AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



EXAM QUESTION PACK

3.1.3 BONDING

SCORE	PERCENTAGE
/1668	%

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Q1.

Lithium hydride, LiH, is an ionic compound containing the hydride ion, H^-
The reaction between LiH and aluminium chloride, $AlCl_3$, produces the ionic compound $LiAlH_4$

(a) Balance the equation below which represents the reaction between LiH and $AlCl_3$

$$LiH + AlCl_3 \rightarrow LiAlH_4 + LiCl$$

(1)

(b) Give the electronic configuration of the hydride ion, H^-

_____

(1)

(c) Predict the shape of the AlH_4^- ion. Explain why it has this shape.

Shape _____

Explanation _____

_____

_____

(3)

(d) A bond in AlH_4^- can be represented by H → Al

Name this type of bond and explain how it is formed.

Type of bond _____

Explanation _____

_____

_____

(3)

(Total 8 marks)

Q2.

(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.

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_____

_____

_____

_____

_____

(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)

Q3.

(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.

_____

_____

_____

_____

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(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.

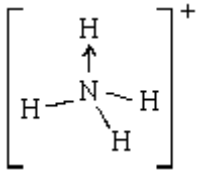
(4)

(Total 12 marks)

Q4.

(a) An ammonium ion, made by the reaction between an ammonia molecule and a hydrogen ion, can be represented as shown in the diagram below.

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(i) Name the type of bond represented in the diagram by N—H

_____

(ii) Name the type of bond represented in the diagram by N→H

_____

(iii) In terms of electrons, explain why an arrow is used to represent this N→H bond.

_____

_____

(iv) In terms of electron pairs, explain why the bond angles in the NH_4^+ ion are all 109° 28'

_____

_____

_____

_____

(7)

(b) Define the term *electronegativity*.

_____

_____

(2)

(c) A bond between nitrogen and hydrogen can be represented as $\overset{\delta-}{N}—\overset{\delta+}{H}$

(i) In this representation, what is the meaning of the symbol $\delta+$?

_____

(ii) From this bond representation, what can be deduced about the electronegativity of hydrogen relative to that of nitrogen?

_____

_____

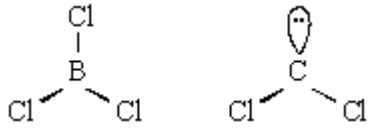
(2)

(Total 11 marks)

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Q5.

(a) The shape of the molecule BCl_3 and that of the unstable molecule CCl_2 are shown below.



(i) Why is each bond angle exactly 120° in BCl_3?

_____

_____

(ii) Predict the bond angle in CCl_2 and explain why this angle is different from that in BCl_3

Predicted bond angle _____

Explanation _____

_____

(5)

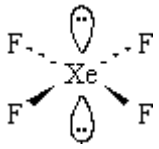
(b) Give the name which describes the shape of molecules having bond angles of 109° 28'.
Give an example of one such molecule.

Name of shape _____

Example _____

(2)

(c) The shape of the XeF_4 molecule is shown below.



(i) State the bond angle in XeF_4

_____

(ii) Suggest why the lone pairs of electrons are opposite each other in this molecule.

_____

_____

(iii) Name the shape of this molecule, given that the shape describes the positions of the Xe and F atoms only.

_____

(4)

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(d) Draw a sketch of the NF_3 molecule. Indicate in your sketch any lone pairs of electrons on nitrogen.

(2)

(Total 13 marks)

Q6.

Which one of the following ions has three lone pairs of electrons around the central atom?

A BF_2^-

B NH_2^-

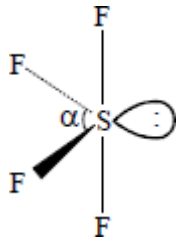
C ClF_2^-

D PF_6^-

(Total 1 mark)

Q7.

Which one of the following is the most likely value for the bond angle α shown in the diagram of SF_4 below?



A 118°

B 101°

C 90°

D 88°

(Total 1 mark)

Q8.

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Which one of the following molecules or ions is pyramidal in shape?

A BF_3

B CH_3^+

C CH_3^-

D SF_3^-

(Total 1 mark)

Q9.

Which one of the following has a shape which is **not** influenced by a lone pair of electrons?

A CH_3OH

B H_2F^+

C BF_3

D NF_3

(Total 1 mark)

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Q1.

This question is about compounds containing fluorine.

(a) Draw the shape of a molecule of krypton difluoride (KrF_2).
Include in your answer any lone pairs of electrons that influence the shape.
Name the shape produced by the atoms in a KrF_2 molecule and suggest a bond angle.

Name of shape _____

Bond angle _____

(3)

(b) There are two lone pairs of electrons on the oxygen atom in a molecule of oxygen difluoride (OF_2).

Explain how the lone pairs of electrons on the oxygen atom influence the bond angle in oxygen difluoride.

_____

_____

_____

_____

_____

_____

_____

(2)

(c) Silicon tetrafluoride (SiF_4) is a tetrahedral molecule.

Deduce the type of intermolecular forces in SiF_4
Explain how this type of intermolecular force arises and why no other type of intermolecular force exists in a sample of SiF_4

Intermolecular forces in SiF_4 _____

Explanation _____

_____

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_____

_____

_____

_____

_____

_____

_____

(3)

(Total 8 marks)

Q2.

This question is about sodium and some of its compounds.

(a) Use your knowledge of structure and bonding to explain why sodium bromide has a melting point that is higher than that of sodium, and higher than that of sodium iodide.

(6)

(b) When 250 mg of sodium were added to 500 cm^3 of water at 25 °C a gas was produced.

Give an equation for the reaction that occurs.
Calculate the volume, in cm^3, of the gas formed at 101 kPa

The gas constant, R = 8.31 J K^{-1} mol^{-1}

Equation _____

Volume _____ cm^3

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(6)

(c) Calculate the concentration, in mol dm^{-3}, of sodium ions in the solution produced in the reaction in **part (b)**.

Concentration _____ mol dm^{-3}

(1)

(d) Sodium reacts with ammonia to form the compound $NaNH_2$ that contains the NH_2^- ion.

