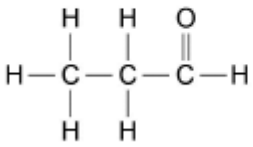
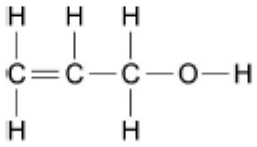
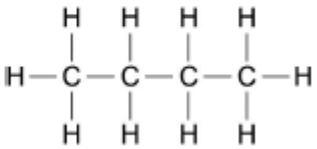
1 The compounds in the table all have a relative molecular mass of 58.0

Name	Propanal	Prop-2-en-1-ol	Butane
Structure			

(a) Explain why determining the precise relative molecular mass of propanal and prop-2-en-1-ol by mass spectrometry could not be used to distinguish between samples of these two compounds.

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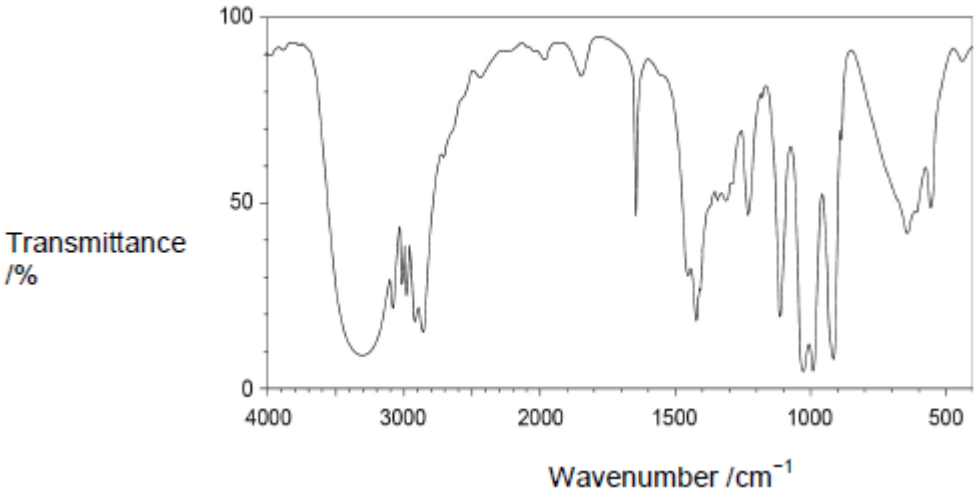
(2)

(b) The infrared spectrum of one of these three compounds is shown below.



Use the spectrum to identify the compound.
State the bond that you used to identify the compound and give its wavenumber range.
You should only consider absorptions with wavenumbers greater than 1500 cm^{-1}.

Compound .....

Bond used to identify compound.....

Wavenumber range of bond used to identify compound ..... cm^{-1}

(2)

(c) Predict the relative boiling points of these three compounds from the highest to the lowest boiling points.

Justify this order in terms of intermolecular forces.

(6)
(Total 10 marks)

2 Use your understanding of intermolecular forces to predict which of these compounds has the highest boiling point.

A HF ⬭

B HCl ⬭

C HBr ⬭

D HI ⬭

(Total 1 mark)

3 Which of these substances does **not** show hydrogen bonding?

A HF ⬭

B NH_3 ⬭

C CH_3COOH ⬭

D CHF_3 ⬭

(Total 1 mark)

4 Which of these substances has permanent dipole-dipole attractions between molecules?

A CCl_4 ⬭

B C_2F_4 ⬭

C $(CH_3)_2CO$ ⬭

D CO_2 ⬭

(Total 1 mark)

5 The table below contains some entropy data relevant to the reaction used to synthesise methanol from carbon dioxide and hydrogen. The reaction is carried out at a temperature of 250 °C.

Substance	$CO_2(g)$	$H_2(g)$	$CH_3OH(g)$	$H_2O(g)$
Entropy ($S^{\ominus}$) / J K^{-1} mol^{-1}	214	131	238	189

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \quad \Delta H = -49 \text{ kJ mol}^{-1}$$

(a) Use this enthalpy change and data from the table to calculate a value for the free-energy change of the reaction at 250 °C.
Give units with your answer.

Free-energy change = ... Units = ...

(4)

(b) Calculate a value for the temperature when the reaction becomes feasible.

Temperature = ... K

(2)

(c) Gaseous methanol from this reaction is liquefied by cooling before storage.

Draw a diagram showing the interaction between two molecules of methanol. Explain why methanol is easy to liquefy.

Diagram

Explanation .....

.....

.....

(4)
(Total 10 marks)

6 Ethanol can be oxidised by acidified potassium dichromate(VI) to ethanoic acid in a two-step process.

ethanol ⟶ ethanal ⟶ ethanoic acid

(a) In order to ensure that the oxidation to ethanoic acid is complete, the reaction is carried out under reflux.

Describe what happens when a reaction mixture is refluxed and why it is necessary, in this case, for complete oxidation to ethanoic acid.

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(3)

(b) Write a half-equation for the overall oxidation of ethanol into ethanoic acid.

.....

(1)

(c) The boiling points of the organic compounds in a reaction mixture are shown in the following table.

Compound	ethanol	ethanal	ethanoic acid
Boiling point / °C	78	21	118

Use these data to describe how you would obtain a sample of ethanal from a mixture of these three compounds. Include in your answer a description of the apparatus you would use and how you would minimise the loss of ethanal. Your description of the apparatus can be either a description in words or a labelled sketch.

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(5)

(d) Use your knowledge of structure and bonding to explain why it is possible to separate ethanal in this way.

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(2)

(e) A student obtained a sample of a liquid using the apparatus in part **(c)**.

Describe how the student could use chemical tests to confirm that the liquid contained ethanal and did **not** contain ethanoic acid.

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(5)
(Total 16 marks)

7 Which compound has the highest boiling point?

A C_2H_4 ⬭

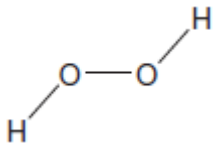
B C_2H_6 ⬭

C CH_3NH_2 ⬭

D CH_3F ⬭

(Total 1 mark)

8 A hydrogen peroxide molecule can be represented by the structure shown.



(a) Suggest a value for the H−O−O bond angle.

.....

(1)

(b) Hydrogen peroxide dissolves in water.

(i) State the strongest type of interaction that occurs between molecules of hydrogen peroxide and water.

.....

(1)

(ii) Draw a diagram to show how one molecule of hydrogen peroxide interacts with one molecule of water.
Include all lone pairs and partial charges in your diagram.

(3)

(c) Explain, in terms of electronegativity, why the boiling point of H_2S_2 is lower than H_2O_2.

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(2)
(Total 7 marks)

9 (a) Ammonia gas readily condenses to form a liquid when cooled.

(i) Name the strongest attractive force between two ammonia molecules.

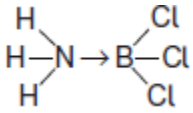
.....

(1)

(ii) Draw a diagram to show how two ammonia molecules interact with each other in the liquid phase.
Include all partial charges and all lone pairs of electrons in your diagram.

(3)

(b) Ammonia reacts with boron trichloride to form a molecule with the following structure.



State how the bond between ammonia and boron trichloride is formed.

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(1)

(c) The following table shows the electronegativity values of some elements.

	H	**Li**	**B**	**C**	**O**	**F**
Electronegativity	2.1	1.0	2.0	2.5	3.5	4.0

(i) Give the meaning of the term **electronegativity.**

.....

.....

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.....

(2)

(ii) Suggest the formula of an ionic compound that is formed by the chemical combination of two different elements from the table.

.....

(1)

(iii) Suggest the formula of the compound that has the least polar bond and is formed by chemical combination of two of the elements from the table.

.....

(1)

(Total 9 marks)

10 Some oil-fired heaters use paraffin as a fuel.
One of the compounds in paraffin is the straight-chain alkane, dodecane ($C_{12}H_{26}$).

(a) Give the name of the substance from which paraffin is obtained.
State the name of the process used to obtain paraffin from this substance.

Substance .....

Process .....

(2)

(b) The combustion of dodecane produces several products.

Write an equation for the **incomplete** combustion of dodecane to produce gaseous products only.

.....

(1)

(c) Oxides of nitrogen are also produced during the combustion of paraffin in air.

(i) Explain how these oxides of nitrogen are formed.

.....

.....

.....

.....

(2)

(ii) Write an equation to show how nitrogen monoxide in the air is converted into nitrogen dioxide.

.....

(1)

(iii) Nitric acid (HNO_3) contributes to acidity in rainwater.

Deduce an equation to show how nitrogen dioxide reacts with oxygen and water to form nitric acid.

.....

(1)

(d) Dodecane ($C_{12}H_{26}$) can be cracked to form other compounds.

(i) Give the general formula for the homologous series that contains dodecane.

.....

(1)

(ii) Write an equation for the cracking of one molecule of dodecane into equal amounts of two different molecules each containing the same number of carbon atoms.
State the empirical formula of the straight-chain alkane that is formed.
Name the catalyst used in this reaction.

Equation .....

Empirical formula of alkane .....

Catalyst .....

.....

(3)

(iii) Explain why the melting point of dodecane is higher than the melting point of the straight-chain alkane produced by cracking dodecane.

.....

