

Name: _____

Bonding and Structure

International A Level

Date:

Time:

Total marks available: 117

Total marks achieved: _____

Fran

Questions

Q1.

This question is about the compound ammonium dichromate(VI), $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$.

(a) $(\text{NH}_4)_2\text{Cr}_2\text{O}_7$ breaks down at around 180 °C, producing an oxide of chromium, nitrogen and water as the only products.

(i) Write an equation for the reaction.

State symbols are not required.

(2)

(ii) Give a name for this type of reaction.

(1)

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(b) When 0.00100 mol of ammonium dichromate(VI) was heated, 25.2 cm³ of nitrogen gas, measured at laboratory temperature, was formed.

Calculate the temperature in the laboratory, in degrees Celsius, using the ideal gas equation. Use atmospheric pressure = 101 kPa.

$$[pV = nRT \quad R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}]$$

(4)

(c) (i) Draw a dot-and-cross diagram of the ammonium ion.

Use dots (●) for the nitrogen electrons and crosses (X) for the hydrogen electrons.

(2)

(ii) Explain the shape of the ammonium ion using electron-pair repulsion theory.

(2)

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(d) Ammonium dichromate(VI) comes with several warnings on its packaging.

- This compound is toxic when inhaled and by passing through the skin.
- Handle with extreme caution.
- Contact can irritate and burn the skin and eyes, with possible eye damage.
- Inhaling can irritate the nose and throat.
- Ammonium dichromate(VI) is a strong oxidiser that enhances the combustion of other substances.

(i) Some of the symbols shown are used for ammonium dichromate(VI).

Identify the symbols for ammonium dichromate(VI) by placing a tick (✓) in the box under each relevant symbol.

(2)

(ii) Suggest why ammonium dichromate(VI) is **not** stored in the same cupboard as alkanes.

(1)

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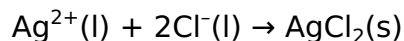
(Total for question = 14 marks)

Q2.

This question is about compounds containing chlorine.

(a) A precipitate of silver chloride is formed when silver nitrate solution reacts with sodium chloride solution.

A student wrote an ionic equation for the reaction.



Explain why this equation is incorrect, even though it is balanced.

(2)

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(b) A sample of a compound is analysed and found to contain **only** 3.09 g carbon, 0.26 g hydrogen and 9.15 g chlorine.

The molar mass of the compound is 97.0 g mol^{-1} .

Calculate the molecular formula of this compound.

You **must** show your working.

(3)

(c) Nitrogen trichloride has the formula NCl_3 .

(i) A sample of nitrogen trichloride contained only nitrogen atoms with mass number 14, and chlorine atoms with mass numbers 35 and 37.

Give the formula and mass/charge ratio for each of the **four** ions responsible for the molecular ion peaks in the mass spectrum of nitrogen trichloride.

(2)

(ii) Complete the table to predict the shape and Cl—N—Cl bond angle in nitrogen trichloride.

(3)

Number of bonding pairs of electrons on nitrogen	
Number of lone pairs of electrons on nitrogen	
Shape of molecule	
Cl—N—Cl bond angle	

(d) Aluminium chloride exists as an ionic lattice in the solid state and as a covalent dimer, Al_2Cl_6 , in the gas phase, just above its boiling temperature.

(i) Explain why aluminium chloride in the solid state has significant covalent character.

(2)

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(ii) Describe how two AlCl_3 molecules are joined together in the dimer.

Include a diagram in your answer.

(2)

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(Total for question = 14 marks)

This question is about nitrogen.

(a) The table shows the successive ionisation energies of nitrogen.