Draw the shape of the NH_2^- ion.
Include any lone pairs of electrons that influence the shape.

Predict the bond angle.
Justify your prediction.

Shape

Bond angle _____

Justification _____

_____

(4)

(Total 17 marks)

Q3.

Which species has a shape that is influenced by the presence of one or more lone pairs of electrons around the central atom?

A $AlCl_3$ ⬭

B ClF_3 ⬭

C IF_6^+ ⬭

D PCl_6^- ⬭

(Total 1 mark)

Q4.

This question is about intermolecular forces.

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(a) Give the meaning of the term electronegativity.

_____

_____

_____

(1)

(b) Explain how permanent dipole-dipole forces arise between hydrogen chloride molecules.

_____

_____

_____

_____

_____

_____

(2)

(c) Complete the table by naming the shape of each molecule.

Place a tick (✔) in the final column if the molecule has a permanent dipole.

Molecule	**Name of shape**	**Tick (✔) if molecule has a permanent dipole**
SiH_4		
PH_3		
$BeCl_2$		
CH_3Cl		

(4)

(Total 7 marks)

Q5.

Which species has one or more bond angle(s) of 90°?

A CH_4 ○

B NH_4^+ ○

C ClF_4^- ○

D $AlCl_4^-$ ○

(Total 1 mark)

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Q6.

Which is the most likely bond angle around the oxygen atom in ethanol?

A 104.5° ○

B 109.5° ○

C 120° ○

D 180° ○

(Total 1 mark)

Q7.

This question is about elements in Group 7 of the Periodic Table and their compounds.

(a) Bromine (Br_2), strontium chloride ($SrCl_2$) and iodine monochloride (ICl) all have similar M_r values.

Suggest, with reasons, the order of melting points for these three substances.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(b) Write an equation for the reaction of chlorine with cold water.

State a reason why chlorine is added to drinking water, and suggest a disadvantage of treating water in this way.

Equation

_____

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Reason _____

_____

Disadvantage _____

_____

_____

(3)

(c) Bromine reacts with phosphorus to form phosphorus tribromide.

Write an equation for this reaction and draw the shape of the phosphorus tribromide molecule formed.

Suggest the bond angle in phosphorus tribromide.

Equation

_____

Shape

Bond angle _____

(3)

(d) Phosphorus pentabromide in the solid state consists of PBr_4^+ and Br^- ions.

Draw the shape of the PBr_4^+ ion and suggest its bond angle.

Shape

Bond angle _____

(2)

(Total 14 marks)

Q8.

Which of these species is **not** planar?

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A HCHO ⬭

B CH_3^+ ⬭

C CH_3OH ⬭

D C_2H_4 ⬭

(Total 1 mark)

Q9.

This question is about the element iodine and its compounds.

(a) Iodine is in Group 7 of the Periodic Table.

Complete the electron configuration of an iodine atom.

[Kr] _____

(1)

(b) Part of the structure of an iodine crystal is shown in the diagram.



Use your knowledge of structure and bonding to explain why the melting point of iodine is low (113.5 °C) and why that of hydrogen iodide is very low (–50.8 °C).

(6)

(c) State why iodine does **not** conduct electricity.

_____

_____

_____

(1)

(d) Deduce an equation for the formation of hydrogen iodide from its elements.

_____

(1)

(e) The triiodide ion is formed when an iodine molecule is bonded to an iodide ion.

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What is the formula of ammonium triiodide?

Tick (✔) **one** box.

NH_3I_3 ☐

NH_3I_4 ☐

NH_4I ☐

NH_4I_3 ☐

(1)

(f) Draw the shape of the IF_3 molecule and the shape of the IF_4^- ion.
Include any lone pairs of electrons that influence each shape.

(2)

(g) Deduce the oxidation state of iodine in the following species.

$Ba(IO_3)_2$

_____

$[H_4IO_6]^-$

_____

(2)

(Total 14 marks)

Q10.

(a) Write an equation, including state symbols, for the reaction with enthalpy change equal to the standard enthalpy of formation for $CF_4(g)$.

_____

(1)

(b) Explain why CF_4 has a bond angle of 109.5°.

_____

_____

_____

_____

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(2)

(c) **Table 1** gives some values of standard enthalpies of formation ($\Delta_f H^\ominus$).

Table 1

Substance	$F_2(g)$	$CF_4(g)$	HF(g)
$\Delta_f H^\ominus$ / kJ mol^{-1}	0	−680	−269

The enthalpy change for the following reaction is −2889 kJ mol^{-1}.

$$C_2H_6(g) + 7F_2(g) \longrightarrow 2CF_4(g) + 6HF(g)$$

Use this value and the standard enthalpies of formation in **Table 1** to calculate the standard enthalpy of formation of $C_2H_6(g)$.

Standard enthalpy of formation of $C_2H_6(g)$ = _____ kJ mol^{-1}

(3)

(d) Methane reacts violently with fluorine according to the following equation.

$$CH_4(g) + 4F_2(g) \longrightarrow CF_4(g) + 4HF(g) \quad \Delta H = -1904 \text{ kJ mol}^{-1}$$

Some mean bond enthalpies are given in **Table 2**.

Table 2

Bond	C−H	C−F	H−F
Mean bond enthalpy / kJ mol^{-1}	412	484	562

A student suggested that one reason for the high reactivity of fluorine is a weak F−F bond.

Is the student correct? Justify your answer with a calculation using these data.

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_____

(4)

(Total 10 marks)

Q11.

Which of these species has a trigonal planar structure?

A PH_3 ⬭

B BCl_3 ⬭

C H_3O^+ ⬭

D CH_3^- ⬭

(Total 1 mark)

Q12.

(a) Explain how the electron pair repulsion theory can be used to deduce the shape of, and the bond angle in, PF_3

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(b) State the full electron configuration of a cobalt(II) ion.

_____

(1)

(c) Suggest **one** reason why electron pair repulsion theory **cannot** be used to predict the shape of the $[CoCl_4]^{2-}$ ion.

