Questions

Q1.

This question is about covalent bonds.

State what is meant by the term covalent bond.

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(Total for question = 2 marks)

Q2.

This question is about aluminium chloride.

Aluminium chloride exists as a dimer, Al_2Cl_6, just above its boiling temperature.

(i) Draw a diagram to show how two $AlCl_3$ molecules are joined together in the dimer.

(1)

(ii) State the type of bond that joins the two $AlCl_3$ molecules together.

(1)

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(Total for question = 2 marks)

Q3.

This question is about covalent bonds.

(i) Ammonia and boron trifluoride react to form a compound NH_3BF_3 which contains a dative covalent bond. Each of the molecules, NH_3 and BF_3, has a different feature of its electronic structure that allows this to happen. Use these two different features to explain how a dative covalent bond is formed.

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(ii) During this reaction, the bond angles about the nitrogen atom and the boron atom change.

State the new H—N—H and F—B—F bond angles.

(2)

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(Total for question = 4 marks)

Q4.

State what is meant by the term electronegativity and hence explain the polarity, if any, of the **bonds** in chlorine trifluoride, ClF_3.

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(Total for question = 3 marks)

Q5.

The table shows some information about the structure and bonding in four substances.

Substance	Structure	Bonding	Melting temperature / K
silicon(IV) oxide	giant	covalent	1883
potassium chloride			1043
iron		metallic	1808
iodine		covalent	387

Explain why the melting temperature of silicon(IV) oxide is much higher than that of iodine, even though the bonding in both is covalent.

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(Total for question = 3 marks)

Q6.

Nitrogen forms several hydrides. In addition to ammonia, NH_3, it forms hydrazine, N_2H_4, in which the two nitrogen atoms are covalently bonded together.

(i) Explain what is meant by a covalent bond.

(2)

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(ii) Draw a dot-and-cross diagram for hydrazine, showing the outer electrons only.

Use crosses (×) to represent the electrons from nitrogen and dots (•) to represent the electrons from hydrogen.

(1)

(iii) Estimate the H—N—H bond angle in hydrazine.

(1)

Bond angle = ...

(Total for question = 4 marks)

Q7.

This is a question about water.

Explain why both water and carbon dioxide molecules have polar bonds but only water is a polar molecule.

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(Total for question = 4 marks)

Q8.

This question is about atomic structure and the Periodic Table.

The melting temperatures of two elements in Period 3 are given in the table.

Element	silicon	chlorine
Melting temperature / K	1683	172

Explain, in terms of the structure and bonding of each element, the difference between these values.

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(Total for question = 3 marks)

Q9.

This question is about crystalline solids.

Iodine and diamond are crystalline solids at room temperature.

Explain why diamond has a much higher melting temperature than iodine.

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(Total for question = 5 marks)

Q10.

This question is about the thermal stability of Group 1 and Group 2 nitrates and carbonates.

Calcium carbonate is thermally decomposed during the manufacture of cement.

(i) Write an equation, including state symbols, for the thermal decomposition of calcium carbonate.

(1)

(ii) Name all the types of bond present in calcium carbonate.

(1)

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(iii) Give a reason, in terms of the bonding, why a high decomposition temperature is required.

(1)

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(Total for question = 3 marks)

Q11.

* Boron and aluminium are in the same group of the Periodic Table. Both form compounds with chlorine and with fluorine.

Aluminium fluoride and aluminium chloride are both crystalline solids at room temperature. Aluminium fluoride sublimes to form a gas at 1291°C (1564 K), whilst aluminium chloride sublimes at 178°C (451 K).

Use the Pauling electronegativity values in the Data Booklet to explain these differences in sublimation temperature.

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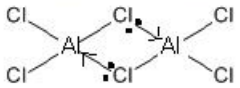
(Total for question = 6 marks)

Mark Scheme

Q1.

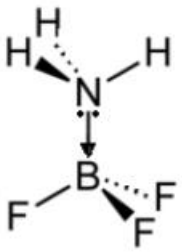
Question Number	Acceptable Answer	Additional Guidance	Mark
	An answer that makes reference to the following points: • (strong electrostatic) attraction **(1)** • between two nuclei and the share /bonding **pair of electrons** **(1)**		**(2)**

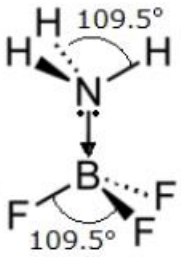
Q2.