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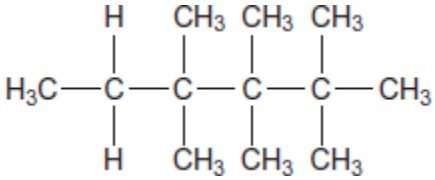
(2)

(e) Give the IUPAC name for the following compound and state the type of structural isomerism shown by this compound and dodecane.



IUPAC name .....

Type of structural isomerism .....

(2)

(f) Dodecane can be converted into halododecanes.

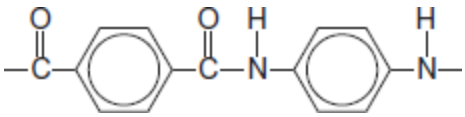
Deduce the formula of a substance that could be reacted with dodecane to produce 1-chlorododecane and hydrogen chloride only.

.....

(1)

(Total 16 marks)

11 Kevlar is a polymer used in protective clothing.
The repeating unit within the polymer chains of Kevlar is shown.



(a) Name the strongest type of interaction between polymer chains of Kevlar.

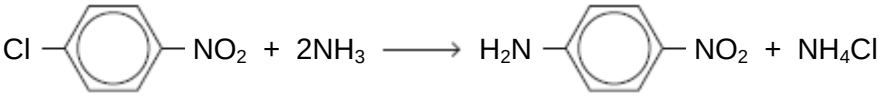
.....

(1)

(b) One of the monomers used in the synthesis of Kevlar is

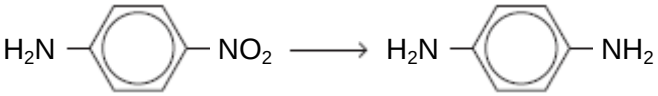
An industrial synthesis of this monomer uses the following two-stage process starting from compound **X**.

Stage **1**



X

Stage **2**



(i) Suggest why the reaction of ammonia with **X** in Stage **1** might be considered unexpected.

.....

.....

.....

.....

(2)

(ii) Suggest a combination of reagents for the reaction in Stage **2**.

.....

(1)

(iii) Compound **X** can be produced by nitration of chlorobenzene.

Give the combination of reagents for this nitration of chlorobenzene.
Write an equation or equations to show the formation of a reactive intermediate from these reagents.

Reagents .....

.....

Equation(s) .....

.....

(3)

(iv) Name and outline a mechanism for the formation of **X** from chlorobenzene and the reactive intermediate in part (iii).

Name of mechanism .....

Mechanism

(4)
(Total 11 marks)

12 Fritz Haber, a German chemist, first manufactured ammonia in 1909.
Ammonia is very soluble in water.

(a) State the strongest type of intermolecular force between one molecule of ammonia and one molecule of water.

.....

(1)

(b) Draw a diagram to show how one molecule of ammonia is attracted to one molecule of water. Include all partial charges and all lone pairs of electrons in your diagram.

(3)

(c) Phosphine (PH_3) has a structure similar to ammonia.

In terms of intermolecular forces, suggest the main reason why phosphine is almost insoluble in water.

.....

.....

(1)

(Total 5 marks)

13 The following equation shows the reaction of a phosphine molecule (PH_3) with an H^+ ion.

$$PH_3 + H^+ \longrightarrow PH_4^+$$

(a) Draw the shape of the PH_3 molecule. Include any lone pairs of electrons that influence the shape.

(1)

(b) State the type of bond that is formed between the PH_3 molecule and the H^+ ion. Explain how this bond is formed.

Name of bond .....

How bond is formed .....

.....

(2)

(c) Predict the bond angle in the PH_4^+ ion.

.....

(1)

(d) Although phosphine molecules contain hydrogen atoms, there is no hydrogen bonding between phosphine molecules.
Suggest an explanation for this.

.....

.....

.....

(1)
(Total 5 marks)

14 Fluorine forms compounds with many other elements.

(a) Fluorine reacts with bromine to form liquid bromine trifluoride (BrF_3).
State the type of bond between Br and F in BrF_3 and state how this bond is formed.

Type of bond .....

How bond is formed .....

.....

(2)

(b) Two molecules of BrF_3 react to form ions as shown by the following equation.

$$2BrF_3 \longrightarrow BrF_2^+ + BrF_4^-$$

(i) Draw the shape of BrF_3 and predict its bond angle.
Include any lone pairs of electrons that influence the shape.

Shape of BrF_3

Bond angle .....

(2)

(ii) Draw the shape of BrF_4^- and predict its bond angle.
Include any lone pairs of electrons that influence the shape.

Shape of BrF_4^-

Bond angle .....

(2)

(c) BrF_4^- ions are also formed when potassium fluoride dissolves in liquid BrF_3 to form $KBrF_4$
Explain, in terms of bonding, why $KBrF_4$ has a high melting point.

.....

.....

.....

.....

.....

(Extra space) .....

.....

(3)

(d) Fluorine reacts with hydrogen to form hydrogen fluoride (HF).

(i) State the strongest type of intermolecular force between hydrogen fluoride molecules.

.....

(1)

(ii) Draw a diagram to show how two molecules of hydrogen fluoride are attracted to each other by the type of intermolecular force that you stated in part (d)(i). Include all partial charges and all lone pairs of electrons in your diagram.

(3)

(e) The boiling points of fluorine and hydrogen fluoride are –188 °C and 19.5 °C respectively. Explain, in terms of bonding, why the boiling point of fluorine is very low.

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.....

(Extra space) .....

.....

(2)
(Total 15 marks)

15 Fluorine and iodine are elements in Group 7 of the Periodic Table.

(a) Explain why iodine has a higher melting point than fluorine.

.....

.....

.....

(Extra space).....

.....

(2)

(b) (i) Draw the shape of the NHF_2 molecule and the shape of the BF_3 molecule.

Include any lone pairs of electrons that influence the shape. In each case name the shape.

Shape of NHF_2 Shape of BF_3

Name of shape of NHF_2 .....

Name of shape of BF_3 .....

(4)

(ii) Suggest a value for the F—N—F bond angle in NH_2I

.....

(1)

(c) State the strongest type of intermolecular force in a sample of NHF_2

.....

(1)

(d) A molecule of NHF_2 reacts with a molecule of BF_3 as shown in the following equation.

$$NHF_2 + BF_3 \longrightarrow F_2HNBF_3$$

State the type of bond formed between the N atom and the B atom in F_2HNBF_3.

Explain how this bond is formed.

Name of type of bond .....

How bond is formed .....

.....

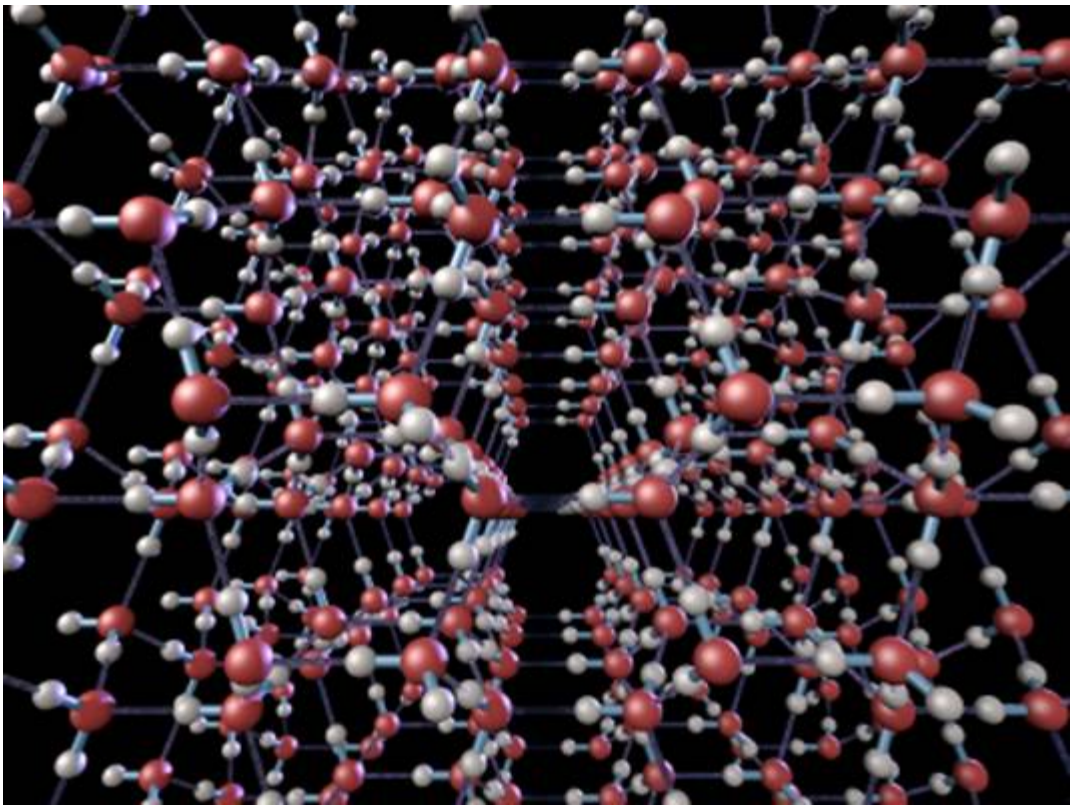
.....

(2)

(Total 10 marks)

16 Water can be found as ice, water and steam.

(a) The following diagram shows the arrangement of some of the water molecules in a crystal of ice.