_____

_____

(1)

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(d) Predict the shape of, and the bond angle in, the complex rhodium ion $[RhCl_4]^{2-}$.

Shape _____

Bond angle _____

(2)

(Total 10 marks)

Q13.

Ammonia reacts with aluminium chloride as shown by the equation:

$$NH_3 + AlCl_3 \longrightarrow H_3NAlCl_3$$

(a) Draw diagrams to illustrate the shapes of NH_3 molecules and of $AlCl_3$ molecules.

Include in your diagrams any lone pairs of electrons that influence the shape.

Indicate the values of the bond angles.

(3)

(b) Name the type of bond formed between N and Al in H_3NAlCl_3 and explain how this bond is formed.

Type of bond _____

Explanation _____

_____

_____

_____

(2)

(c) Explain how the value of the Cl-Al-Cl bond angle in $AlCl_3$ changes, if at all, on formation of the compound H_3NAlCl_3

_____

_____

_____

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_____

(2)

(Total 7 marks)

Q14.

(a) Van der Waals' forces exist between all molecules.

Explain how these forces arise.

_____

_____

_____

_____

_____

(3)

(b) The table shows the boiling points of methanol (CH_3OH) and methanethiol (CH_3SH).

Compound	**Boiling point / °C**
Methanol	65
Methanethiol	6

(i) Explain, in terms of their intermolecular forces, why the boiling points of these compounds are different.

_____

_____

_____

_____

_____

_____

(3)

(ii) Suggest how a mixture of methanol and methanethiol could be separated.

_____

_____

(1)

(c) Suggest why methaneselenol (CH_3SeH) has a higher boiling point than methanethiol (CH_3SH).

_____

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_____

_____

_____

(2)

(d) Sulfur forms many molecular compounds with the halogens.

(i) Draw the shape of an SF_6 and of an SF_4 molecule.
Include any lone pairs that influence the shape.
State the bond angle(s) in SF_6 and in SF_4.
Name the shape of SF_6.

	SF_6	**SF_4**
Shape		
Bond angle(s)		
Name of shape		

(6)

(ii) SCl_2 reacts with NaF to form SF_4 and S_2Cl_2 and one other product.

Write an equation for the reaction.

_____

(2)

(Total 17 marks)

Q15.

This question is about the elements in Period 3 of the Periodic Table.

(a) State the element in Period 3 that has the highest melting point.
Explain your answer.

Element _____

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Explanation _____

_____

_____

_____

_____

(3)

(b) State the element in Period 3 that has the highest first ionisation energy.
Explain your answer.

Element _____

Explanation _____

_____

_____

_____

_____

(3)

(c) Suggest the element in Period 3 that has the highest electronegativity value.

_____

(1)

(d) Chlorine is a Period 3 element.
Chlorine forms the molecules ClF_3 and CCl_2

(i) Use your understanding of electron pair repulsion to draw the shape of ClF_3 and the shape of CCl_2
Include any lone pairs of electrons that influence the shape.

Shape of ClF_3 Shape of CCl_2

(2)

(ii) Name the shape of CCl_2

_____

(1)

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(iii) Write an equation to show the formation of one mole of ClF_3 from its elements.

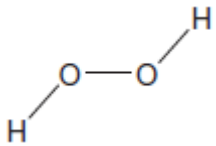
_____

(1)

(Total 11 marks)

Q16.

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)

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

_____

_____

_____

_____

_____

(2)

(Total 7 marks)

Q17.

Thallium is in Group 3 of the Periodic Table.
Thallium reacts with halogens to form many compounds and ions.

(a) Draw the shape of the $TlBr_3^{2-}$ ion and the shape of the $TlCl_4^{3-}$ ion.
Include any lone pairs of electrons that influence the shapes.

Name the shape made by the atoms in $TlBr_3^{2-}$ and suggest a value for the bond angle.

_____

(4)

(b) Thallium(I) bromide (TlBr) is a crystalline solid with a melting point of 480 °C.

Suggest the type of bonding present in thallium(I) bromide and state why the melting point is high.

_____

_____

_____

_____

_____

_____

(3)

(c) Write an equation to show the formation of thallium(I) bromide from its elements.

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_____

(1)

(Total 8 marks)

Q18.

Aluminium and thallium are elements in Group 3 of the Periodic Table.
Both elements form compounds and ions containing chlorine and bromine.

(a) Write an equation for the formation of aluminium chloride from its elements.

_____

(1)

(b) An aluminium chloride molecule reacts with a chloride ion to form the $AlCl_4^-$ ion.

Name the type of bond formed in this reaction. Explain how this type of bond is formed in the $AlCl_4^-$ ion.

Type of bond _____

Explanation _____

_____

_____

(2)

(c) Aluminium chloride has a relative molecular mass of 267 in the gas phase.

Deduce the formula of the aluminium compound that has a relative molecular mass of 267

_____

(1)

(d) Deduce the name or formula of a compound that has the same number of atoms, the same number of electrons and the same shape as the $AlCl_4^-$ ion.

_____

(1)

(e) Draw and name the shape of the $TlBr_5^{2-}$ ion.

Shape of the $TlBr_5^{2-}$ ion.

Name of shape _____

(2)

(f) (i) Draw the shape of the $TlCl_2^+$ ion.

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(1)

(ii) Explain why the $TlCl_2^+$ ion has the shape that you have drawn in part (f)(i).

_____

_____

_____

(1)

(g) Which **one** of the first, second or third ionisations of thallium produces an ion with the electron configuration [Xe] $5d^{10}6s^1$?

Tick (✓) one box.

First ☐

Second ☐

Third ☐

(1)
(Total 10 marks)

Q19.

Chlorine can form molecules and ions that contain only chlorine, or that contain chlorine combined with another element.

(a) Use your understanding of the electron pair repulsion theory to draw the shape of the $AsCl_3$ molecule and the shape of the Cl_3^+ ion.
Include any lone pairs of electrons that influence the shape.

Name the shape made by the atoms in the $AsCl_3$ molecule and in the Cl_3^+ ion.

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_____

_____

(4)

(b) Explain why the $AsCl_4^+$ ion has a bond angle of 109.5°.