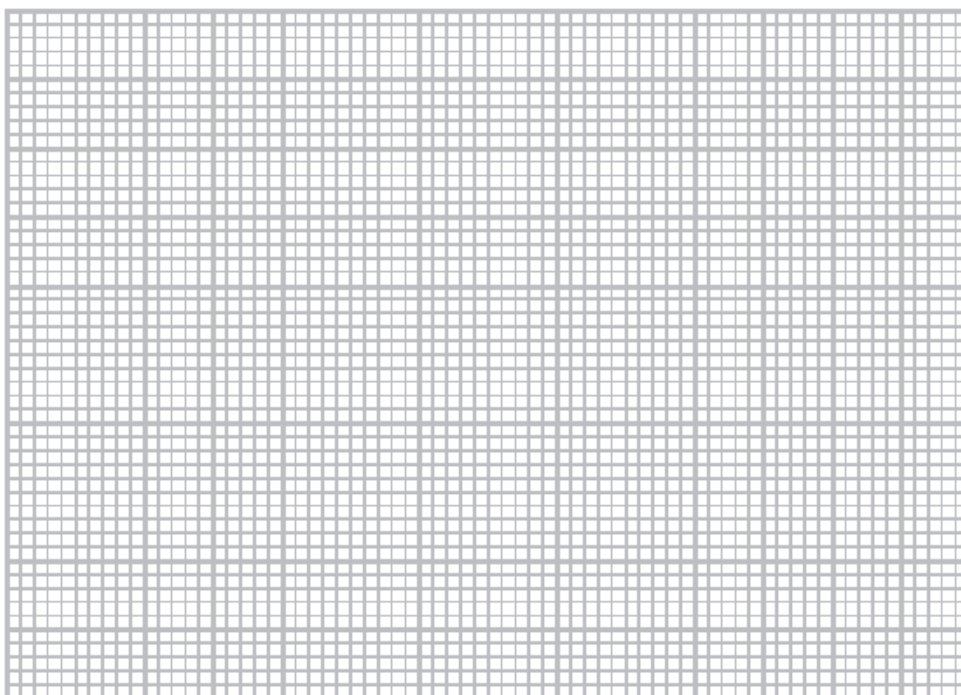
Ionisation number	Ionisation energy / kJ mol^{-1}	log (ionisation energy)
1	1402	3.15
2	2856	3.46
3	4578	3.66
4	7475	3.87
5	9445	3.98
6	53268	
7	64362	

(i) Complete the table.

(1)

(ii) Plot a graph of log (ionisation energy) against ionisation number.

(3)



(iii) Give a reason why the logarithm of the ionisation energy, rather than just the ionisation energy, is used to plot this graph.

(1)

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(iii) A sample of nitrogen gas occupied 108 cm^3 at a temperature of $25 \text{ }^\circ\text{C}$ and a pressure of $1.36 \times 10^5 \text{ Pa}$.

Using the ideal gas equation, calculate the number of moles of nitrogen gas in this sample.

$$[pV = nRT \quad R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}]$$

(4)

(Total for question = 18 marks)

Q4.