With reference to the structure shown above give **one** reason why ice is less dense than water.

.....

.....

.....

(1)

(b) Water and methane have similar relative molecular masses and both contain the element hydrogen.
The table below gives some information about water and methane.

	H_2O	CH_4
M_r	18.0	16.0
Melting point / K	273	91

(i) State the strongest type of intermolecular force holding the water molecules together in the ice crystal.

.....

(1)

(ii) State the strongest type of intermolecular force in methane.

.....

(1)

(iii) Give **one** reason why the melting point of ice is higher than the melting point of methane.

.....

.....

.....

(1)

(c) A molecule of H_2O can react with an H^+ ion to form an H_3O^+ ion.

(i) Draw and name the shape of the H_3O^+ ion. Include any lone pairs of electrons.

Shape of the H_3O^+ ion

Name of shape .....

(2)

(ii) Suggest a value for the bond angle in the H_3O^+ ion.

.....

(1)

(iii) Identify **one** molecule with the same number of atoms, the same number of electrons and the same shape as the H_3O^+ ion.

.....

(1)

(d) Water can also form the hydroxide ion.
State the number of lone pairs of electrons in the hydroxide ion.

.....

(1)
(Total 9 marks)

17 Fluorine forms many compounds that contain covalent bonds.

(a) (i) State the meaning of the term *covalent bond*.

.....

.....

(1)

(ii) Write an equation to show the formation of one molecule of ClF_3 from chlorine and fluorine molecules.

.....

(1)

(b) Draw the shape of a dichlorodifluoromethane molecule (CCl_2F_2) and the shape of a chlorine trifluoride molecule (ClF_3). Include any lone pairs of electrons that influence the shape.

Shape of CCl_2F_2 Shape of ClF_3

(2)

(c) Suggest the strongest type of intermolecular force between CCl_2F_2 molecules.

.....

(1)

(d) BF_3 is a covalent molecule that reacts with an F^- ion to form a BF_4^- ion.

(i) Name the type of bond formed when a molecule of BF_3 reacts with an F^- ion. Explain how this bond is formed.

Type of bond .....

Explanation .....

.....

.....

.....

(3)

(ii) State the bond angle in the BF_4^- ion

.....

(1)

(e) An ultrasound imaging agent has the formula C_4F_{10}
It can be made by the reaction of butane and fluorine as shown in the following equation.

$$C_4H_{10} + 10F_2 \rightarrow C_4F_{10} + 10HF$$

Calculate the percentage atom economy for the formation of C_4F_{10} in this reaction.
Give your answer to three significant figures.

.....

.....

(2)
(Total 11 marks)

18 The table below shows the boiling points of some hydrogen compounds formed by Group 6 elements.

	H_2O	H_2S	H_2Se	H_2Te
Boiling point / K	373	212	232	271

(a) State the strongest type of intermolecular force in water and in hydrogen sulfide (H_2S).

Water .....

Hydrogen sulfide .....

.....

(2)

(b) Draw a diagram to show how two molecules of water are attracted to each other by the type of intermolecular force you stated in part (a). Include partial charges and all lone pairs of electrons in your diagram.

(3)

(c) Explain why the boiling point of water is much higher than the boiling point of hydrogen sulfide.

.....

.....

(1)

(d) Explain why the boiling points increase from H_2S to H_2Te

.....

.....

(2)

(e) When H^+ ions react with H_2O molecules, H_3O^+ ions are formed.

Name the type of bond formed when H^+ ions react with H_2O molecules.
Explain how this type of bond is formed in the H_3O^+ ion.

Type of bond .....

Explanation .....

.....

(2)

(f) Sodium sulfide (Na_2S) has a melting point of 1223 K.
Predict the type of bonding in sodium sulfide and explain why its melting point is high.

Type of bonding .....

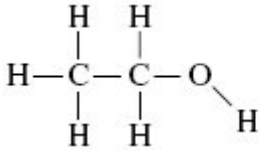
Explanation .....

.....

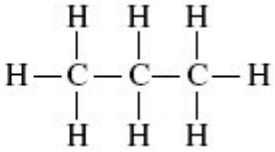
.....

(3)
(Total 13 marks)

19 (a) Two organic compounds with similar relative molecular masses are shown below.



Ethanol



Propane

(i) State the type of bond present between the C and H atoms in both of these molecules. Explain how this type of bond is formed.

Type of bond .....

Explanation .....

(2)

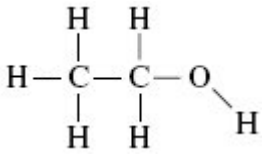
(ii) State the strongest type of intermolecular force present in each compound.

Liquid ethanol .....

Liquid propane ….....

(2)

(b) Ethanol dissolves in water. Draw a diagram to show how one molecule of ethanol interacts with one molecule of water in the solution. Include partial charges and all lone pairs. The ethanol molecule has been drawn for you.



(3)

(c) Ethanol was the fuel used in the first mass-produced car, the Model T Ford.

(i) Write an equation which shows how ethanol burns completely in air to form carbon dioxide and water as the only products.

.....

(1)

(ii) Suggest **one** environmental problem caused by incomplete combustion of ethanol in a car engine.

.....

.....

(1)

(iii) Suggest **one** economic problem for the car user caused by incomplete combustion of ethanol in the car engine.

.....

.....

(1)

(d) Propane is also used as a fuel, although sometimes it can be contaminated with sulfur-containing impurities. When this propane burns, these impurities form sulfur dioxide.

(i) State how the sulfur dioxide can be removed from the waste gases produced when this propane is burned on a large scale in industry. Suggest a reason why the method you have stated may not be 100% efficient.

How removed .....

.....

Reason for less than 100% efficiency .....

.....

(2)

(ii) Although propane has a boiling point of –42 °C, it is usually supplied as a liquid for use in camping stoves. Suggest why it is supplied as a liquid.

.....

.....

(1)
(Total 13 marks)

20 The table below shows the electronegativity values of some elements.

	H	C	N	O
Electronegativity	2.1	2.5	3.0	3.5

(a) State the meaning of the term *electronegativity*.

.....

.....

.....

(2)

(b) State the strongest type of intermolecular force in the following compounds.

Methane (CH_4) .....

Ammonia (NH_3) .....

(2)

(c) Use the values in the table to explain how the strongest type of intermolecular force arises between two molecules of ammonia.

.....

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.....

.....

.....

(3)

(d) Phosphorus is in the same group of the Periodic Table as nitrogen.

A molecule of PH_3 reacts with an H^+ ion to form a PH_4^+ ion.

Name the type of bond formed when PH_3 reacts with H^+ and explain how this bond is formed.

Type of bond .....

Explanation .....

.....

.....

(3)

(e) Arsenic is in the same group as nitrogen. It forms the compound AsH_3

Draw the shape of an AsH_3 molecule, including any lone pairs of electrons. Name the shape made by its atoms.

Shape

Name of shape .....

(2)

(f) The boiling point of AsH_3 is –62.5 °C and the boiling point of NH_3 is –33.0 °C.

Suggest why the boiling point of AsH_3 is lower than that of NH_3

.....

.....

.....

(1)

(g) Balance the following equation which shows how AsH_3 can be made.

..... $AsCl_3$ + ... $NaBH_4$ → ..... AsH_3 + ... NaCl + ... BCl_3

(1)

(Total 14 marks)

21 The elements phosphorus, sulfur, chlorine and argon are in the p block of the Periodic Table.

(a) State why these elements are classified as p block elements.

.....

(1)

(b) State the trend in atomic radius from phosphorus to chlorine and explain the trend.

Trend .....

Explanation .....

.....

.....

(3)

(c) In terms of structure and bonding, explain why sulfur has a higher melting point than phosphorus.

.....

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.....

(3)

(d) In terms of atomic structure, explain why the van der Waals' forces in liquid argon are very weak.

.....

.....

.....

(2)

(Total 9 marks)

22 The table below shows the electronegativity values of some elements.

	Fluorine	Chlorine	Bromine	Iodine	Carbon	Hydrogen
Electronegativity	4.0	3.0	2.8	2.5	2.5	2.1

(a) Define the term *electronegativity*.

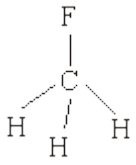
.....

.....

.....

(2)

(b) The table below shows the boiling points of fluorine, fluoromethane (CH_3F) and hydrogen fluoride.

	F–F		H–F
Boiling point/K	85	194	293

(i) Name the strongest type of intermolecular force present in:

Liquid F_2 .....

Liquid CH_3F .....

Liquid HF .....

(ii) Explain how the strongest type of intermolecular force in liquid HF arises.

.....

.....

.....

.....

(6)

(c) The table below shows the boiling points of some other hydrogen halides.

	HCl	HBr	HI
Boiling point / K	188	206	238

(i) Explain the trend in the boiling points of the hydrogen halides from HCl to HI.

.....

.....

.....

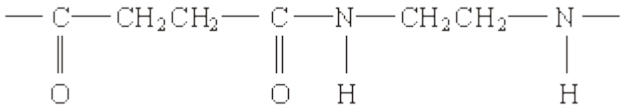
(ii) Give **one** reason why the boiling point of HF is higher than that of all the other hydrogen halides.

.....

.....

(3)
(Total 11 marks)

23 (a) The structure below shows the repeating unit of a polymer.