_____

_____

_____

_____

(2)

(Total 6 marks)

Q20.

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)

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

_____

_____

_____

(1)

(Total 5 marks)

Q21.

(a) Boron trichloride (BCl_3) can be prepared as shown by the following equation.

$$B_2O_3(s) + 3C(s) + 3Cl_2(g) \longrightarrow 2BCl_3(g) + 3CO(g)$$

A sample of boron oxide (B_2O_3) was reacted completely with carbon and chlorine. The two gases produced occupied a total volume of 5000 cm^3 at a pressure of 100 kPa and a temperature of 298 K.

Calculate the mass of boron oxide that reacted.
Give your answer to 3 significant figures.

(The gas constant R = 8.31 J K^{-1} mol^{-1})

_____

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(b) Boron trichloride can also be prepared from its elements.

Write an equation for this reaction.
Explain why boron trichloride has a trigonal planar shape with equal bond angles.

_____

_____

_____

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_____

(3)

(c) (i) Boron trichloride is easily hydrolysed to form two different acids as shown in the following equation.

$$BCl_3(g) + 3H_2O(l) \longrightarrow H_3BO_3(aq) + 3HCl(aq)$$

Calculate the concentration, in mol dm^{-3}, of hydrochloric acid produced when 43.2 g of boron trichloride are added to water to form 500 cm^3 of solution.
Give your answer to 3 significant figures.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(ii) Boric acid (H_3BO_3) can react with sodium hydroxide to form sodium borate and water.
Write an equation for this reaction.

_____

(1)

(d) Boron trichloride can be reduced by using hydrogen to form pure boron.

$$BCl_3(g) + 1\frac{1}{2} H_2(g) \longrightarrow B(s) + 3HCl(g)$$

Calculate the percentage atom economy for the formation of boron in this reaction.

Apart from changing the reaction conditions, suggest **one** way a company producing pure boron could increase its profits from this reaction.

_____

_____

_____

_____

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_____

(3)

(e) A different compound of boron and chlorine has a relative molecular mass of 163.6 and contains 13.2% of boron by mass.

Calculate the molecular formula of this compound.
Show your working.

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 20 marks)

Q22.

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)

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(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.

_____

_____

_____

_____

_____

(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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(2)
(Total 15 marks)

Q23.

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

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

_____

_____

_____

(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 NHF_2

_____

(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.

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Name of type of bond _____

How bond is formed _____

_____

_____

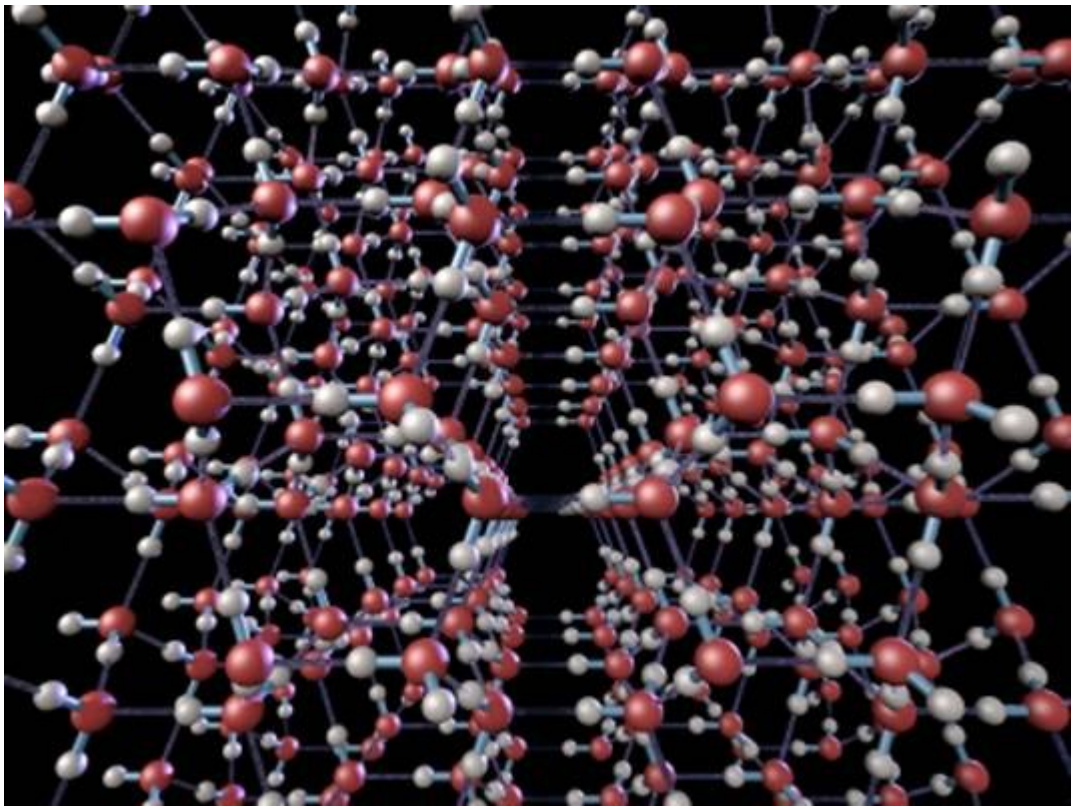
(2)

(Total 10 marks)

Q24.

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.

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	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.

_____

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(1)

(Total 9 marks)

Q25.

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

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_____

(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)

Q26.

A molecule of ClF_3 reacts with a molecule of AsF_5 as shown in the following equation.

$$ClF_3 + AsF_5 \rightarrow ClF_2^+ + AsF_6^-$$

Use your understanding of electron pair repulsion to draw the shape of the AsF_5 molecule and the shape of the ClF_2^+ ion. Include any lone pairs of electrons.

Name the shape made by the atoms in the AsF_5 molecule and in the ClF_2^+ ion.

Predict the bond angle in the ClF_2^+ ion.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(Total 5 marks)

Q27.

(a) Complete the electronic configuration for the sodium ion, Na^+
$1s^2$ _____

(1)

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(b) (i) Write an equation, including state symbols, to represent the process for which the energy change is the second ionisation energy of sodium.

