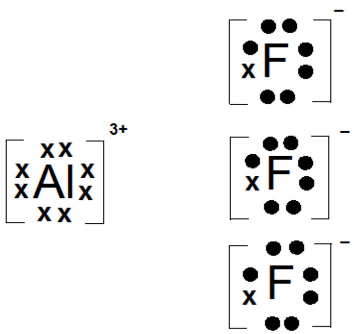
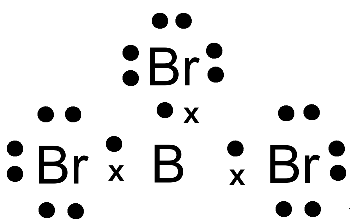
Question			Answer	Mark	Guidance
1	(a)		$2Al + 3F_2 \rightarrow 2AlF_3$ ✓	1	**ALLOW** multiples **IGNORE** state symbols
	(b)	(i)	Repeating pattern ✓ of oppositely charged ions ✓	2	**ALLOW** 'regular' **OR** 'alternating' **OR** 'uniform (arrangement)' for 'repeating pattern' **ALLOW** positive and negative ions **OR** aluminium ions and fluoride ions **ALLOW** oppositely charged ions from a labelled diagram
		(ii)	 Al with 8 (or no) outermost electrons **AND** 3 x fluoride (ions) with '*dot-and-cross*' outermost octet ✓ Correct charges ✓	2	For first mark: If 8 electrons are shown in the cation then the 'extra' electron in the anion must match the symbol chosen for the electrons in the cation **IGNORE** inner shells **IGNORE** circles **ALLOW** one mark if both electron arrangements and charges are correct but only one F is drawn. **ALLOW** one mark if incorrect symbol is the only error, unless ECF from 2(a) in which both marks are available **DO NOT ALLOW** any marks for BF_3 **ALLOW** $3[F^-]$ $3[F]^-$ $[F^-]_3$ (brackets not required) **DO NOT ALLOW** $[F_3]^-$ $[F_3]^{3-}$ $[3F]^{3-}$ $[F]_3^-$
	(c)	(i)	A shared pair of electrons.	1	
	(c)	(ii)	 ✓	1	

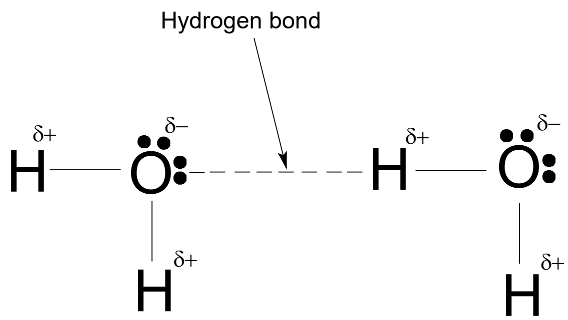
Question			Answer	Mark	Guidance
	(d)		*Conductivity of Al mark* M1: Aluminium conducts in solid and molten states ✓	5	**ALLOW** ‘carries charge’ for conducts **IGNORE** ‘charge carriers’ for ‘electrons’ or ‘ions’ for M2, M3 and M4.
			Reason for conductivity of Al mark M2: Aluminium has delocalised electrons ✓		*Quality of written communication:* ‘delocalis(z)ed’ spelled correctly and used in context for the second marking point. **DO NOT ALLOW** M2 if incorrect bonding is seen for Al **DO NOT ALLOW** ‘ions move’ for solid Al. **IGNORE** ‘ions move’ for molten Al.
			Conductivity and reason for molten AlF_3 mark M3: Aluminium fluoride conducts when molten **AND** because it has mobile **ions** ✓		**IGNORE** references to ‘aqueous’ AlF_3 for M3 **IGNORE** ‘delocalised ions’ **OR** ‘free ions’ for mobile ions in M3 **DO NOT ALLOW** M3 if incorrect bonding is seen in AlF_3 **DO NOT ALLOW** any mention of electrons moving for M3 **DO NOT ALLOW** suggestion that it is only positive or only negative ions moving for M3 For conductivity parts of M3 + M4 **ALLOW** ‘AlF_3 only conducts when molten’
			Conductivity and reason for solid AlF_3 mark M4: Aluminium fluoride does not conduct when solid **AND** Solid aluminium fluoride has **ions** which are fixed (in position) **OR ions** are held (in position) **OR ions** are not mobile **AND** In an (ionic) lattice **OR** (ionic) structure **OR** by (ionic) bonds ✓		**ALLOW** Solid AlF_3 is a poor conductor for M4 **ALLOW** second and third statements to be unlinked in separate sentences for M4 **IGNORE** ‘there are no delocalised electrons’ for M4 **DO NOT ALLOW** M4 if incorrect bonding is seen in AlF_3 Lattice **OR** structure **OR** ionic bonds can be seen anywhere in relation to AlF_3.
					ALLOW Solid BBr_3 is a poor conductor for M5 **ALLOW** electrons are fixed in position **OR** used in bonds