Question Number	Answer	Additional Guidance	Mark
(i)	• diagram showing two $AlCl_3$ molecules joined through two chlorine atoms	Example of diagram  Allow dot-and-cross diagram Ignore missing arrows / direction of arrows Ignore missing lone pairs	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	• dative (covalent) bonds or coordinate bonds	Allow this labelled on diagram in (i) Do not award this mark if dative bonds shown as arrows starting from aluminium in (c)(i)	(1)

Q3.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • donation of **lone pair** (of electrons) from nitrogen / **lone pair** from ammonia **(1)** • to the boron (atom) which is electron deficient / has only 6 electrons in outer shell / has 6 valence electrons / can accept two electrons to complete octet /can accept two electrons to get a full (outer) shell **(1)**	Allow 'non-bonding pair' for lone pair Allow 'sharing' for donation Do not penalise donation to F atoms, but can only score M1 in this case Allow just 'boron has an incomplete outer shell' Allow boron has an empty (p-)orbital Do not award M2 for just 'nitrogen shares lone pair with boron atom' or similar M1 may be scored from a diagram here **OR** a diagram in **(d)(ii)** e.g.  scores only M1	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• HNH angle is (approximately) 109.5° **(1)** • FBF angle is (approximately) 109.5° **(1)**	May be shown on a diagram, including on a diagram in **(i)** e.g  Allow 1 for just 109.5° if it has not been made clear that this angle applies to BOTH bond angles Both angles change to 109.5° scores 2 Allow 109-110°	**(2)**

Q4.

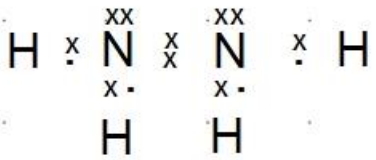
Question Number	Acceptable Answers	Additional Guidance	Mark
	An explanation that makes reference to the following points:	Penalise fluor**ide**/chlor**ide** / molecules once only Allow 'element' for atom	**(3)**
	• electronegativity is the (relative) ability of an atom to attract the (bonding) electron**s** (in a covalent bond) **(1)**	Do not allow 'species' for atom	
	• fluorine is more electronegative than chlorine/fluorine is the most electronegative (element) **(1)**	Allow fluorine has an electronegativity of 4.0 and chlorine of 3.0	
	• so fluorine is δ− **and** chlorine is δ+ **(1)**	Could be shown on a diagram Ignore references to overall polarity No TE on incorrect M2	

Q5.

Question Number	Acceptable Answer		Additional Guidance	Mark
	An explanation that makes reference to the following points:			(3)
	• silicon(IV) oxide/ silicon dioxide (is a giant structure therefore) contains many (strong covalent) bonds	(1)	Allow silicon oxide	
	• iodine – (only) weak intermolecular / London forces/bonds must be broken	(1)	Do not award covalent bonds are broken Accept dispersion force / instantaneous dipole-induced dipole / van der Waals	
	• more **energy** is required to break the stronger bonds in silicon(IV) oxide/ silicon dioxide (hence higher melting temperature)	(1)	Allow reverse argument M3 can be awarded even if M2 is incorrect	

Q6.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	A description that makes reference to the following points: • (electrostatic / electric(al)) attraction of (two) **nuclei** (1) • with a shared pair /2 electrons (1)	Allow a pair of electrons between the nuclei	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• correct dot and cross diagram	 Allow diagram with all dots, all crosses, dots and crosses in reversed order, or a mix of dots and crosses Allow non-bonding pairs on N to be shown separated Allow H at any position around N Ignore circles used to show shells Ignore inner electrons if shown Ignore lines representing bonds	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• bond angle = 107°	Allow angles in the range 105 to 108°	(1)