_____

(2)

(ii) Explain why the second ionisation energy of sodium is greater than the second ionisation energy of magnesium.

_____

_____

_____

_____

(3)

(iii) An element **X** in Period 3 of the Periodic Table has the following successive ionisation energies.

	First	Second	Third	Fourth
Ionisation energies / kJ mol^{-1}	577	1820	2740	11600

Deduce the identity of element **X**.

_____

(1)

(c) State and explain the trend in atomic radius of the Period 3 elements from sodium to chlorine.

Trend _____

Explanation _____

_____

_____

(3)

(d) Explain why sodium has a lower melting point than magnesium.

_____

_____

_____

_____

(3)

(e) Sodium reacts with ammonia to form the compound $NaNH_2$ which contains the NH_2^- ion. Draw the shape of the NH_2^- ion, including any lone pairs of electrons.

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Name the shape made by the three atoms in the NH_2^- ion.

Shape of NH_2^-

Name of shape _____

(2)

(f) In terms of its electronic configuration, give **one** reason why neon does not form compounds with sodium.

_____

(1)

(Total 16 marks)

Q28.

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)

Q29.

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(a) Describe the bonding in, and the structure of, sodium chloride and ice. In each case draw a diagram showing how each structure can be represented. Explain, by reference to the types of bonding present, why the melting point of these two compounds is very different.

(12)

(b) Explain how the concept of bonding and non-bonding electron pairs can be used to predict the shape of, and bond angles in, a molecule of sulfur tetrafluoride, SF_4. Illustrate your answer with a diagram of the structure.

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(8)

(Total 20 marks)

Q30.

The equation below shows the reaction between boron trifluoride and a fluoride ion.

$$BF_3 + F^- \rightarrow BF_4^-$$

(i) Draw diagrams to show the shape of the BF_3 molecule and the shape of the BF_4^- ion. In each case, name the shape. Account for the shape of the BF_4^- ion and state the bond angle present.

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_____

_____

_____

_____

_____

_____

(6)

(ii) In terms of the electrons involved, explain how the bond between the BF_3 molecule and the F^- ion is formed. Name the type of bond formed in this reaction.

_____

_____

_____

_____

_____

_____

(3)

(Total 9 marks)

Q31.

In which one of the following species is the shape influenced by the presence of one or more lone pairs of electrons?

A NH_2^-

B NH_4^+

C $[CH_3NH_3]^+$

D $[Co(NH_3)_6]^{2+}$

(Total 1 mark)

Q32.

(a) Complete the following table.

	Relative mass	Relative charge
Neutron		
Electron		

(2)

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(b) An atom has twice as many protons as, and four more neutrons than, an atom of ^{9}Be. Deduce the symbol, including the mass number, of this atom.

_____

(2)

(c) Draw the shape of a molecule of $BeCl_2$ and the shape of a molecule of Cl_2O. Show any lone pairs of electrons on the central atom. Name the shape of each molecule.

$BeCl_2$ *Cl_2O*

Name of shape _____ *Name of shape* _____

(4)

(d) The equation for the reaction between magnesium hydroxide and hydrochloric acid is shown below.

$$Mg(OH)_2(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + 2H_2O(l)$$

Calculate the volume, in cm^3, of 1.00 mol dm^{-3} hydrochloric acid required to react completely with 1.00 g of magnesium hydroxide.

_____

_____

_____

_____

_____

_____

(4)

(Total 12 marks)

Q33.

Phosphorus and nitrogen are in Group V of the Periodic Table and both elements form hydrides. Phosphine, PH_3, reacts to form phosphonium ions, PH_4^+, in a similar way to that by which ammonia, NH_3, forms ammonium ions, NH_4^+

(a) Give the name of the type of bond formed when phosphine reacts with an H^+ ion. Explain how this bond is formed.

Type of bond _____

Explanation _____

_____

_____

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(3)

(b) Draw the shapes, including any lone pairs of electrons, of a phosphine molecule and of a phosphonium ion.
Give the name of the shape of the phosphine molecule and state the bond angle found in the phosphonium ion.

PH_3 PH_4^+

Shape of PH_3 _____ *Bond angle in PH_4^+* _____

(4)

(Total 7 marks)

Q34.

Which one of the following molecules is **not** planar?

A BF_3

B NCl_3

C C_2H_4

D HCHO

(Total 1 mark)

Q35.

(a) Ammonia, NH_3, reacts with sodium to form sodium amide, $NaNH_2$, and hydrogen.

(i) Write an equation for the reaction between ammonia and sodium.

_____

(ii) Draw the shape of an ammonia molecule and that of an amide ion, NH_2^-

In each case show any lone pairs of electrons.

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NH_3 NH_2^-

(iii) State the bond angle found in an ammonia molecule.

_____

(iv) Explain why the bond angle in an amide ion is smaller than that in an ammonia molecule.

_____

_____

_____

_____

(6)

(b) A salt, **X**, contains 16.2% by mass of magnesium, 18.9% by mass of nitrogen and 64.9% by mass of oxygen.

(i) State what is meant by the term *empirical formula*.

_____

_____

(ii) Determine the empirical formula of **X**.

_____

_____

_____

_____

(3)

(Total 9 marks)

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Q1.

This question is about sodium and some of its compounds.

(a) Use your knowledge of structure and bonding to explain why sodium bromide has a melting point that is higher than that of sodium, and higher than that of sodium iodide.

(6)

(b) When 250 mg of sodium were added to 500 cm^3 of water at 25 °C a gas was produced.

Give an equation for the reaction that occurs.
Calculate the volume, in cm^3, of the gas formed at 101 kPa

The gas constant, R = 8.31 J K^{-1} mol^{-1}

Equation _____

Volume _____ cm^3

(6)

(c) Calculate the concentration, in mol dm^{-3}, of sodium ions in the solution produced in the reaction in **part (b)**.

Concentration _____ mol dm^{-3}

(1)

(d) Sodium reacts with ammonia to form the compound $NaNH_2$ that contains the NH_2^- ion.