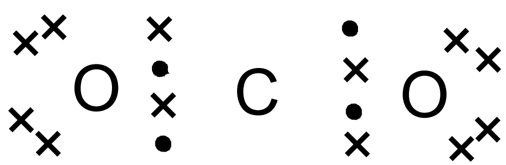
Question			Answer	Mark	Guidance
			Conductivity and reason for BBr_3 mark M5 Boron tribromide does not conduct in solid and molten states **AND** Boron tribromide has no mobile electrons **OR** no (mobile) ions **OR** no mobile charge carriers **OR** no mobile charged particles ✓		**IGNORE** ‘there are no delocalised electrons’ **OR** ‘there are no free electrons’ for M5 **DO NOT ALLOW** M5 if incorrect bonding is seen in BBr_3 eg ‘ions are fixed in position’ **ALLOW** ‘no (free) ions’
1	**(e)**	**(i)**	$Al^{2+}(g) \rightarrow Al^{3+}(g) + e^-$ ✓	1	State symbols required (ignore states on electrons) **ALLOW** $Al^{2+}(g) - e^- \rightarrow Al^{3+}(g)$ **ALLOW** e for e^-
		(ii)	All (thirteen) ionisation energies show an increase ✓ The two largest increases are between the third and fourth **AND** the eleventh and twelfth ionisation energies ✓	2	**IGNORE** line if drawn **IGNORE** 0 if included **ALLOW** one mark for three lines (no crosses) showing an increase between: first and third; fourth and eleventh; twelfth and thirteenth **AND** Largest increases between each line **ALLOW** crosses outside grid
			Total	**15**	

Question			Answer	Mark	Guidance
2	**(a)**		The attraction (between nuclei and outermost electrons) increases (across the period) **AND** The nuclear charge increases **OR** The number of protons increase ✓ (Outer) electrons are in the same shell **OR** (Outer) electrons experience similar shielding **OR** Same number of shells **OR** Atomic radius decreases ✓	2	**ALLOW** There is no change in shielding But **DO NOT ALLOW** 'there is no shielding' **DO NOT ALLOW** electrons are at the same distance

Question			Answer	Mark	Guidance
	(b)		*M1 NH_3 forces mark* NH_3 has hydrogen bonding ✓ *M2 F_2 **AND** Br_2 forces mark* F_2 **AND** Br_2 have van der Waals' (forces) ✓ *M3 Type of particle mark* Forces **OR** attractions are between molecules **OR** are intermolecular for ammonia **AND** Forces **OR** attractions are between molecules **OR** are intermolecular for fluorine **OR** for bromine ✓	5	*Quality of written communication:* 'molecule(s)' or 'intermolecular' spelled correctly once and used in context for the third marking point. **ALLOW** H-bonding for hydrogen bonding **IGNORE** van der Waals' forces **AND** permanent dipoles in M1 **IGNORE** covalent bonds for M1 **AND** M2 **ALLOW**, for van der Waal's: vdWs **OR** induced dipole temporary **OR** instantaneous dipole (-dipole) forces **ALLOW** for forces: attractions **OR** interactions; **DO NOT ALLOW** M3, M4 or M5 if covalent **OR** ionic bonds are the forces between the particles in that mark M3 can be seen anywhere eg in M1 NH_3 has hydrogen bonding between molecules **AND** the intermolecular force in Br_2 is stronger than that of F_2 eg a generic statement such as 'boiling point of these substances is determined by strength of *intermolecular bonding'* eg 'All these *molecules* are *held* together by weak forces'

