increases/ protons increase ✓</p> <p>electrons added to the same shell OR screening OR shielding remains the same ✓</p> <p>greater attraction OR greater pull ✓</p>	3	<p><i>USE annotations with ticks, crosses, etc, etc for this part.</i></p> <p>Nuclear OR proton(s) OR nucleus spelt correctly ONCE</p> <p>IGNORE 'atomic number increases' IGNORE 'nucleus gets bigger' 'charge increases' is not sufficient ALLOW 'effective nuclear charge increases' OR 'shielded nuclear charge increases'</p> <p>IGNORE reference to atomic radius staying the same</p> <p>ALLOW shielding is similar DO NOT ALLOW extra shielding</p> <p>A comparison must be included: i.e. 'greater pull', 'more pull', 'held more tightly';</p>
	Total	8	

Section 1 : 128.

Question		Expected Answers	Marks	Additional Guidance
		intermolecular forces OR weak bonds OR weak forces between the layers OR Soft - because layers can slide ✓		
c	i	0.0268 OR 0.027 OR 0.02675 mol ✓	1	NO OTHER ACCEPTABLE ANSWER
	ii	1.61×10^{22} ✓	1	ALLOW 1.6×10^{22} up to calculator value ALLOW ECF answer to (i) $\times 6.02 \times 10^{23}$ ALLOW any value for N_A in the range: $6.0 \times 10^{23} - 6.1 \times 10^{23}$
Total			11	

Question		Expected Answers	Marks	Additional Guidance
5	a	BaO ✓ Ba ₃ N ₂ ✓	2	Treat any shown charges as working and ignore. Treat B for Ba as a slip.
	b	i	1	mark is for the working out which MUST lead to the correct answer of 8×10^{-4} up to calculator value
		ii	1	ALLOW 19 up to calculator value.
		iii	1	ALLOW 8.01×10^{-3} up to calculator value.
		iv	1	ALLOW a correct range of pH.
	c	Less barium to react OR some barium has already reacted ✓	1	ALLOW less volume because contains some BaO or Ba₃N₂
	d	reactivity increases (down the group) ✓ atomic radii increase OR there are more shells ✓ there is more shielding OR more screening ✓ the nuclear attraction decreases OR Increased shielding and distance outweigh the increased nuclear charge ✓ easier to remove (outer) electrons OR ionisation energy decreases ✓	5	USE annotations with ticks, crosses, ecf, etc for this part. DO NOT ALLOW more orbitals OR more sub-shells 'More' is essential ALLOW 'more electron repulsion from inner shells' ALLOW 'nuclear pull' IGNORE any reference to 'effective nuclear charge' ALLOW easier to form positive ion
		Total	12	

Question			Expected Answers	Marks	Additional Guidance
3	(a)	(i)	mol HCl = 1.50×10^{-2} ✓ volume HCl(aq) = 75.0 ✓	2	ALLOW answers to 2 significant figures ALLOW ecf from wrong number of moles i.e. <u>moles of HCl x 1000</u> 0.200 ALLOW one mark for 37.5 (from incorrect 1:1 ratio)
		(ii)	180 ✓	1	No other acceptable answer
	(b)	$\text{CaCO}_3(\text{s}) \longrightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$ equation ✓ state symbols ✓	2	state symbols are dependent on correct formulae of CaCO_3, CaO and CO_2 DO NOT ALLOW the 'equation mark' if O_2 is seen on both sides (but note that the 'state symbol mark' may still be accessible)	
	(c)	(i)	$\text{Ca}(\text{OH})_2$ ✓	1	IGNORE charges, even if wrong
		(ii)	$\text{Ca}(\text{NO}_3)_2$ ✓	1	IGNORE charges, even if wrong
Total				7	

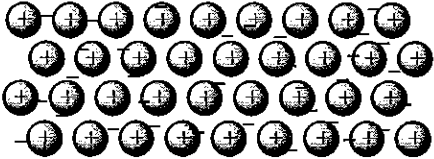
Question	Expected Answers	Marks	Additional Guidance
iii	tetrahedral ✓ 109.5° ✓	2	ALLOW 109-110°
iv	ions OR electrons cannot move in a solid ✓ ions can move OR are mobile in solution ✓	2	ALLOW ions can move in liquid DO NOT ALLOW ions can move when molten ALLOW 1 mark for: 'ions can only move in solution'
c i	$2\text{NH}_3 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4$ ✓	1	ALLOW $2\text{NH}_4\text{OH} + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4 + 2\text{H}_2\text{O}$ ALLOW $\text{NH}_3 + \text{H}^+ \rightarrow \text{NH}_4^+$ ALLOW any correct multiple IGNORE state symbols
ii	when the H^+ in an acid is replaced by a metal ion OR an ammonium ion OR a + ion ✓	1	ALLOW H for H^+ ; ALLOW 'metal' for 'metal ion' i.e.: H in an acid can be replaced by a metal
iii	accepts a proton OR accepts H^+ ✓	1	ALLOW donates a lone pair ALLOW removes H^+ ALLOW forms OH^- ions
iv	132.1 ✓	1	IGNORE units NO OTHER ACCEPTABLE ANSWER
Total		15	