Q7.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • **(M1)** oxygen is more electronegative than hydrogen **and** carbon **(1)** • **(M2)** which results in a polar bond with oxygen δ– so carbon **and** hydrogen δ+ **(1)** • **(M3)** carbon dioxide is a symmetrical/linear molecule and so the dipole moments/vectors cancel **(1)** • **(M4)** the lone pairs of electrons of oxygen/ the V-shape of the water molecule mean that the dipole moments/ vectors do not cancel **(1)**	Accept supporting diagrams which illustrate the following: Accept electronegativity values stated Allow oxygen has a greater force of attraction for the bonded electron pairs than hydrogen **or** carbon Penalise the failure to refer to carbon and hydrogen once only Allow 'symmetrical so dipoles/ polar bonds cancel' Allow angular/bent for V-shape Penalise reference to just 'charges' once only in M3 and M4 if dipoles not stated or shown in the answer	**(4)**

Q8.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • silicon – giant atomic / giant covalent / giant molecular / macromolecular **and** contains covalent bonds **(1)** • chlorine - (simple) molecular / molecules / diatomic / Cl_2 **and** contains London forces **(1)** • (covalent) bonds in silicon are stronger than London forces/ intermolecular forces in chlorine **or** covalent bonds take more energy to break than London forces / intermolecular forces **(1)**	Do not allow just 'silicon is a covalent molecule' Do not allow reference to ions or metallic bonding Allow dispersion forces / van der Waals' / attractions between temporary dipole and induced dipole/ attractions between instantaneous dipole (- induced dipole) for London forces Do not award covalent bonds being broken in chlorine Ignore silicone for silicon as correct spelling is given in the paper	**(3)**

Q9.

Question Number	Answer	Additional Guidance	Mark
	An explanation that makes reference to the following points: • iodine is (simple) molecular (1) • diamond is a giant (covalent / lattice) structure (with 4 covalent bonds per carbon atom) (1) • iodine molecules are held together by weak London forces / dispersion forces / van der Waal's forces / instantaneous induced dipole-dipole attractions (1) • carbon atoms in diamond are held together by (strong) covalent bonds (1) • strong covalent bonds require more energy to break than intermolecular forces	Allow iodine is made up of (I_2) molecules Do not award diamond molecules Allow weak intermolecular forces Do not award strong intermolecular forces Award converse argument for less energy need to break intermolecular forces Single sentences may contain more than one marking point. For example 'iodine molecules are held together by weak intermolecular forces' scores (2)	(5)

Q10.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• correct formulae and state symbols of each species	$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• ionic **and** covalent (bonding)	Ignore reference to single/double/dative	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• strong bonds within the carbonate ion / CO_3^{2-} /C-O bond / C=O bond	Ignore bonds between the ions / (Ca^{2+} and CO_3^{2-}) are strong	(1)

Q11.

Question Number	Acceptable Answer	Additional Guidance	Mark
*	This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5–4 / 3 3–2 / 2 1 / 1 0 / 0	Guidance on how the mark scheme should be applied: The mark for indicative content should be added to the mark for lines of reasoning. For example, an answer with five indicative marking points, which is partially structured with some linkages and lines of reasoning, scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	(6)

<table>
<tr><th>Question Number</th><th>Acceptable Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>*
contd</td><td>The following table shows how the marks should be
awarded for structure and lines of reasoning.
<table><tr><td></td><td>Number of marks awarded for structure of answer and sustained line of reasoning</td></tr><tr><td>Answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout.</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning.</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured.</td><td>0</td></tr></table></td><td>In general it would be expected
that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark
for reasoning, and 0, 1 or 2
indicative points would score zero marks for reasoning.

Reasoning marks may be reduced for extra incorrect chemistry</td><td>(6)</td></tr>
<tr><td></td><td>Indicative content:
• aluminium and chlorine electronegativity difference 1.5 AND aluminium and fluorine electronegativity difference 2.5

• aluminium chloride (mostly) covalent / (small) molecule

• aluminium fluoride (bonds) more polar

• aluminium chloride molecular so weak(er) intermolecular forces / London forces

• aluminium fluoride is a giant structure/ strong electrostatic forces of attraction between the ions

• more energy needed to break the stronger bonds to cause sublimation in aluminium fluoride</td><td>Allow all 3 electronegativity values / difference between F and Cl is 1 / difference between differences is 1/ F is 4, CL is 3 and this is a significant difference

Allow mostly/more ionic

Allow weak(er) dipole-dipole interactions
Do not award any suggestion of breaking covalent bonds

Allow stronger dipole-dipole attractions

Allow (dative) covalent bonds breaking (to form small molecule / AlF_3)</td><td></td></tr>
</table>