Question			Answer	Mark	Guidance
			M4 Br_2 / F_2 comparison mark The van der Waals' forces in Br_2 are greater than in F_2 **AND** Because bromine has more electrons than fluorine ✓ *M5 Br_2 / NH_3 / F_2 comparison mark* The van der Waals' forces in Br_2 are greater than hydrogen bonding in NH_3 **AND** hydrogen bonding in NH_3 is stronger than van der Waals' forces in F_2 ✓		If correct force is given in M2 **ALLOW**, for M4, 'intermolecular force in Br_2 is stronger than that in F_2' **ALLOW** more van der Waals' for greater van der Waals' **ALLOW** more shells of electrons **IGNORE** 'permanent dipoles' in NH_3 for M5 if quoted in addition to hydrogen bonding If correct force is given in M1 **AND** M2 **ALLOW**, for M5, 'intermolecular force in Br_2 is stronger than that in NH_3' **AND** 'intermolecular force in NH_3 is stronger than that in F_2' If incorrect intermolecular force is given in M1 **OR** M2 **ALLOW** this as ECF for M5 but **DO NOT ALLOW** if the comparison is based only on van der Waals' forces Eg **DO NOT ALLOW** the van der Waals' forces in bromine are stronger than those in ammonia which in turn are stronger than those in fluorine
			Total	**7**	

Question			Answer	Mark	Guidance
3	(a)	(i)	*The Dipole Mark* At least one $H^{\delta+}$ **AND** one $O^{\delta-}$ shown correctly on each water molecule (see diagram) ✓  *The Hydrogen bonding Mark* **One** Hydrogen bond between H in one water molecule and a lone pair of O in an adjacent water molecule ✓	2	**DO NOT ALLOW** $H^{\delta-}$ **OR** $O^{\delta+}$ **IGNORE** lone pairs for first marking point All Hydrogen bonds must hit a lone pair Hydrogen bond does NOT need to be labelled but it must be different from the covalent bond if it is not labelled **ALLOW** H-bond as label **ALLOW** only one lone pair on O atom **ALLOW** additional, correctly drawn Hydrogen bonded water molecules with correct dipoles **DO NOT ALLOW** more than two lone pairs on O atom

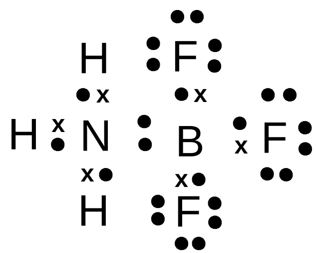
Question			Answer	Mark	Guidance
3	(a)	(ii)	*Property 1* Ice is less dense than water ✓ *Explanation 1* The molecules in ice are held apart by hydrogen bonds ✓ **OR** ice has an open lattice **OR** structure *Property 2* Ice has a relatively high melting point ✓ *Explanation 2* Hydrogen bonds are relatively strong OR Hydrogen bonds are stronger (than other intermolecular attractions or forces) OR More energy is needed to overcome hydrogen bonding	4	**ALLOW** ice floats (on water) **ALLOW** ice contracts when it melts **ALLOW** ice (water) has a higher melting point than expected **OR** predicted **ALLOW** other expressions which convey that the melting point is anomalously high eg 'Ice has an unusually high melting point' **IGNORE** boiling point **IGNORE** the following unqualified statements 'Ice has a higher melting point' or 'Ice has a high melting point' **IGNORE** references to surface tension as a property **IGNORE** explanations of surface tension **ALLOW** hydrogen bonds are the strongest intermolecular attraction or force **DO NOT ALLOW** 'hydrogen bonds are strong' but **ALLOW** this as part of a qualified statement (eg 'hydrogen bonds are strong compared with weak van der Waals forces')
3	(b)		 '*dot-and-cross'* of CO_2 ✓	1	Lone pairs on O must be seen Lone pairs may be seen as 4 individual electrons **ALLOW** correct use of three different symbols