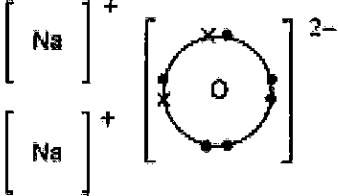
Question		Expected Answers	Marks	Additional Guidance
				$\frac{\text{mass of one mole of atoms}}{12}$ ✓ $\frac{1}{12}$ th ✓ the mass of one mole / 12 g of carbon-12 ✓
(b)	(i)	Mg ✓ oxidation number changes from 0 to (+)2 OR oxidation number increases by 2 ✓	2	ALLOW correct oxidation numbers shown in equation 2nd mark is dependent on identification of Mg IGNORE electrons
	(ii)	Mg/solid dissolves OR Mg/solid disappears OR (Mg/solid) forms a solution ✓ bubbles OR fizzes OR effervesces OR gas produced ✓	2	IGNORE metal reacts IGNORE temperature change IGNORE steam produced DO NOT ALLOW carbon dioxide gas produced DO NOT ALLOW hydrogen produced without gas
(c)	(i)	$M(\text{MgSO}_4) = 120.4 \text{ OR } 120 \text{ (g mol}^{-1}\text{)} \checkmark$ $\text{mol MgSO}_4 = \frac{1.51}{120.4} = 0.0125 \text{ mol} \checkmark$	2	ALLOW 0.013 up to calculator value of 0.012541528 correctly rounded (from $M = 120.4 \text{ g mol}^{-1}$) ALLOW 0.013 up to calculator value of 0.012583333 correctly rounded (from $M = 120 \text{ g mol}^{-1}$) ALLOW ecf from incorrect M i.e. $1.51 \div M$
	(ii)	$\frac{1.57}{18.0} = 0.0872(2) \text{ (mol)} \checkmark$	1	ALLOW 0.09 up to calculator value of 0.08722222
	(iii)	$x = 7 \checkmark$	1	ALLOW ecf i.e. answer to (ii) + answer to (i) ALLOW correctly calculated answer from 1 significant figure up to calculator value, ie, x does not have to be a whole number. Likely response = 6.95 ✓
Total			15	

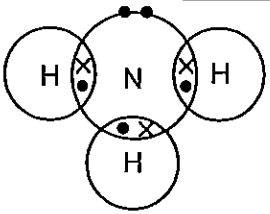
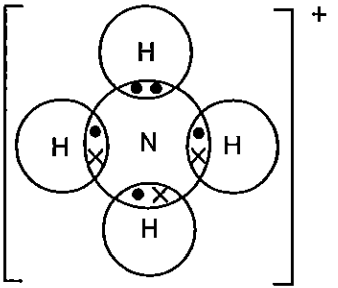
Question	Expected Answers	Marks	Additional Guidance
ii	It has been both oxidised and reduced OR Its oxidation state has increased and decreased ✓ it has been oxidised (from 0) to +1 AND it has been reduced (from 0) to -1 ✓ (These two points together subsume the first marking point)	2	ALLOW 'chlorine' OR 'it' DO NOT ALLOW chloride IF CORRECT OXIDATION STATES IN (i), ALLOW 2 marks for: it is oxidised to form HClO it is reduced to form HCl
iii	$\text{Cl}_2 + 2\text{NaOH} \rightarrow \text{NaClO} + \text{NaCl} + \text{H}_2\text{O}$ ✓	1	IGNORE state symbols
d i	$2\text{ClO}_2 \rightarrow \text{Cl}_2 + 2\text{O}_2$ OR $\text{ClO}_2 \rightarrow \frac{1}{2}\text{Cl}_2 + \text{O}_2$ ✓	1	IGNORE state symbols
ii	divides each % by correct A_r : i.e. $\frac{1.20}{1.0} : \frac{42.0}{35.5} : \frac{56.8}{16.0}$ OR 1.20, 1.18, 3.55 ✓ HClO_3 ✓	2	ALLOW 1 mark for empirical formula of HCl_2O_6 (use of atomic numbers) ALLOW 1 mark for empirical formula of $\text{H}_3\text{Cl}_3\text{O}$ (upside-down expression) ALLOW ECF for use of incorrect A_r values to get empirical formula but only if no over-rounding ALLOW 2 marks for correct answer of HClO_3
iii	the oxidation number of chlorine ✓	1	ALLOW 'the oxidation state of chlorine OR oxidation number of chlorine is 5' DO NOT ALLOW 'it' instead of 'chlorine' DO NOT ALLOW 'the oxidation state OR number of chloride is 5'
Total		14	