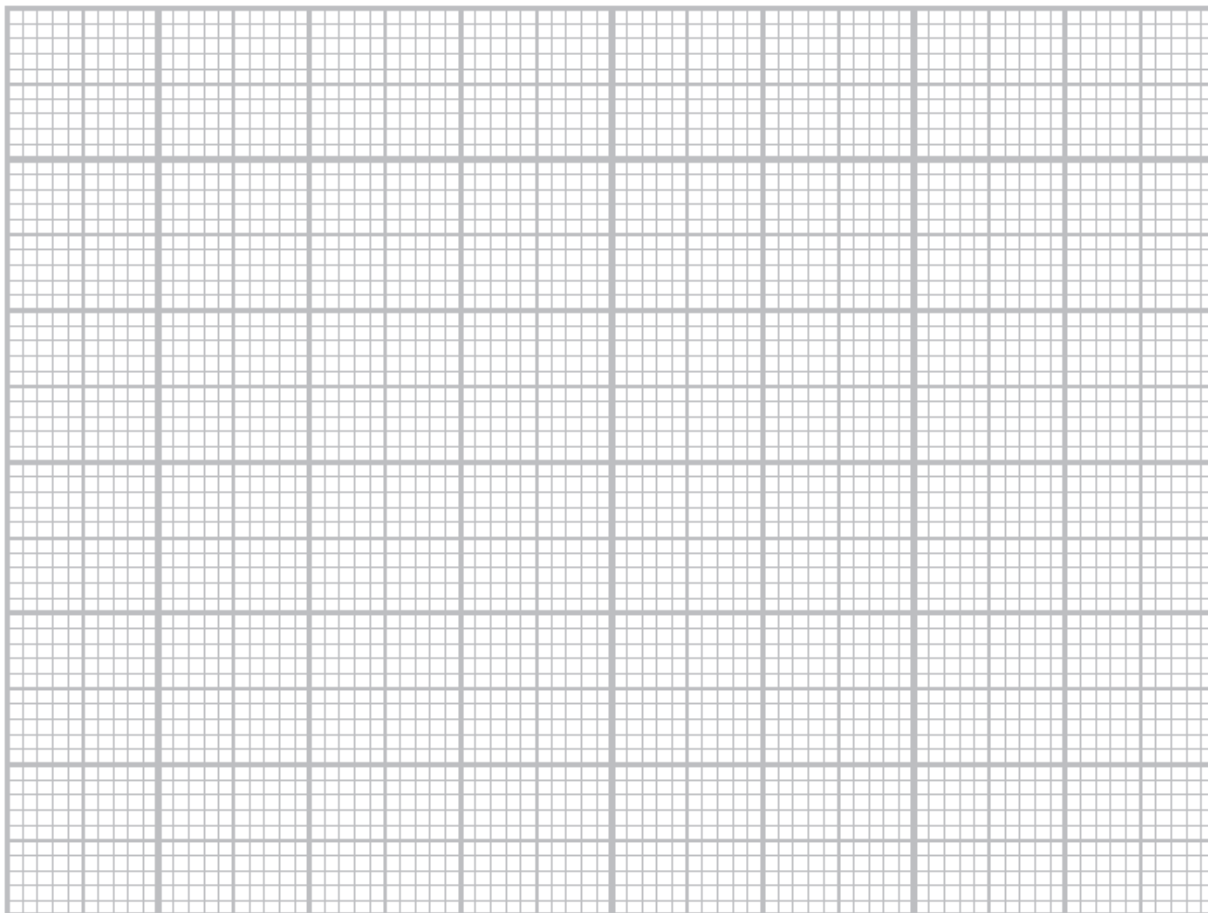
This question is about the elements in Period 3 of the Periodic Table, and some of their compounds.

(a) The atomic radii of six of the elements are given.

Symbol	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic number	11	12	13	14	15	16	17	18
Atomic radius / nm	0.191	0.160	0.130			0.102	0.099	0.095

(i) Plot a graph of atomic radius against atomic number.

(2)



(ii) Use the graph to estimate the atomic radius of silicon, Si.

(1)

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(iii) Suggest an explanation for the decrease in atomic radius as atomic number increases across a period.

(3)

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(b) The melting temperatures of sodium, sodium chloride and chlorine are given in the table.

Complete the table to show the type of structure, the type of bond or force broken on melting and the particles involved.

(6)

Substance	Sodium	Sodium chloride	Chlorine
Melting temperature / °C	98	801	-101
Type of structure	giant		simple molecular
Type of bond or force broken on melting			
Particles involved			chlorine molecules

(c) Solid phosphorus(V) chloride contains PCl_4^+ ions.

(i) Draw a dot-and-cross diagram of a PCl_4^+ ion.

Show only outer shell electrons.

(1)

(ii) Predict the shape of a PCl_4^+ ion.

Justify your answer.

(3)

Shape

Justification

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(Total for question = 16 marks)

Q5.

Answer the question with a cross in the box you think is correct . If you change your mind about an answer, put a line through the box and then mark your new answer with a cross .

In which sequence are the molecules in order of **decreasing** bond angle?