Draw the shape of the NH_2^- ion.
Include any lone pairs of electrons that influence the shape.

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Predict the bond angle.
Justify your prediction.

Shape

Bond angle _____

Justification _____

_____

(4)

(Total 17 marks)

Q2.

(a) Nickel is a metal with a high melting point.

(i) State the block in the Periodic Table that contains nickel.

_____

(1)

(ii) Explain, in terms of its structure and bonding, why nickel has a high melting point.

_____

_____

_____

_____

_____

(2)

(iii) Draw a labelled diagram to show the arrangement of particles in a crystal of nickel.
In your answer, include at least six particles of each type.

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(2)

(iv) Explain why nickel is ductile (can be stretched into wires).

_____

_____

_____

(1)

(b) Nickel forms the compound nickel(II) chloride ($NiCl_2$).

(i) Give the full electron configuration of the Ni^{2+} ion.

_____

(1)

(ii) Balance the following equation to show how anhydrous nickel(II) chloride can be obtained from the hydrated salt using $SOCl_2$
Identify **one** substance that could react with both gaseous products.

.....$NiCl_2.6H_2O(s)$ + ... $SOCl_2(g)$ ⟶ .....$NiCl_2(s)$ + ...$SO_2(g)$ + ...$HCl(g)$

Substance _____

(2)

(Total 9 marks)

Q3.

This question is about some Period 3 elements and their oxides.

(a) Describe what you would observe when, in the absence of air, magnesium is heated strongly with water vapour at temperatures above 373 K.
Write an equation for the reaction that occurs.

Observations _____

_____

_____

_____

_____

Equation _____

(3)

(b) Explain why magnesium has a higher melting point than sodium.

_____

_____

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_____

_____

(2)

(c) State the structure of, and bonding in, silicon dioxide.
Other than a high melting point, give **two** physical properties of silicon dioxide that are characteristic of its structure and bonding.

Structure _____

Bonding _____

Physical property 1 _____

Physical property 2 _____

(4)

(d) Give the formula of the species in a sample of solid phosphorus(V) oxide.
State the structure of, and describe fully the bonding in, this oxide.

Formula _____

Structure _____

Bonding _____

_____

_____

_____

(4)

(e) Sulfur(IV) oxide reacts with water to form a solution containing ions.

Write an equation for this reaction.

_____

(1)

(f) Write an equation for the reaction between the acidic oxide, phosphorus(V) oxide, and the basic oxide, magnesium oxide.

_____

(1)

(Total 15 marks)

Q4.

Group 2 metals and their compounds are used commercially in a variety of processes.

(a) Strontium is extracted from strontium oxide (SrO) by heating a mixture of powdered strontium oxide and powdered aluminium.

Consider these standard enthalpies of formation.

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	SrO(s)	$Al_2O_3(s)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	– 590	– 1669

$$3SrO(s) + 2Al(s) \longrightarrow 3Sr(s) + Al_2O_3(s)$$

Use these data and the equation to calculate the standard enthalpy change for this extraction of strontium.

The use of powdered strontium oxide and powdered aluminium increases the surface area of the reactants.
Suggest **one** reason why this increases the reaction rate.

Suggest **one** major reason why this method of extracting strontium is expensive.

(5)

(b) Explain why calcium has a higher melting point than strontium.

(2)

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(c) Magnesium is used in fireworks. It reacts rapidly with oxygen, burning with a bright white light. Magnesium reacts slowly with cold water.

Write an equation for the reaction of magnesium with oxygen.

Write an equation for the reaction of magnesium with cold water.

Give a medical use for the magnesium compound formed in the reaction of magnesium with cold water.

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 10 marks)

Q5.

Group 2 elements and their compounds have a wide range of uses.

(a) For parts (a)(i) to (a)(iii), draw a ring around the correct answer to complete each sentence.

(i) From $Mg(OH)_2$ to $Ba(OH)_2$, the solubility in water

decreases.

increases.

stays the same.

(1)

(ii) From Mg to Ba, the first ionisation energy

decreases.

increases.

stays the same.

(1)

(iii) From Mg to Ba, the atomic radius

decreases.

increases.

stays the same.

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(1)

(b) Explain why calcium has a higher melting point than strontium.

_____

_____

_____

_____

_____

(2)

(c) Acidified barium chloride solution is used as a reagent to test for sulfate ions.

(i) State why sulfuric acid should **not** be used to acidify the barium chloride.

_____

_____

_____

(1)

(ii) Write the **simplest ionic** equation for the reaction that occurs when acidified barium chloride solution is added to a solution containing sulfate ions.

_____

(1)

(Total 7 marks)

Q6.

There are several types of crystal structure and bonding shown by elements and compounds.

(a) (i) Name the type of bonding in the element sodium.

_____

(1)

(ii) Use your knowledge of structure and bonding to draw a diagram that shows how the particles are arranged in a crystal of sodium.
You should identify the particles and show a minimum of six particles in a two-dimensional diagram.

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(2)

(b) Sodium reacts with chlorine to form sodium chloride.

(i) Name the type of bonding in sodium chloride.

_____

(1)

(ii) Explain why the melting point of sodium chloride is high.

_____

_____

_____

_____

(2)

(c) The table below shows the melting points of some sodium halides.

	NaCl	NaBr	NaI
Melting point /K	1074	1020	920

Suggest why the melting point of sodium iodide is lower than the melting point of sodium bromide.

_____

_____

(1)

(Total 7 marks)

Q7.

Group 2 metals and their compounds are used commercially in a variety of processes and applications.

(a) State a use of magnesium hydroxide in medicine.

_____

(1)

(b) Calcium carbonate is an insoluble solid that can be used in a reaction to lower the acidity of the water in a lake.

Explain why the rate of this reaction decreases when the temperature of the water in the lake falls.

_____

_____

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_____

_____

_____

(3)

(c) Strontium metal is used in the manufacture of alloys.

(i) Explain why strontium has a higher melting point than barium.

_____

_____

_____

_____

(2)

(ii) Write an equation for the reaction of strontium with water.