By considering the functional group formed during polymerisation, name this type of polymer and the type of polymerisation involved in its formation.

Type of polymer .....

Type of polymerisation .....

(2)

(b) Draw the structure of the species present in solid aminoethanoic acid, H_2NCH_2COOH

(1)

(c) Explain why the melting point of aminoethanoic acid is much higher than that of hydroxyethanoic acid, $HOCH_2COOH$

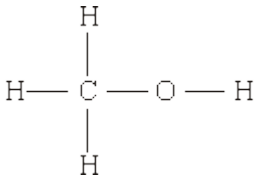
.....

.....

.....

(2)
(Total 5 marks)

24 (a) Methanol has the structure



Explain why the O–H bond in a methanol molecule is polar.

.....

.....

.....

(2)

(b) The boiling point of methanol is +65 °C; the boiling point of oxygen is –183 °C. Methanol and oxygen each have an M_r value of 32. Explain, in terms of the intermolecular forces present in each case, why the boiling point of methanol is much higher than that of oxygen.

.....

.....

.....

.....

(3)
(Total 5 marks)

25 Which one of the following statements is **not** correct?

A The first ionisation energy of iron is greater than its second ionisation energy.

B The magnitude of the lattice enthalpy of magnesium oxide is greater than that of barium oxide.

C The oxidation state of iron in $[Fe(CN)_6]^{3-}$ is greater than the oxidation state of copper in $[CuCl_2]^-$

D The boiling point of C_3H_8 is lower than that of CH_3CH_2OH

(Total 1 mark)

26 (a) Name the strongest type of intermolecular force between hydrogen fluoride molecules and draw a diagram to illustrate how two molecules of HF are attracted to each other.
In your diagram show all lone pairs of electrons and any partial charges. Explain the origin of these charges.
Suggest why this strong intermolecular force is not present between HI molecules.

(7)

(b) Crystals of sodium chloride and of diamond both have giant structures. Their melting points are 1074 K and 3827 K, respectively. State the type of structure present in each case and explain why the melting point of diamond is so high.

(4)
(Total 11 marks)

27 (a) Both HF and HCl are molecules having a polar covalent bond. Their boiling points are 293 K and 188 K respectively.

(i) State which property of the atoms involved causes a bond to be polar.

.....

.....

(ii) Explain, in terms of the intermolecular forces present in each compound, why HF has a higher boiling point than HCl.

.....

.....

.....

.....

.....

(4)

(b) When aluminium chloride reacts with chloride ions, as shown by the equation below, a co-ordinate bond is formed.

$$AlCl_3 + Cl^- \rightarrow AlCl_4^-$$

Explain how this co-ordinate bond is formed.

.....

.....

.....

(2)

(c) Draw the shape of the PCl_5 molecule and of the PCl_4^+ ion. State the value(s) of the bond angles.

PCl_5 PCl_4^+

Bond angle(s) ..... *Bond angle(s)* .....

(4)

(Total 10 marks)

28 The ester methyl ethanoate is hydrolysed as shown in the following equation.

$$CH_3COOCH_3(l) + H_2O(l) \rightleftharpoons CH_3COOH(l) + CH_3OH(l) \quad \Delta H^{\ominus} = +3 \text{ kJ mol}^{-1}$$

Which one of the following compounds from the reaction mixture has no hydrogen bonding between its molecules when pure?

A $CH_3COOCH_3(l)$

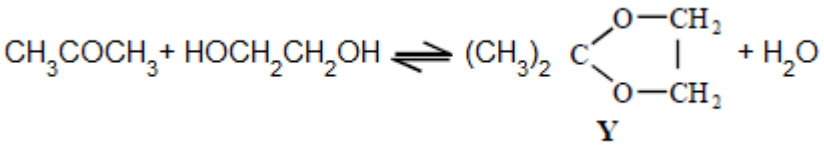
B $H_2O(l)$

C $CH_3COOH(l)$

D $CH_3OH(l)$

(Total 1 mark)

29 This question is about the reaction between propanone and an excess of ethane-1,2-diol, the equation for which is given below.



Y

In a typical procedure, a mixture of 1.00 g of propanone, 5.00 g of ethane-1,2-diol and 0.100 g of benzenesulphonic acid, $C_6H_5SO_3H$, is heated under reflux in an inert solvent. Benzenesulphonic acid is a strong acid.

Which one of the following statements is **not** true?

A Ethane-1,2-diol and water can form hydrogen bonds.

B Ethane-1,2-diol is soluble in water.

C Propane has a higher boiling point than ethane-1,2-diol.

D **Y** and water are polar molecules.

(Total 1 mark)

30 (a) Predict the shapes of the SF_6 molecule and the $AlCl_4^-$ ion. Draw diagrams of these species to show their three-dimensional shapes. Name the shapes and suggest values for the bond angles. Explain your reasoning.

(8)

(b) Perfume is a mixture of fragrant compounds dissolved in a volatile solvent.

When applied to the skin the solvent evaporates, causing the skin to cool for a short time. After a while, the fragrance may be detected some distance away. Explain these observations.

(4)
(Total 12 marks)

31 The table below shows some values of melting points and some heat energies needed for melting.

Substance	I_2	NaCl	HF	HCl	HI
Melting point/K	387	1074	190	158	222
Heat energy for melting /kJ mol^{-1}	7.9	28.9	3.9	2.0	2.9

(a) Name **three** types of intermolecular force.

Force 1 .....

Force 2 .....

Force 3 .....

(3)

(b) (i) Describe the bonding in a crystal of iodine.

.....

.....

(ii) Name the crystal type which describes an iodine crystal.

.....

(iii) Explain why heat energy is required to melt an iodine crystal.

.....

.....

(4)

(c) In terms of the intermolecular forces involved, suggest why

(i) hydrogen fluoride requires more heat energy for melting than does hydrogen chloride,

.....

.....

.....

.....

(ii) hydrogen iodide requires more heat energy for melting than does hydrogen chloride.

.....

.....

.....

(5)

(d) (i) Explain why the heat energy required to melt sodium chloride is large.

.....

.....

(ii) The heat energy needed to vaporise one mole of sodium chloride (171 kJ mol^{-1}) is much greater than the heat energy required to melt one mole of sodium chloride. Explain why this is so.

.....

.....

(3)

(e) In terms of its structure and bonding, suggest why graphite has a very high melting point.

.....

.....

.....

(2)
(Total 17 marks)

32 Predict which one of the following has the highest boiling temperature.

A $CH_3COOCH_2CH_3$

B $CH_3CH_2CH_2CH_2OH$

C $CH_3CH_2CH_2CH_2CH_3$

D $CH_3CH_2CH_2CHO$

(Total 1 mark)

Mark schemes

1

(a) M1 have the same molecular formula
or are C_3H_6O
or both have the same number/amount of each type of atom or same amount of each element
or are isomers

Not just the same atoms;

1

M2 identical / exactly the same / same precise (relative) molecular mass / formula mass / M_r

Same (relative) molecular mass / formula mass / M_r is NOT enough got score M2

Allow same accurate (relative) molecular mass / formula mass / M_r

Ignore reference to number of decimal places

1

(b) M1 prop-2-en-1-ol

Must refer to this compound clearly by name or structure (not to alcohol alone); ignore minor slips in name/structure

1

M2 O(-)H (alcohol) and 3230–3550 (cm^{-1}), or
C=C and 1620–1680 (cm^{-1})

Marked independently from M1

Could score from bond labelled on correct signal on spectrum

Allow any value within these ranges

If additional incorrect signals given penalise M2

Ignore signals below 1500 cm^{-1} and C-H signals

1

(c) (i) Determine the level by looking at the chemical content. (**NB** - If there is clear breakage of covalent bonds then max level 2 (max 3 marks).

(ii) The mark within that level is then determined by looking at how coherent and logical the answer is and by use of terminology; start at the higher mark and penalise poor terminology/explanation; examples of terminology that would reduce the mark to the lower one:

- reference to van der Waals 'bonds' or dipole-dipole 'bonds in relevant compounds that are being credited
- uncertainty about whether hydrogen bonds are the O-H bonds within or are forces/bonds between molecules (if the alcohol is being credited)
- use of 'vdw' or 'dip-dip' unless these terms 'van der Waals' for 'dipole-dipole' have been used elsewhere in answer (note that IMF and H-bond would not be penalised)

(iii) If the answer does not achieve level 1, then 1 mark maximum could be scored for any correct point from the list of indicative content

Level 3

- **Relative order** of boiling points of **all three** compounds
- Strongest intermolecular force of **all three** compounds identified
- Answer explains this coherently and logically and uses correct terminology for all **three** compounds

5-6 marks

Level 2

- **Relative** boiling points of **two** compounds correctly compared
- Strongest intermolecular force for these **two** compounds correctly identified
- Answer explains this coherently and logically and uses correct terminology for **these two** compounds

3-4 marks

Level 1

- **One** compound with the **highest** or **lowest** boiling point is correctly identified
- Strongest intermolecular force for that **one** compound identified
- Answer explains this coherently and logically and uses correct terminology for **this one** compound
- Allow 1 mark for individual correct point from indicative content on the right if no other mark scored

1-2 marks

Level 0

None of the indicative chemistry content given.