- A** $\text{BeCl}_2 > \text{BCl}_3 > \text{CH}_4$
- B** $\text{BeCl}_2 > \text{NH}_3 > \text{CH}_4$
- C** $\text{CH}_4 > \text{BCl}_3 > \text{BeCl}_2$
- D** $\text{CH}_4 > \text{NH}_3 > \text{BeCl}_2$

(Total for question = 1 mark)

Q6.

This question is about bonding.

(a) Draw an electron density map for a molecule of oxygen.

(1)

(b) Draw a diagram to show the shape of a water molecule.

Give the bond angle.

(2)

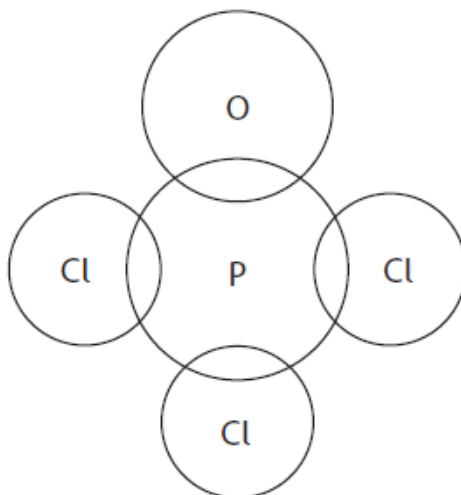
Bond angle

(c) The compound POCl_3 has a simple molecular structure.

(i) Complete the dot-and-cross diagram for the POCl_3 molecule.

Use crosses (x) for the phosphorus electrons, dots (•) for the chlorine electrons and circles (○) for the oxygen electrons.

(2)



(ii) Explain the shape of this molecule using the electron-pair repulsion theory.

(3)

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(d) The properties of metals depend on their structure and bonding.

(i) Draw a labelled diagram to show the metallic bonding in calcium.

(2)

(ii) Explain how the electrical conductivity, high melting temperature and malleability of metals depend on their structure and bonding.

(3)

Electrical conductivity.....

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High melting temperature

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Malleability

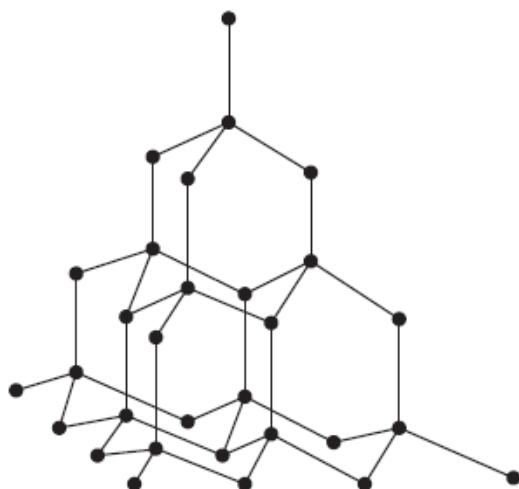
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(e) Diamond, graphite and graphene are all forms of carbon.

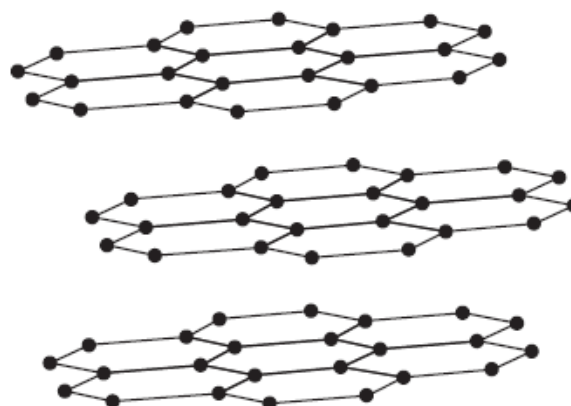
(i) Explain **two** ways in which the physical properties of diamond and graphite differ.

Refer to their structure and bonding in your answer.

(4)



diamond



graphite

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(ii) State how the structure of graphene is related to the structure of graphite.