_____

(1)

(d) Magnesium can be used in the extraction of titanium.

(i) Write an equation for the reaction of magnesium with titanium(IV) chloride.

_____

(1)

(ii) The excess of magnesium used in this extraction can be removed by reacting it with dilute sulfuric acid to form magnesium sulfate.

Use your knowledge of Group 2 sulfates to explain why the magnesium sulfate formed is easy to separate from the titanium.

_____

_____

_____

(1)

(Total 9 marks)

Q8.

(a) (i) Define the term *relative atomic mass* (A_r) of an element.

_____

_____

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_____

_____

(2)

(ii) A sample of the metal silver has the relative atomic mass of 107.9 and exists as two isotopes. In this sample, 54.0% of the silver atoms are one isotope with a relative mass of 107.1

Calculate the relative mass of the other silver isotope.

State why the isotopes of silver have identical chemical properties.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(b) The isotopes of silver, when vaporised, can be separated in a mass spectrometer.

Name the **three** processes that occur in a mass spectrometer before the vaporised isotopes can be detected.

State how each process is achieved.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

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(6)

(c) State the type of bonding involved in silver.

Draw a diagram to show how the particles are arranged in a silver lattice and show the charges on the particles.

(3)

(d) Silver reacts with fluorine to form silver fluoride (AgF).

Silver fluoride has a high melting point and has a structure similar to that of sodium chloride.

State the type of bonding involved in silver fluoride.

Draw a diagram to show how the particles are arranged in a silver fluoride lattice and show the charges on the particles.

Explain why the melting point of silver fluoride is high.

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_____

_____

(5)

(Total 20 marks)

Q9.

(a) When aluminium is added to an aqueous solution of copper(II) chloride, $CuCl_2$, copper metal and aluminium chloride, $AlCl_3$, are formed. Write an equation to represent this reaction.

_____

(1)

(b) (i) State the general trend in the first ionisation energy of the Period 3 elements from Na to Ar.

_____

(ii) State how, and explain why, the first ionisation energy of aluminium does not follow this general trend.

_____

_____

_____

_____

(4)

(c) Give the equation, including state symbols, for the process which represents the second ionisation energy of aluminium.

_____

(1)

(d) State and explain the trend in the melting points of the Period 3 metals Na, Mg and Al.

Trend _____

Explanation _____

_____

_____

(3)

(Total 9 marks)

Q10.

(a) (i) Describe the bonding in a metal.

_____

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_____

_____

(ii) Explain why magnesium has a higher melting point than sodium.

_____

_____

_____

(4)

(b) Why do diamond and graphite both have high melting points?

_____

_____

_____

_____

(3)

(c) Why is graphite a good conductor of electricity?

_____

(1)

(d) Why is graphite soft?

_____

_____

_____

(2)

(Total 10 marks)

Q11.

Which one of the following does **not** contain any delocalised electrons?

A poly(propene)

B benzene

C graphite

D sodium

(Total 1 mark)

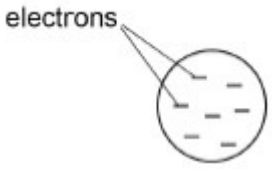
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Q1.

This question is about atomic structure.

In the nineteenth century JJ Thomson discovered the electron. He suggested that negative electrons were found throughout an atom like 'plums in a pudding of positive charge'.

The diagram shows an atom of element **R** using the 'plum pudding' model.
An atom of **R** contains seven electrons.



(a) State **two** differences between the 'plum pudding' model and the model of atomic structure used today.

1. _____

_____

2. _____

_____

(2)

(b) Deduce the full electron configuration of an atom of element **R**.

_____

(1)

(c) Identify **R** and deduce the formula of the compound formed when **R** reacts with the Group 2 metal in the same period as **R**.

_____

(1)

(Total 4 marks)

Q2.

This question is about sodium and some of its compounds.

(a) Use your knowledge of structure and bonding to explain why sodium bromide has a melting point that is higher than that of sodium, and higher than that of sodium iodide.

(6)

(b) When 250 mg of sodium were added to 500 cm^3 of water at 25 °C a gas was produced.

Give an equation for the reaction that occurs.
Calculate the volume, in cm^3, of the gas formed at 101 kPa

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The gas constant, R = 8.31 J K^{-1} mol^{-1}

Equation _____

Volume _____ cm^3

(6)

(c) Calculate the concentration, in mol dm^{-3}, of sodium ions in the solution produced in the reaction in **part (b)**.

Concentration _____ mol dm^{-3}

(1)

(d) Sodium reacts with ammonia to form the compound $NaNH_2$ that contains the NH_2^- ion.

Draw the shape of the NH_2^- ion.
Include any lone pairs of electrons that influence the shape.

Predict the bond angle.
Justify your prediction.

Shape

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Bond angle _____

Justification _____

_____

(4)

(Total 17 marks)

Q3.

Element Q forms a sulfate with formula QSO_4

Which of these could represent the electronic configuration of an atom of Q?

A $[Ne]3s^1$ ⬭

B $[Ne]3s^2$ ⬭

C $[Ne]3s^23p^1$ ⬭

D $[Ne]3s^13p^2$ ⬭

(Total 1 mark)

Q4.

What is the formula of calcium nitrate(V)?

A $CaNO_3$ ⬭

B $Ca(NO_3)_2$ ⬭

C Ca_2NO_2 ⬭

D $Ca(NO_2)_2$ ⬭

(Total 1 mark)

Q5.

Some airbags in cars contain sodium azide (NaN_3).

(a) Sodium azide is made by reacting dinitrogen monoxide gas with sodium amide ($NaNH_2$) as shown by the equation.

$$2NaNH_2 + N_2O \longrightarrow NaN_3 + NaOH + NH_3$$

Calculate the mass of sodium amide needed to obtain 550 g of sodium azide, assuming there is a 95.0% yield of sodium azide.
Give your answer to 3 significant figures.

_____

_____

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(5)

(b) If a car is involved in a serious collision, the sodium azide decomposes to form sodium and nitrogen as shown in the equation.