0 marks

Indicative chemistry content:

• Correct order (highest to lowest) = prop-2-en-1-ol > propanal > butane

• Prop-2-en-1-ol has hydrogen bonds

• Propanal has (permanent) dipole-dipole forces

• Butane has van der Waals' forces

• Strength of intermolecular forces:
hydrogen bonds > dipole-dipole > van der Waals

(Note - actual values for reference are prop-2-en-1-ol 97°C, propanal 46°C and butane −1°C)

[10]

2 A

[1]

3 D

[1]

4 C

[1]

5 (a) $\Delta S = 238 + 189 - 214 - 3 \times 131 = -180$ J K^{-1} mol^{-1}

1

$\Delta G = \Delta H - T\Delta S$

1

$= -49 - \frac{523 \times (-180)}{1000}$

1

$= +45.1 \text{ kJ mol}^{-1}$

Units essential

1

(b) When $\Delta G = 0$, $\Delta H = T\Delta S$ therefore $T = \Delta H / \Delta S$

1

$= -49 \times 1000 / -180 = 272$ (K)

Mark consequentially to ΔS in part (a)

1

(c) Diagram marks

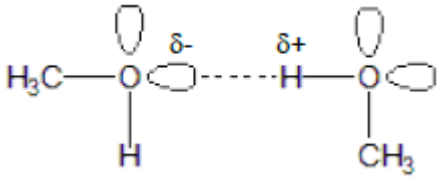


Diagram of a molecule showing O–H bond and two lone pairs on each oxygen

1

Labels on diagram showing δ+ and δ- charges

Allow explanation of position of δ+ and δ- charges on H and O

1

Diagram showing δ+ hydrogen on one molecule attracted to lone pair on a second molecule

1

Explanation mark

Hydrogen bonding (the name mentioned) is a strong enough force (to hold methanol molecules together in a liquid)

1

[10]

6 (a) A mixture of liquids is heated to boiling point for a prolonged time

1

Vapour is formed which escapes from the liquid mixture, is changed back into liquid and returned to the liquid mixture

1

Any ethanal and ethanol that initially evaporates can then be oxidised

1

(b) $CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 4H^+ + 4e^-$

1

(c) Mixture heated in a suitable flask / container

A labelled sketch illustrating these points scores the marks

1

With still head containing a thermometer

1

Water cooled condenser connected to the still head and suitable cooled collecting vessel

1

Collect sample at the boiling point of ethanal

1

Cooled collection vessel necessary to reduce evaporation of ethanal

1

(d) Hydrogen bonding in ethanol and ethanoic acid or no hydrogen bonding in ethanal

1

Intermolecular forces / dipole-dipole are weaker than hydrogen bonding

1

(e) Reagent to confirm the presence of ethanal:

Add Tollens' reagent / ammoniacal silver nitrate / aqueous silver nitrate followed by 1 drop of aqueous sodium hydroxide, then enough aqueous ammonia to dissolve the precipitate formed

OR

Add Fehling's solution

1

Warm

M2 and M3 can only be awarded if M1 is given correctly

1

Result with Tollen's reagent:

Silver mirror / black precipitate

OR

Result with Fehling's solution:

Red precipitate / orange-red precipitate

1

Reagent to confirm the absence of ethanoic acid

Add sodium hydrogencarbonate or sodium carbonate

1

Result; no effervescence observed; hence no acid present

1

M5 can only be awarded if M4 is given correctly

OR

Reagent; add ethanol and concentrated sulfuric acid and warm

Result; no sweet smell / no oily drops on the surface of the liquid,

hence no acid present

[16]

7 C

[1]

8 (a) 94−105.5°

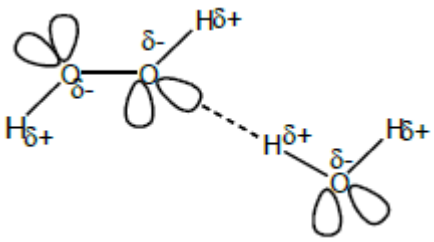
1

(b) (i) Hydrogen bond(ing) / H bonding / H bonds

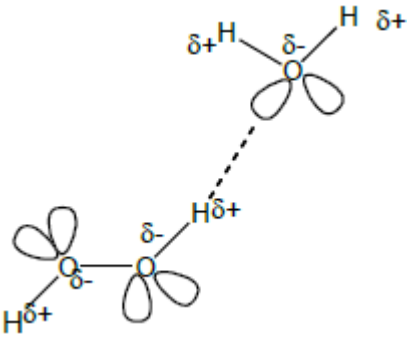
Not just hydrogen

1

(ii)



OR



1 mark for all lone pairs

1 mark for partial charges on the O and the H that are involved in H bonding

1 mark for the H-bond, from Hδ+ on one molecule to lone pair on O of other molecule

3

(c) Electronegativity of S lower than O or electronegativity difference between H and S is lower

Mark independently

1

No hydrogen bonding <u>between H_2S_2 molecules</u>

Or <u>only</u> van der Waals / <u>only</u> dipole-dipole forces <u>between H_2S_2 molecules</u>

If breaking covalent bonds CE = 0

1

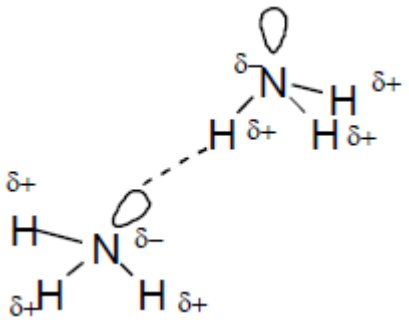
[7]

9 (a) (i) Hydrogen bonds / H bonds

Not just hydrogen.

1

(ii)



M1 – lone pair on each N.

M2 – correct partial charges must be shown on the N and H of a bond in each molecule.

M3 – for the H bond from lone pair on N to the Hδ^+ on the other NH_3 molecule.

If not ammonia molecules, CE = 0 / 3.

3

(b) Lone pair / both electrons / 2 electrons / electron pair on N(H_3) is donated to B(Cl_3)

Allow both electrons in the bond come from N(H_3).

1

(c) (i) The power of an <u>atom</u> or <u>nucleus</u> to withdraw or attract electron<u>s</u> or electron density or a pair of electrons (towards itself)

1

in a <u>covalent</u> bond

1

(ii) LiF **OR** Li_2O **OR** LiH

Allow Li_2O_2, allow correct lithium carbide formula.

1

(iii) BH_3 / H_3B

Allow B_2H_6 / H_6B_2

Do not allow lower case letters.

1

[9]

10 (a) Crude oil **OR** petroleum

Not petrol.

1

Fractional distillation / fractionation

Not distillation alone.

1

(b) $C_{12}H_{26} + 12.5O_2 \longrightarrow 12CO + 13H_2O$

Allow balanced equations that produce CO_2 in addition to CO.

Accept multiples.

1

(c) (i) M1 Nitrogen and oxygen (from air) react / combine / allow a correct equation

If nitrogen from petrol / paraffin / impurities CE = 0 / 2.

1

M2 at high temperatures

Allow temperatures above 1000 °C or spark.

Not just heat or hot.

M2 dependent on M1.

But allow 1 mark for nitrogen and oxygen together at high temperatures.

1

(ii) $2NO + O_2 \longrightarrow 2NO_2$

Allow multiples.

1

(iii) $4NO_2 + 2H_2O + O_2 \longrightarrow 4HNO_3$

Allow multiples.

1

(d) (i) C_nH_{2n+2}

Allow C_xH_{2x+2}

CnH2n+2

Allow CxH2x+2

1

(ii) $C_{12}H_{26} \longrightarrow C_6H_{14} + C_6H_{12}$

Only.

1

C_3H_7

Only.

1

Zeolite / aluminosilicate(s)

Ignore aluminium oxide.

1

(iii) Larger molecule / longer carbon chain / more electrons / larger surface area

1

More / stronger van der Waals' forces between molecules

Allow dispersion forces / London forces / temporary induced dipole-dipole forces between molecules.

If breaking bonds, CE = 0 / 2.

1

(e) 2,2,3,3,4,4-hexamethylhexane

Only.

Ignore punctuation.

1

Chain

Ignore branch(ed).

1

(f) Cl_2

Only.

Cl–Cl

Not CL_2 or Cl2 or CL2 or Cl^2 or CL^2.

Ignore Chlorine.

1

[16]

11 (a) Hydrogen bond(ing)

Allow H bonding.

Penalise mention of any other type of bond.

1

(b) (i) Ammonia is a nucleophile

Allow ammonia has a lone pair.

1

Benzene repels nucleophiles

Allow (benzene) attracts / reacts with electrophiles.

OR *benzene repels electron rich species or lone pairs.*

OR *C–Cl bond is short / strong / weakly polar.*

1

(ii) H_2 / Ni **OR** H_2 / Pt **OR** Sn / HCl **OR** Fe / HCl

Ignore dil / conc of HCl.

Ignore the term 'catalyst'.

Allow H_2SO_4 with Sn and Fe but not conc.

Ignore NaOH following correct answer.

Not $NaBH_4$ nor $LiAlH_4$.

1

(iii) conc HNO_3

conc H_2SO_4

1

If either or both conc missed can score 1 for both acids.