(1)

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(iii) State a use for graphene, identifying the property that makes it suitable for that use.

(2)

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(Total for question = 20 marks)

Q7.

The bonding **within** an ammonium ion, NH_4^+ , is formed by

(1)

- A** covalent bonding only
- B** covalent and dative covalent bonding only
- C** covalent and ionic bonding only
- D** covalent, dative covalent and ionic bonding

(Total for question = 1 mark)

Q8.

Water reacts with H^+ ions to form H_3O^+ ions.

Identify the bonding **within** the H_3O^+ ion.

(1)

- A** covalent bonding only
- B** covalent and dative covalent bonding only
- C** covalent, dative covalent and ionic bonding
- D** ionic bonding only

(Total for question = 1 mark)

Q9.

Metallic bonding is the strong electrostatic attraction between

- A** anions and cations
- B** atoms and delocalised electrons
- C** ions and delocalised electrons
- D** two nuclei and a shared pair of electrons

(Total for question = 1 mark)

Q10.

The ionic radius of Al^{3+} is smaller than that of N^{3-} .

This is because Al^{3+} has

- A** fewer protons but more electrons than N^{3-}

- B** more protons but fewer electrons than N^{3-}
- C** more protons than N^{3-} but the same number of electrons as N^{3-}
- D** the same number of protons as N^{3-} but fewer electrons

(Total for question = 1 mark)

Q11.

Answer the question with a cross in the box you think is correct . If you change your mind about an answer, put a line through the box and then mark your new answer with a cross .

Which pair of ions will form the compound with the most covalent character?

- A** Li^+ and I^-
- B** Na^+ and Br^-
- C** K^+ and Cl^-
- D** Rb^+ and F^-

(Total for question = 1 mark)

Q12.

Answer the question with a cross in the box you think is correct . If you change your mind about an answer, put a line through the box and then mark your new answer with a cross .

Covalent bonding is best described as the electrostatic attraction between

- A** oppositely charged ions
- B** positive ions and delocalised electrons
- C** a shared pair of electrons

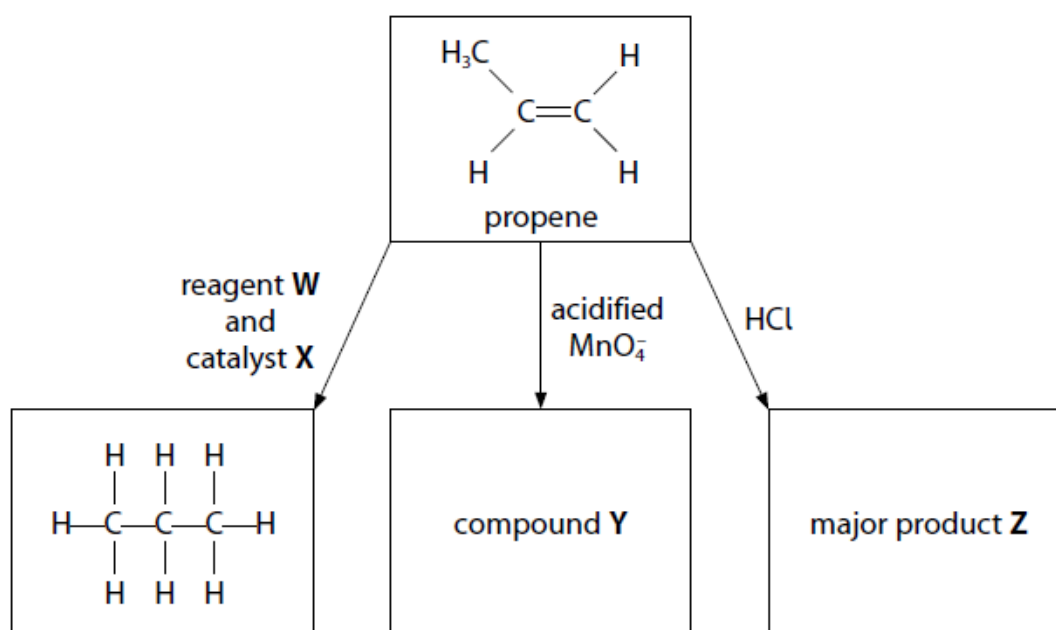
- D** two nuclei and a shared pair of electrons

(Total for question = 1 mark)

Q13.