Question			Answer	Mark	Guidance
	(c)		Giant covalent (lattice) ✓	1	**ALLOW** 'Giant lattice with covalent bonds' **ALLOW** 'Giant covalent bonds' **IGNORE** ' Giant molecular' or 'macromolecular' **DO NOT ALLOW** 'Covalent bonds between molecules'
	(d)		*Conductivity of Na mark* M1: Sodium conducts in the solid and molten states ✓ *Reason for conductivity of Na mark* M2: Sodium has delocalised electrons (in both solid and liquid state) ✓ *Conductivity of Na_2O mark* M3: Na_2O conducts when molten and not when solid ✓ *Reason for conductivity of Na_2O marks* M4: Molten Na_2O has **ions** which are mobile ✓ M5: Solid Na_2O has **ions** which are fixed (in position) **OR ions** are held (in position) **OR ions** are not mobile **AND** in an (ionic) lattice **OR** structure ✓	5	Quality of written communication 'delocalis(z)ed spelled correctly once and used in context for second marking point **ALLOW** 'carries charge' for conducts for M1 and M3 **IGNORE** 'charge carriers' for electrons **OR** ions for M2, M4 and M5 **DO NOT ALLOW** M2 if incorrect bonding is seen for Na **DO NOT ALLOW** ions move for solid Na for M2 **IGNORE** ions move for molten Na for M2 **ALLOW** solid Na_2O is a poor conductor for M3 **IGNORE** references to aqueous Na_2O for M3 **IGNORE** references to aqueous Na_2O for M4 **IGNORE** 'delocalised ions' **OR** 'free ions' for 'mobile ions' for M4 **DO NOT ALLOW** M4 **AND** M5 if incorrect bonding is seen in Na_2O **DO NOT ALLOW** any mention of electrons moving for M4 **DO NOT ALLOW** suggestion that it is only positive or only negative ions move for M4 **IGNORE** 'there are no delocalised electrons' for M5 **ALLOW** first and second statements of M5 to be unlinked in separate sentences **ALLOW** 'ions fixed in position by ionic bonds' for M5
			Total	**13**	

Question			Answer	Marks	Guidance
4	(a)	(i)	P in P_4 is 0 **AND** in PH_3 is –3 **AND** in NaH_2PO_2 is (+)1 ✓ Phosphorus has been oxidised (from 0) to +1✓ Phosphorus has been reduced (from 0) to –3 ✓	3	**FULL ANNOTATIONS WITH TICKS, CROSSES, CON, etc MUST BE USED** **ALLOW** oxidation states written above the equation if not seen in the text BUT **IGNORE** oxidation states written above the equation if seen in the text **ALLOW** 3– **AND** 1+ **DO NOT ALLOW ions** **DO NOT ALLOW** P^{3-} in PH_3 **OR** P^+ in NaH_2PO_2 **DO NOT ALLOW** phosph**ide** or phosph**ine** or phosphate in place of phosphorus **ALLOW** P or P_4 for phosphorus **ALLOW** ECF for the second and third marks if **ONE** incorrect oxidation number is assigned but directional changes are correct eg P = 0 and –3 and +2 instead of 0 and –3 and +1. **IGNORE** references to electron loss / gain If correct oxidation numbers are seen **ALLOW** second **AND** third marking points for: 'Phosphorus is oxidised to form NaH_2PO_2' **AND** 'Phosphorus is reduced to form PH_3' **IF** neither second and third marks have been awarded **ALLOW** for **ONE** mark: Phosphorus has been both oxidised and reduced **OR** Phosphorus's oxidation number has increased and decreased