1

$HNO_3 + 2H_2SO_4 \longrightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$

OR using two equations

$HNO_3 + H_2SO_4 \longrightarrow H_2NO_3^+ + HSO_4^-$

$H_2NO_3^+ \longrightarrow H_2O + NO_2^+$

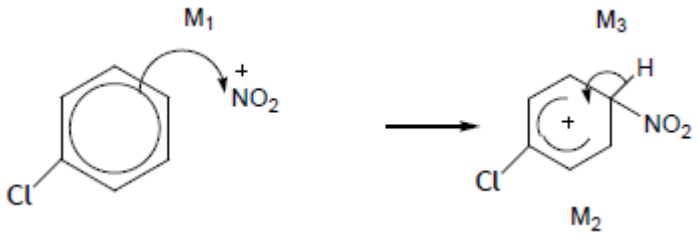
Allow 1:1 equation.

$HNO_3 + H_2SO_4 \longrightarrow NO_2^+ + H_2O + HSO_4^-$.

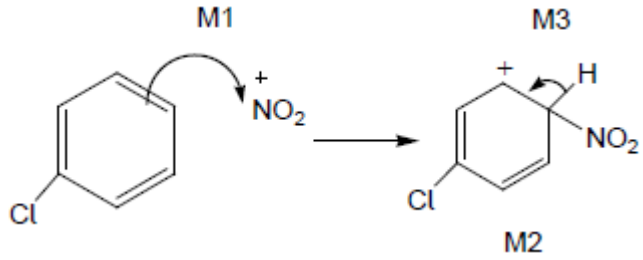
1

(iv) Electrophilic substitution

1



OR



- *Ignore position or absence of Cl in M1 but must be in correct position for M2.*
- *M1 arrow from within hexagon to N or <u>+ on N</u>.*
- *Allow NO_2^+ in mechanism.*
- *Bond to NO_2 must be to N for structure mark M2.*
- *Gap in horseshoe must be centered around correct carbon (C1).*
- *+ in intermediate not too close to C1 (allow on or "below" a line from C2 to C6).*
- *M3 arrow into hexagon unless Kekule.*
- *Allow M3 arrow independent of M2 structure.*
- *Ignore base removing H in M3.*
- *+ on H in intermediate loses M2 not M3.*

3

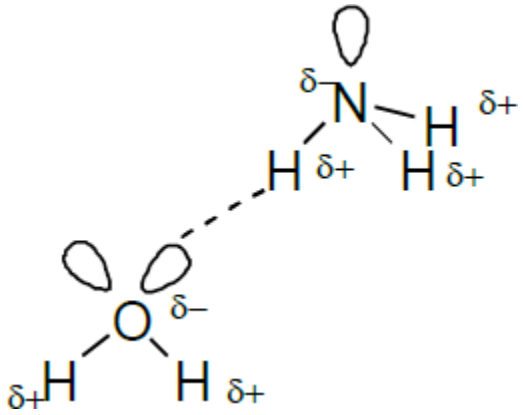
[11]

12 (a) Hydrogen bonding / hydrogen bonds / H-bonding / H-Bonds

Not just hydrogen.

1

(b)

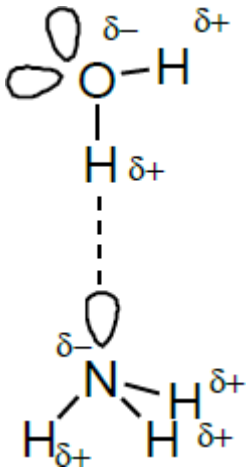


One mark for minimum of 4 correct partial charges shown on the N-H and O-H

One mark for the 3 lone pairs.

One mark for H bond from the lone pair on O or N to the $H^{\delta+}$

OR



The N-H-O should be linear but can accept if the lone pair on O or N hydrogen bonded to the H

If wrong molecules or wrong formula, CE = 0/3

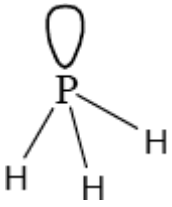
3

(c) (Phosphine) does not form hydrogen bonds (with water)

1

[5]

13 (a)



Need to see 3 P–H bonds and one lone pair (ignore shape).

1

(b) Coordinate / dative

If not coordinate / dative then chemical error CE=0 unless blank or covalent then M1 = 0 and mark on.

1

Pair of electrons on P(H_3) donated (to H+)

Do not allow a generic description of a coordinate bond.

1

(c) 109.5° / 109½ / 109° 28'

Allow answers in range between 109° to 109.5°

1

(d) Difference in electronegativity between P and H is too small

Allow P not very electronegative / P not as electronegative as N, O and F / P not electronegative enough / P not one of the 3 most electronegative elements.

Do not allow phosphine is not very electronegative.

1

[5]

14 (a) Covalent

If not covalent CE = 0/2

If dative covalent CE = 0/2

If blank mark on

Ignore polar

If number of pairs of electrons specified, must be 3

1

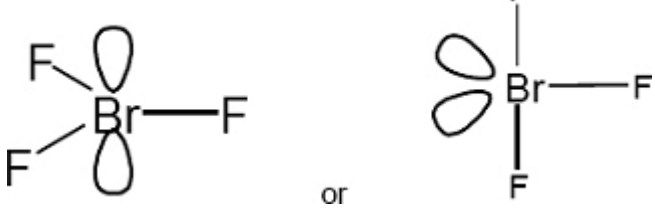
Shared <u>pair</u>(s) of electrons / one electron from Br and one electron from F

Not 2 electrons from 1 atom

Not shared pair between ions/molecules

1

(b) (i)



BrF_3 should have 3 bp and 2 lp and correct atoms for the mark

Penalise Fl

1

BrF_3 if trigonal planar shown = 120°

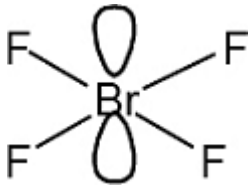
Allow 84 – 90° or 120° and ignore 180°

or if T shape shown 84 – 90°

Irrespective of shape drawn

1

(ii)



BrF_4^- should have 4 bp and 2 lp and all atoms for the mark (ignore sign)

Allow Fl

1

BrF_4^- 90°

Only

Ignore 180°

1

(c) Ionic or (forces of) attraction between ions / bonds between ions

If molecules, IMF, metallic, CE =0

If covalent bonds mentioned, 0/3, unless specified <u>within</u> the BrF_4^- ion and not broken

Ignore atoms

1

Strong (electrostatic) attraction / strong bonds / lots of energy needed to break bonds

1

Between K^+ and BrF_4^- ions/oppositely charged ions / + and – ions

If ions mentioned they must be correct

Strong bonds between + and – ions =3/3

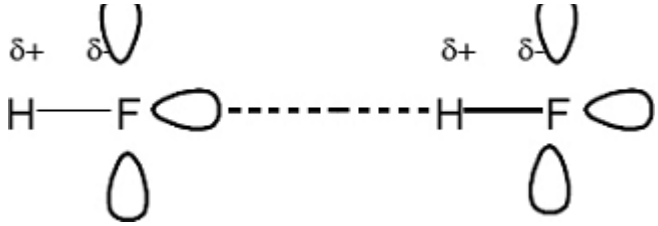
1

(d) (i) Hydrogen <u>bonds</u>/hydrogen <u>bonding</u>/H <u>bonds</u>/H <u>bonding</u>

Not just hydrogen

1

(ii)



One mark for 4 partial charges

One mark for 6 lone pairs

One mark for H bond from the <u>lone pair to the Hδ+</u>

Allow Fl

If more than 2 molecules are shown they must all be correct. Treat any errors as contradictions within each marking point.

CE = 0/3 if incorrect molecules shown.

3

(e) vdw / van der Waals forces between molecules

QoL

Not vdw between HF molecules, CE = 0/2

vdw between atoms, CE = 0/2

If covalent, ionic, metallic, CE=0/2

1

IMF are weak / need little energy to break IMF / easy to overcome IMF

1

[15]

15 (a) Iodine has more electrons / iodine is bigger (atom or molecule) / iodine has bigger M_r / bigger surface area

1

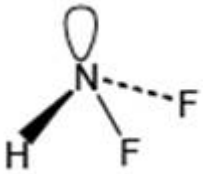
<u>Stronger</u> / <u>more</u> van der Waals forces / vdw / London / temporarily induced dipole / dispersion forces <u>between molecules</u>

1

Stronger VdW intermolecular forces = M2

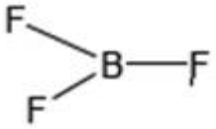
If stated VdW between atoms lose M2

(b) (i)



Mark is for 3 bp and 1 lp attached to N (irrespective of shape)

1



Mark is for 3 bp and 0 lp attached to B (irrespective of shape)

1

NHF_2 shape - pyramidal / trigonal pyramid

Accept tetrahedral / triangular pyramid

1

BF_3 shape - <u>trigonal planar</u>

Not triangular or triangular planar

1

(ii) 107°

Allow 106-108°

1

(c) Hydrogen bonds

Allow H-Bonds

Not just Hydrogen

Apply list principle eg Hydrogen bonding and dipole-dipole = 0

1

(d) Coordinate / dative covalent / dative

If covalent mark on

If ionic / metallic CE = 0

1

Lone pair / both electrons/ 2 electrons <u>on N(HF_2)</u> donated (to BF_3)

Direction of donation needed here

1

[10]

16

(a) Water or H_2O or molecules (in ice) are held further apart (than in liquid water)/(more) space/gaps/holes in structure/Water or H_2O or molecules (in ice) are more spread out

Allow water (liquid) is more compact/less space/gaps/holes

CE if holes filled with air, O_2 etc

CE if macromolecule

CE if atoms further apart (since ambiguous)