Alkenes contain a double bond between two carbon atoms.

(a) Some reactions of propene are shown.



(i) Give the names of reagent **W** and catalyst **X**.

(2)

Reagent **W**

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Catalyst **X**

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(ii) Draw the displayed formula of compound **Y**.

(1)

(iii) Draw the skeletal formula of the major product **Z**.

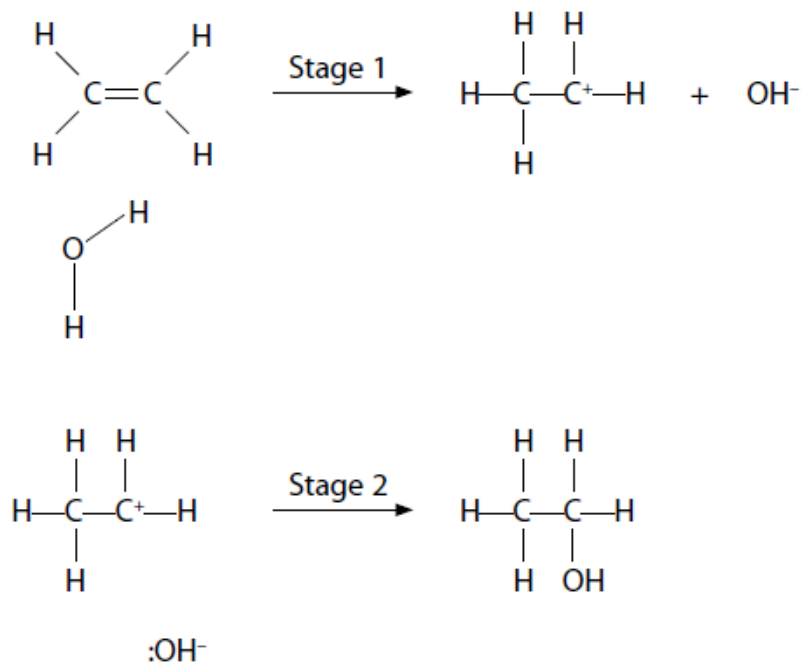
(1)

(b) Ethene reacts with steam in the presence of a catalyst to form ethanol.

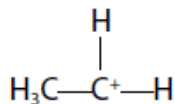
The mechanism takes place in two stages.

(i) Complete the simplified mechanism for the reaction by adding curly arrows and the relevant dipole.

(4)



(ii) Predict the shape of the intermediate ion with reference to the positively-charged carbon. Justify your answer.



(3)

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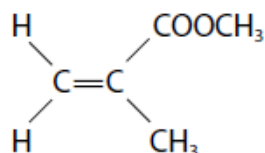
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(c) Methyl 2-methylpropenoate has the structure:



Draw a section of the polymer formed from methyl 2-methylpropenoate, showing two repeat units.

(2)

(Total for question = 13 marks)

Q14.

Answer the question with a cross in the box you think is correct . If you change your mind about an answer, put a line through the box and then mark your new answer with a cross .

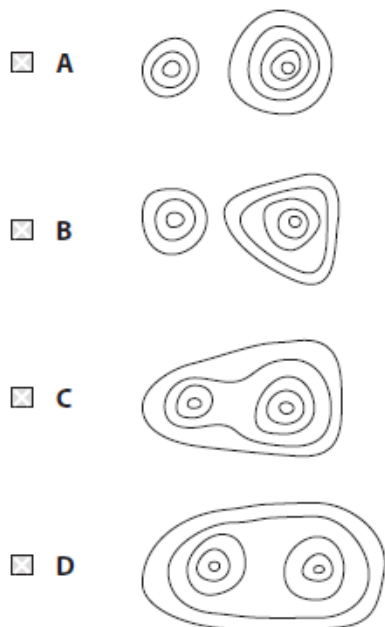
Which of these has the **greatest** electrical conductivity?