Section 2

/ 20
7

Question	Expected Answers	Marks	Additional Guidance
2 (a)	 <p>regular arrangement of labelled + ions with some attempt to show electrons ✓</p> <p>scattering of labelled electrons between other species OR a statement anywhere of delocalised electrons (can be in text below) ✓</p> <p>metallic bond as (electrostatic) attraction between the electrons and the positive ions ✓</p>	3	<p>Lattice must have at least 2 rows of positive ions If a metal ion is shown (e.g. Na⁺), it must have the correct charge</p> <p>ALLOW for labels: + ions, positive ions, cations If '+' is unlabelled in diagram, award the label for '+' from a statement of 'positive ions' in text below DO NOT ALLOW as label or text positive atom OR protons OR nuclei</p> <p>ALLOW e⁻ OR e as label for electron DO NOT ALLOW '-' as label for electron</p>
(b) (i)	$4 \text{ Na} + \text{O}_2 \longrightarrow 2 \text{ Na}_2\text{O}$ <p>OR</p> $2 \text{ Na} + \frac{1}{2} \text{ O}_2 \longrightarrow \text{Na}_2\text{O} \checkmark$	1	<p>ALLOW correct multiples including fractions IGNORE state symbols</p>
	(ii) (electrostatic) attraction between oppositely charged ions ✓	1	

Question	Expected Answers	Marks	Additional Guidance
(iii)	 <p>Na shown with either 8 or 0 electrons AND O shown with 8 electrons with 6 crosses and 2 dots (or vice versa) ✓ Correct charges on both ions ✓</p>	2	<p>For 1st mark, if 8 electrons shown around cation then 'extra' electron(s) around anion must match symbol chosen for electrons in cation Shell circles not required</p> <p>IGNORE inner shell electrons</p> <p>ALLOW: 2[Na⁺] 2[Na]⁺ [Na⁺]₂ (brackets not required) DO NOT ALLOW [Na₂]²⁺ / [Na₂]⁺ / [2Na]²⁺ DO NOT ALLOW: [Na₂]²⁺ [Na₂]⁺ [2Na]²⁺ [Na]₂⁺</p>
(c)	<p>sodium is a (good) conductor because it has mobile electrons OR delocalised electrons OR electrons can move ✓</p> <p>sodium oxide does not conduct as a solid ✓</p> <p>sodium oxide conducts when it is a liquid ✓</p> <p>ions cannot move in a solid ✓</p> <p>ions can move OR are mobile when liquid ✓</p>	5	<p>Throughout this question, 'conducts' and 'carries charge' are treated as equivalent terms.</p> <p>DO NOT ALLOW 'free electrons' for mobile electrons</p> <p>ALLOW poor conductor OR bad conductor 'Sodium oxide only conducts when liquid' is insufficient to award 'solid conductivity' mark</p> <p>ALLOW ions are fixed in place IGNORE electrons IGNORE charge carriers</p> <p>IGNORE 'delocalised ions' or 'free ions' for mobile ions Any mention of electrons moving is a CON</p>
Total		12	

Question			Expected Answers	Marks	Additional Guidance
2	a	i	a shared pair of electrons ✓	1	ALLOW any response that communicates electron pair ALLOW shared pairs
		ii		1	Must be 'dot-and-cross' circles for outer shells NOT needed IGNORE inner shells Non-bonding electrons of N do not need to be shown as a pair.
		iii	Shape: pyramidal OR (trigonal) pyramid ✓ Explanation: There are 3 bonded pairs and 1 lone pair ✓ Lone pairs repel more than bonded pairs ✓	3	ALLOW 'bonds' for 'bonded pairs' DO NOT ALLOW 'atoms repel' DO NOT ALLOW electrons repel ALLOW LP for 'lone pair' ALLOW BP for bonded pair
	b	i	$1s^2 2s^2 2p^6 3s^2 3p^6$ ✓	1	ALLOW subscripts
		ii		1	IGNORE inner shells IGNORE '+' sign BUT a DO NOT ALLOW '-' sign. Brackets and circles not required

Question	Expected Answers	Marks	Additional Guidance
	iii tetrahedral ✓ 109.5° ✓	2	ALLOW 109–110°
	iv ions OR electrons cannot move in a solid ✓ ions can move OR are mobile in solution ✓	2	ALLOW ions can move in liquid DO NOT ALLOW ions can move when molten ALLOW 1 mark for: 'ions can only move in solution'
c	i $2\text{NH}_3 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4$ ✓	1	ALLOW $2\text{NH}_4\text{OH} + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4 + 2\text{H}_2\text{O}$ ALLOW $\text{NH}_3 + \text{H}^+ \rightarrow \text{NH}_4^+$ ALLOW any correct multiple IGNORE state symbols
	ii when the H^+ in an acid is replaced by a metal ion OR an ammonium ion OR a + ion ✓	1	ALLOW H for H^+ ; ALLOW 'metal' for 'metal ion' i.e.: H in an acid can be replaced by a metal
	iii accepts a proton OR accepts H^+ ✓	1	ALLOW donates a lone pair ALLOW removes H^+ ALLOW forms OH^- ions
	iv 132.1 ✓	1	IGNORE units NO OTHER ACCEPTABLE ANSWER
	Total	15	

Section 3

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