Ignore spaces filled with H_2O

Ignore reference to H bonds

Allow better tessellation in liquid water

1

(b) (i) Hydrogen bonding

Allow H bonds

Do not allow 'hydrogen' only but mark on

1

(ii) Van der Waals'/VdW

Allow London forces, dispersion forces, temporary induced dipole forces

1

(iii) Hydrogen bonding is stronger (than van der Waals forces)/IMF in ice stronger (than IMF in methane)/H bonds take more energy to break

Not H Bonds are strong (needs comparison)

If (b)(i) OR (ii) is incorrect, cannot award (b)(iii)

If (b)(i) and/or (ii) is blank, can score (b)(iii)

1

(c) (i) Structure showing 3 bonds to H and 1 lone pair

1

(trigonal) pyramid(al)/(distorted) tetrahedral

do not insist on the + sign

Allow triangular pyramid

Not square pyramid

Ignore bond angles in structure

M2 independent of M1

1

(ii) 107°

Allow range 106 – 108°

Ignore °(C)

1

(iii) NH_3/ammonia

Contradictions (eg NH_4 ammonia) CE = 0

1

(d) 3

Allow three/III/3 lone pairs/3lp/3 lone pairs of electrons

1

[9]

17 (a) (i) shared <u>pair of electrons</u>

Can have one electron from each atom contributes to the bond
Not both electrons from one atom

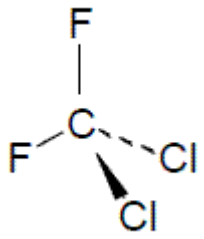
1

(ii) $\frac{1}{2}Cl_2 + \frac{3}{2}F_2 \rightarrow ClF_3$

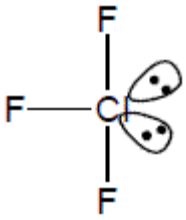
1

Only
Ignore state symbols even if wrong

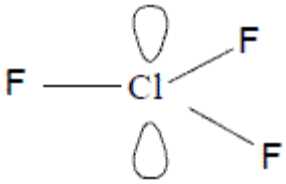
(b)



1



OR

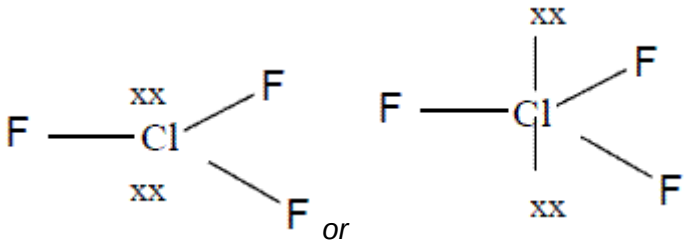


Allow any structure with 4 bp

In $CClF_2$, watch for Cl in centre- it must be C

Ignore wrong bond angles

Representations of lone pairs allowed are the two examples shown with or without the electrons in the lobe.
Also they can show the lone pair for either structure by two crosses/dots or a line with two crosses/dots on it e.g.



Or a structure with 3 bp and 2 lp

1

(c) Dipole – dipole

Allow van der Waals/vdw/London/dispersion/temporary dipole – induced dipole
Not dipole alone

1

(d) (i) Coordinate/dative (covalent)

If wrong CE = 0/3 but if 'covalent' or left top line blank, mark on.

1

(Lone) pair of electrons/both electrons (on F^-)

CE if lone pair is from B

1

Donated from F^-/fluoride or donated to the BF_3

Must have the – sign on the F ie F^-

Ignore Fl^-
M3 dependent on M2

1

(ii) 109° to 109.5°

1

(e) $\frac{238 \times 100}{438}$

For 1 mark allow 238 as numerator and 438 as denominator or correct strings

1

= 54.3%

2 marks if correct answer to 3 sig figs.
54% or greater than 3 sig figs = 1 mark

1

[11]

18 (a) Hydrogen/H bonds

Not just hydrogen

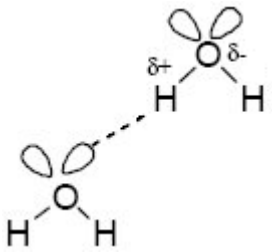
1

van der Waals/vdw/dipole-dipole/London/temporarily induced dipole/dispersion forces

Not just dipole

1

(b)



M1 for partial charges as indicated in diagram (correct minimum)
M2 for all four lone pairs
M3 for H bond from the lp to the H (δ+) on the other molecule
Lone pair on hydrogen CE = 0
OHO CE = 0
If only one molecule of water shown
CE = 0

3

(c) Hydrogen bonds/IMF (in water) stronger

OR

IMF/VDW/dipole-dipole forces (in H_2S) are weaker

OR

H bonding is the strongest IMF

Ignore energy references
Comparison must be stated or implied

1

(d) Atoms/molecules get larger/more shells/more electrons/more surface area

Not heavier/greater Mr

1

therefore increased Van der Waals/IMF forces

Ignore references to dipole-dipole forces

1

(e) Dative (covalent)/coordinate

If not dative/coordinate CE = 0/2
If covalent or blank read on

1

(Lone) pair/both electrons/two electrons on O(H_2) donated (to H^+)
OR pair/both electrons come from O(H_2)

Explanation of a coordinate bond specific to oxygen or water required
Not just H+ attracted to lone pair since that is nearer to a H bond

1

(f) ionic

1

if not ionic CE = 0

oppositely charged ions/+ and – ions or particles

atoms or molecules loses M2 and M3

1

ions attract strongly OR strong/many (ionic) bonds must be broken

S^- loses M2
Reference to IMF loses M2 and M3

1

[13]

19 (a) (i) Covalent;

If not covalent CE = 0.
If blank, mark on.

1

Shared pair of electrons (one from each atom);

Not shared electrons.

1

(ii) Hydrogen bonds / H bonds;

Not just hydrogen.

1

Van der Waals/London/dispersion forces/temporary induced dipole;

1

(b) Showing all the lone pairs on both molecules;

Allow showing both lone pairs on the O involved in the H-bond.

1

Showing the partial charges on O and H on both molecules;

Allow showing both partial charges on the O and H of the other molecule involved in the H bond.

1

Showing the Hydrogen bond from the lone pair on O of one molecule to the delta + on the H of the other molecule;

1

(c) (i) $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$;

Accept multiples.
Allow C_2H_6O.

1

(ii) CO is (produced which is) toxic/ poisonous/C (may be produced) which is toxic/ C is a respiratory irritant/ C (particles) exacerbate asthma/C causes global dimming/ smog;

Must relate to C or CO.
Any mention of SO_2 NO_2 or other pollutants CE = 0.

1

(iii) More fuel needed (which costs more)/Wastes fuel/ less fuel burnt (so need more to buy more)/engine gets sooty so need to pay for engine to be cleaned/Have to fit catalytic converter;

Not just costs more.
Not engine gets sooty unless qualified.

1

(d) (i) (React) with CaO/ calcium oxide/quicklime/lime;

Accept $CaCO_3$/ calcium carbonate/limestone.
Not chalk.

1

All the sulfur dioxide may not react with the CaO or $CaCO_3$ / may not have time to react/ incomplete reaction;

Accept incomplete reaction.

1

(ii) Occupies a (much) smaller volume;

Not easier to store or transport.

1

[13]

20 (a) Ability/power of an atom/element/nucleus to withdraw electron density or electron cloud or a pair of electrons (towards itself);

Not withdraw an electron
If ref to ionic, metallic , imf etc then CE = 0

1

From a covalent bond or from a shared pair of electrons;

Not distort
Not remove electrons

1

(b) Van der Waals/ vdw/London/ temporary (induced) dipole/ dispersion forces;

1

Hydrogen bonds/H bonds;

Not just hydrogen

1

(c) (Large) electronegativity difference between N + H/ difference of 0.9/ N very electronegative;

Insufficient to say N= 3.1 and H = 2.1

1

Forms N δ– / H δ+ or dipole explained in words;

Not N becomes (fully) negative or vice versa

1

Lone pair on N attracts/forms weak bonds with H (δ+);

QWC
Can score M2 and 3 from a diagram

1

(d) Co-ordinate/dative;

If not correct then CE = 0. If covalent/blank mark on.