- A** SF₆(g)
- B** H₂O(l)
- C** Hg(l)
- D** Na₂O(s)

(Total for question = 1 mark)

Q15.

Which diagram best represents the electron density map of a hydrogen chloride molecule?



(Total for question = 1 mark)

Q16.

Answer the question with a cross in the box you think is correct . If you change your mind about an answer, put a line through the box and then mark your new answer with a cross .

Which of these does **not** have a structure formed by a giant lattice of carbon atoms?

- A C₆₀ fullerene
- B diamond
- C graphene
- D graphite

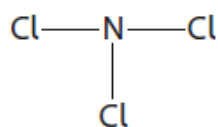
(Total for question = 1 mark)

Q17.

This question is about the structure and bonding of Group 5 chlorides.

(a) Nitrogen trichloride, NCl_3 , has a molecular structure.

The displayed formula of a molecule of NCl_3 is shown.



Complete the table for this molecule.

(3)

Number of bond pairs around N atom	
Number of lone pairs around N atom	
Cl-N-Cl bond angle	
Name of shape of molecule	

(b) Under standard conditions, phosphorus(V) chloride (PCl_5) is a solid made up of PCl_4^+ cations and PCl_6^- anions.

Antimony(V) chloride (SbCl_5) is a liquid made up of SbCl_5 molecules.

(i) Explain why PCl_5 has a higher melting temperature than SbCl_5 .

(2)

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(ii) Draw a dot-and-cross diagram to show the bonding in a molecule of SbCl_5 .

Use dots (\bullet) to represent the Sb electrons, and crosses (\times) to represent the Cl electrons. Show outer electrons only.

(2)

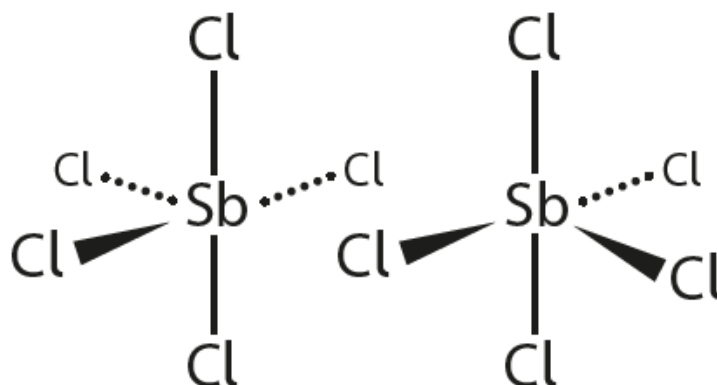
(c) At low temperatures, SbCl_5 converts to $\text{Sb}_2\text{Cl}_{10}$ which contains dative covalent bonds.

(i) State what is meant by the term dative covalent bond.

(1)

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(ii) Complete the diagram to show the dative covalent bonds in $\text{Sb}_2\text{Cl}_{10}$.

(1)



(d) Arsenic also forms a pentachloride with the formula AsCl_5 .

Give **one** possible reason why nitrogen is the only Group 5 element that does **not** form a pentachloride.

(1)

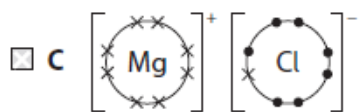
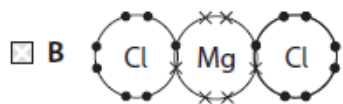
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(Total for question = 10 marks)

Q18.

Which is the dot-and-cross diagram for magnesium chloride?

Only outer shell electrons are shown.



(Total for question = 1 mark)

Q19.

Which ion has the greatest polarising power?



(Total for question = 1 mark)