Question			Answer	Marks	Guidance
	(a)	(ii)	**First check the answer on the answer line.** **If answer** = 360 (cm^3) award 2 marks Correctly calculates amount of P_4 = 1.86/124.0 = 0.015(0) mol ✓ Correctly calculates volume of PH_3 = 0.015(0) x 24000 = 360 (cm^3) ✓	2	If there is an alternative answer, check to see if there is any ECF credit possible using working below **ALLOW** ECF for wrong amount of P_4 x 24000 for second mark **ALLOW** one mark for (1.86/31.0) x 24000 = 1440 **DO NOT ALLOW** 2nd mark for 1.86 x 24000 = 44640 **ALLOW** calculator value or rounding to 2 significant figures or more **BUT IGNORE** 'trailing' zeroes, eg 0.200 allowed as 0.2.
	(b)		$4PH_3 + 8O_2 \rightarrow P_4O_{10} + 6H_2O$ ✓	1	**ALLOW** correct multiples **IGNORE** state symbols
	(c)	(i)	The hydrogen **ions OR** H^+ **OR** protons (of phosphoric acid) are replaced by sodium **ions OR** Na^+ ✓	1	**ALLOW** Na ions **OR** positive ions replace H ions **OR** metal ions have replaced hydrogen ions **OR** protons **DO NOT ALLOW** Na replaces H. Ions are key in either word or symbol form. **DO NOT ALLOW** incorrect charge on Na ions (eg Na^{2+})
		(ii)	Correctly calculates 0.100 x 15 / 1000 = 1.5(0) x 10^{-3} **OR** 0.0015(0) ✓	1	
		(iii)	22.5 ✓	1	**ALLOW** ECF from (ii) Answer from (ii) x (3/0.2) x 1000
	(d)	(i)	hydrogen bonding ✓ Permanent dipole(–dipole interactions) ✓	2	

Question			Answer	Marks	Guidance
	(d)	**(ii)**	the intermolecular forces are weaker in PH_3 ✓	1	**ALLOW** the energy needed to overcome the intermolecular forces in NH_3 is greater Check table in part (i) **IF** NH_3 = hydrogen bonds **AND** PH_3 = permanent dipoles **OR** van der Waal's forces; **ALLOW** 'Hydrogen Bonds are stronger' **ORA** **IF** NH_3 = permanent dipoles **AND** PH_3 = van der Waal's forces; **ALLOW** 'permanent dipoles are stronger' **ORA** **IF** NH_3 = permanent dipoles **AND** PH_3 = permanent dipoles; **ALLOW** 'permanent dipoles are stronger **in** $\mathbf{NH_3}$' **ORA** **DO NOT ALLOW** PH_3 has weaker vdW's than NH_3 **DO NOT ALLOW** NH_3 has stronger hydrogen bonds than PH_3 **DO NOT ALLOW** implication that covalent bonds are broken
	(e)	**(i)**	Both electrons have been donated by one atom ✓	1	**ALLOW** 'they' for electrons **IGNORE** elements for atom **DO NOT ALLOW** 'transfer' in place of 'donated' **DO NOT ALLOW** more than one electron pair is donated

Question			Answer	Marks	Guidance
	(e)	**(ii)**	 Correct '*dot-and-cross*' arrangement of B covalently '*dot-and-cross*' bonded to three F atoms, including full octet on F atoms **AND** Correct '*dot-and-cross*' arrangement of N covalently '*dot-and-cross*' bonded to three H atoms ✓ Dative covalent shown between N and B atoms ✓	2	Must be '*dot-and-cross*', but **ALLOW** other symbols for electrons of third and fourth atoms eg Δ, +, o, etc Circles for outer shells are not needed **IGNORE** inner shells **IGNORE** use of charges Non-bonding electrons of F do not need to be seen as pairs **IGNORE** dative-covalent arrows from N to B, but **DO NOT ALLOW** arrow from B to N **DO NOT ALLOW** two separate molecules for first mark **DO NOT ALLOW** dative covalent bond mark if electron pair matches the B electrons ie to be correct the dative pair must be the same symbol as non-bonding electrons on F atoms if only two symbols are used **DO NOT ALLOW** dative covalent bond mark if F atoms have no non-bonding electrons **UNLESS** B has different electron symbol to N or H atoms
		(iii)	BF_3 = 120(∘) ✓ H_3NBF_3 = 109.5(∘) ✓	2	**ALLOW** 109–110(∘) for H_3NBF_3

Question			Answer	Marks	Guidance
	(e)	**(iv)**	(N in) NH_3 has three bonding pairs and one lone pair of electrons ✓ (N in) H_3NBF_3 has **four** bonding pairs (and no lone pairs) of electrons **OR** Lone pair on N now becomes bonding pair ✓ Lone pair of electrons repels **more** than bonding pairs ✓	3	**ALLOW** 'bonds' for 'bonding pairs' **IGNORE** 'electrons repel' **DO NOT ALLOW** 'atoms repel'
			Total	**20**	