1

Both electrons/ lone pair (on P/PH_3)

Not lone pair on hydrogen

1

Shares/donated from P(H_3)/ to H(δ+);

1

(e) 3 bonds and 1 lp attached to As;

Must label H and As atoms
Accept distorted tetrahedral not bent tetrahedral

1

Pyramidal/tetrahedral/ trigonal pyramidal;

Not bipyramidal/triangular

1

(f) (Only) weak Van der Waals forces between molecules /AsH_3 has weaker IMF /ammonia has hydrogen bonding/ more energy needed to break IMF's in ammonia/ Van der Waals weaker than H bonds;

Accept has no H bonds.
Ignore dp-dp in AsH_3 provided ammonia has stronger IMF.
If between atoms mentioned CE=0
Break bonds CE = 0

1

(g) $4AsCl_3 + 3NaBH_4 \rightarrow 4AsH_3 + 3NaCl + 3BCl_3$;

Accept multiples

1

[14]

21 (a) Outer electrons are in p orbitals

1

(b) decreases

1

Number of protons increases

1

Attracting outer electrons in the same shell (or similar shielding)

1

(c) Sulfur molecules (S_8) are larger than phosphorus (P_4)

1

Therefore van der Waals' forces between molecules are stronger

1

Therefore more energy needed to loosen forces between molecules

1

(d) Argon particles are single atoms with electrons closer to nucleus

1

Cannot easily be polarised (or electron cloud not easily distorted)

1

[9]

22 (a) tendency / strength / ability / power of an atom / element / nucleus to attract / pull / withdraw electrons / e - density / bonding pair / shared pair

1

in a covalent bond

1

(b) (i) F_2 = van der Waals' / induced/temporary dipole-dipole / dispersion / London forces

1

CH_3F dipole-dipole

(not just 'dipole')

1

HF = hydrogen bonding

(not just 'H' / 'hydrogen')

1

(ii) large difference in electronegativity between H and F / F most/very/much more electronegative / values '4' & '2.1' quoted

(not just 'high er')

1

$^{\delta+}H\text{-}F^{\delta-}$ dipole created or dipole clearly implied

(accept arguments such as 'uneven charge in bond'/ 'polar bond' ∴ F slightly negative / H slightly positive)

1

attraction/bond formed between δ+H and lone pair on F

(M2 / M3 may be scored from a diagram)

(CE if full charges shown - lose M2 and M3)

1

(c) (i) van der Waals' / induced/temporary dipole-dipole / dispersion / London forces / attractions

(ignore references to dipole-dipole)

1

increase with the increasing M_r / size / mass / N^0 of e^- / size of e^- cloud (in the hydrogen halides)

(if ionic, or if 'covalent bonds broken' = CE = 0)

(mark M1 and M2 separately)

1

(ii) hydrogen bonding stronger than van der Waals' attraction/forces

(accept hydrogen bonding is very strong / strongest)

(accept arguments such as 'HF has H-bonds, others <u>only</u> have van der Waals')

(not just 'HF has H-bonding')

1

[11]

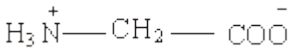
23 (a) polyamide or nylon (2,4)

(allow nylon without numbers but if numbers are present they must be correct)

1

condensation

1

(b) 

1

(c) ionic bonding in aminoethanoic acid

(can only score if includes that aminoethanoic is ionic)

1

stronger attractions than Hydrogen bonding in hydroxyethanoic acid

(e.g. stronger Hydrogen bonding in aminoethanoic acid scores 0)

(mention of electrostatic forces between molecules scores 0)

1

[5]

24 (a) Oxygen more/very/highly electronegative (than hydrogen)
OR oxygen has stronger attraction for <u>bonding</u> electrons / <u>bonding</u> electrons drawn towards oxygen;

1

causes higher e^- density round oxygen atom / causes $H^{\delta+}$ $O^{\delta-}$;

1

(b) van der Waals' forces between oxygen <u>molecules;</u>

1

Hydrogen bonding between methanol molecules;

1

H-B stronger than van der Waals' *OR* stronger IMF in methanol;

(if dipole-dipole forces in O_2 or methanol, allow comparison, hence max 2)

(if ionic/covalent etc. max 1)

(mention of bond break = CE = 0)

1

[5]

25 A

[1]

26 (a) Hydrogen bonding *(full name)*

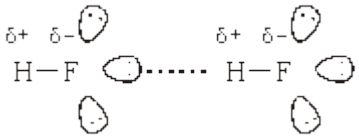
1

Diagram shows at least one $^{\delta+}$H **and** at least one $^{\delta-}$F

(If full charges shown, M2 = 0)

1

3 lone pairs shown on at least one fluorine atom
H-bond indicated, between H and a lone pair on F



(If atoms not identified, zero for diag)

('Fl' for fluorine - mark to Max 2)

*(Max 1 if only one HF molecule shown, **or** HCl shown)*

1

Dipole results from electronegativity difference **or** values quoted

('difference' may be inferred)

(Allow explanation – e.g. F attracts bonding electrons more strongly than H)

1

QoL Fluorine more/very electronegative **or** iodine less electronegative **or** electronegativity difference too small in HI
Comparison required, may be implied.

1

HI dipole weaker or bonding e^- more equally shared - wtte

1

(b) NaCl is ionic (lattice)

(Treat atoms/molecules as a contradiction)

(Accept 'cubic lattice')

1

Diamond is macromolecular/giant covalent/giant atomic/giant molecular

(NOT molecular or tetrahedral)

(Ionic/van der Waals' = CE = 0)

1

(Many) covalent/C-C bonds need to be broken / overcome

(NOT just 'weakened' etc.)

('Covalent' may be inferred from diagram)

(Treat diagram of graphite (without one of diamond) as a contradiction – lose M2 but allow M3/M4])

2

Which takes much energy **or** covalent bonds are strong

(References to van Der Waals' bonds breaking lose M3/M4)

1

[11]

27

(a) (i) Electronegativity (difference) or suitable description **(1)**

Accept F and Cl are highly electronegative
Not both atoms are highly electronegative

(ii) HF = hydrogen bonding **(1)**
HCl = (permanent) dipole-dipole bonding **or** even van de Waals' **(1)**
Hydrogen bonding stronger / is the strongest IMF **(1)**

Accept a statement that HF must have the stronger IMF, even if no IMFs identified

*The explanation **must** be based on **intermolecular** forces/attractions*

Note: if the explanation is clearly intramolecular = CE

4

(b) Electron pair **or** lone pair donated **(1)**

Do not accept 'donation of electrons'

From chloride ion to Al **or** $AlCl_3$ **(1)**

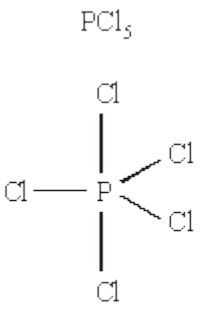
M1 can be earned by a general explanation of coordinate bonding, even if the electron pair is said to come from Al. The second mark, M2, is for this specific bond

Ignore missing charge

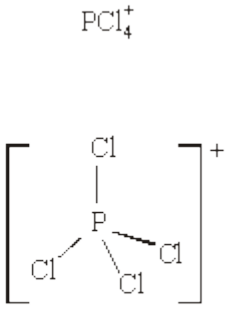
2

(c)

4



(1)



(1)

PCl_5 shown as trigonal bipyramid
[Look for: ONE solid linear Cl-P-Cl bond]

Bond Angle(s) 90° and 120° **(1)**

PCl_4^+ shown as tetrahedral
NO solid linear Cl-P-Cl bonds]

Bond angle(s) 109 or 109.5° **(1)**

[10]

28 A

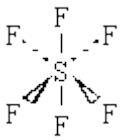
[1]

29 C

[1]

30 (a) SF_6 shown as octahedral / square based bipyramid **(1)**
Bond angle: 90° **or** 180° and 90° **(1)**
Shape = octahedral **(1)**

If lone pair shown then C.E. = 0 / 4

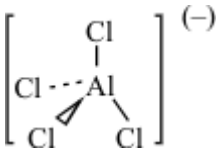


Wrong symbols - no diagram mark

Equal repulsion between 6 bonding **or** shared electron pairs **QoL (1)**

$AlCl_4^-$ shape shown as tetrahedral **(1)**
Bond angle = 109° to 109.5° **(1)**
Shape = tetrahedral **(1)**

If lone pair shown then C.E = 0/4



(Equal repulsion between) 4 bonding pairs **or** shared electron pairs **(1)**

QoL may be awarded here also
Mark all points independently

8

(b) Solvent has low bp or weak intermolecular forces **or** evaporates quickly **(1)**

(Solvent) needs energy to evaporate **(to overcome intermolecular forces) or** valid reference to latent heat of vaporisation **(or evaporation is endothermic) (1)**

OR higher energy or faster molecules more likely to escape so mean energy (and hence temperature) falls

Energy taken from the skin (and so it cools) **(1)**

Fragrance or perfume (molecules) slowly spreads (through the room) **(1)**

By random movement **or** diffusion (of the perfume / fragrance) **(1)**

4

[12]

31 (a) *Force 1:* Van der Waals' **(1)**

Force 2: dipole - dipole **(1)**

Force 3: hydrogen bonding **(1)**

OR London, Dispersion, temporary dipole

3

(b) (i) covalent between atoms **(1)**

OR within molecule

Van der Waals' between molecules **(1)**

(ii) molecular **(1)**

(iii) Bonds (or forces) between molecules must be broken or loosened **(1)**

OR V.dW forces

OR intermolecular forces

Mention of ions CE=0

4

(c) (i) H-Bonding in HF **(1)**

(dipole-) dipole in HCl **(1)**

OR V.dW

H-bonding is stronger than dipole-dipole or V.dW **(1)**

OR H-bonding is a strongest intermolecular force for 3rd mark

(ii) HI bigger molecule than HCl **(1)**

OR Heavier, more e's, more electron shells, bigger M_r, more polarisable

Therefore the forces between HI molecules are stronger **(1)**

QL mark (Look for unambiguous statements using correct terminology)

5

(d) (i) ionic **(1)**

Strong forces between ions **(1)**

OR lots of energy required to break bonds

(ii) All bonds must be broken **(1)**

mention of molecules etc CE=0

3

(e) macromolecular **(1)**

OR giant molecule / lattice or correct diagram

Strong covalent bonds **(1)**

OR lots of energy required to break bonds

2

[17]

32 B

[1]