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

The nitrogen produced then inflates the airbag to a volume of 7.50×10^{-2} m^3 at a pressure of 150 kPa and temperature of 35 °C.

Calculate the minimum mass of sodium azide that must decompose.
(The gas constant $R = 8.31$ J K^{-1} mol^{-1})

(6)

(c) Sodium azide is toxic. It can be destroyed by reaction with an acidified solution of nitrous acid (HNO_2) as shown in the equation.

$$2NaN_3 + 2HNO_2 + 2HCl \longrightarrow 3N_2 + 2NO + 2NaCl + 2H_2O$$

(i) A 500 cm^3 volume of the nitrous acid solution was used to destroy completely 150 g of the sodium azide.

Calculate the concentration, in mol dm^{-3}, of the nitrous acid used.

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_____

_____

_____

_____

(3)

(ii) Nitrous acid decomposes on heating.

Balance the following equation for this reaction.

$$.....HNO_2 \longrightarrow .....HNO_3 + ...NO + ...H_2O$$

(1)

(d) Sodium azide has a high melting point.

Predict the type of bonding in a crystal of sodium azide.
Suggest why its melting point is high.

Type of bonding _____

Reason for high melting point _____

_____

_____

_____

_____

(3)

(e) The azide ion has the formula N_3^-

(i) The azide ion can be represented as $N \equiv N - N^-$

One of these bonds is a co−ordinate bond.

On the following diagram, draw an arrowhead on one of the bonds to represent the direction of donation of the lone pair in the co−ordinate bond.

$$N \equiv N - N^-$$

(1)

(ii) Give the formula of a molecule that has the same number of electrons as the azide ion.

_____

(1)

(iii) Which is the correct formula of magnesium azide?

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Tick (✓) **one** box.

Mg_3N ☐

MgN ☐

MgN_6 ☐

Mg_3N_2 ☐

(1)

(Total 21 marks)

Q6.

Zinc forms many different salts including zinc sulfate, zinc chloride and zinc fluoride.

(a) People who have a zinc deficiency can take hydrated zinc sulfate ($ZnSO_4.xH_2O$) as a dietary supplement.

A student heated 4.38 g of hydrated zinc sulfate and obtained 2.46 g of anhydrous zinc sulfate.

Use these data to calculate the value of the integer *x* in $ZnSO_4.xH_2O$
Show your working.

_____

_____

_____

_____

_____

_____

_____

(3)

(b) Zinc chloride can be prepared in the laboratory by the reaction between zinc oxide and hydrochloric acid.
The equation for the reaction is

$$ZnO + 2HCl \longrightarrow ZnCl_2 + H_2O$$

A 0.0830 mol sample of pure zinc oxide was added to 100 cm^3 of 1.20 mol dm^{-3} hydrochloric acid.

Calculate the maximum mass of anhydrous zinc chloride that could be obtained from the products of this reaction.

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(4)

(c) Zinc chloride can also be prepared in the laboratory by the reaction between zinc and hydrogen chloride gas.

$$Zn + 2HCl \longrightarrow ZnCl_2 + H_2$$

An impure sample of zinc powder with a mass of 5.68 g was reacted with hydrogen chloride gas until the reaction was complete. The zinc chloride produced had a mass of 10.7 g.

Calculate the percentage purity of the zinc metal.
Give your answer to 3 significant figures.

(4)

(d) Predict the type of crystal structure in solid zinc fluoride and explain why its melting point is high.

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_____

(3)

(Total 14 marks)

Q7.

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.

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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)

Q8.

(a) (i) Define the term *relative atomic mass* (A_r) of an element.

_____

_____

_____

_____

(2)

(ii) A sample of the metal silver has the relative atomic mass of 107.9 and exists as two isotopes. In this sample, 54.0% of the silver atoms are one isotope with a relative mass of 107.1

Calculate the relative mass of the other silver isotope.

State why the isotopes of silver have identical chemical properties.

_____

_____

_____

_____

_____

_____

_____

_____

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(4)

(b) The isotopes of silver, when vaporised, can be separated in a mass spectrometer.

Name the **three** processes that occur in a mass spectrometer before the vaporised isotopes can be detected.

State how each process is achieved.

(6)

(c) State the type of bonding involved in silver.

Draw a diagram to show how the particles are arranged in a silver lattice and show the charges on the particles.

(3)

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(d) Silver reacts with fluorine to form silver fluoride (AgF).

Silver fluoride has a high melting point and has a structure similar to that of sodium chloride.

State the type of bonding involved in silver fluoride.

Draw a diagram to show how the particles are arranged in a silver fluoride lattice and show the charges on the particles.

Explain why the melting point of silver fluoride is high.

_____

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_____

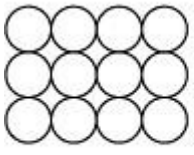
(5)

(Total 20 marks)

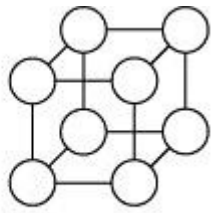
Q9.

At room temperature, both sodium metal and sodium chloride are crystalline solids which contain ions.

(a) On the diagrams for sodium metal and sodium chloride below, mark the charge for each ion.



Sodium metal



Sodium chloride

(2)

(b) (i) Explain how the ions are held together in solid sodium metal.

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_____

_____

(ii) Explain how the ions are held together in solid sodium chloride.

_____

_____

(iii) The melting point of sodium chloride is much higher than that of sodium metal. What can be deduced from this information?

_____

_____

(3)

(c) Compare the electrical conductivity of solid sodium metal with that of solid sodium chloride. Explain your answer.

Comparison _____

_____

Explanation _____

_____

_____

(3)

(d) Explain why sodium metal is malleable (can be hammered into shape).

_____

_____

(1)

(e) Sodium chlorate(V), $NaClO_3$, contains 21.6% by mass of sodium, 33.3% by mass of chlorine and 45.1% by mass of oxygen.

(i) Use the above data to show that the empirical formula of sodium chlorate(V) is $NaClO_3$

_____

_____

_____

_____

_____

(ii) Sodium chlorate(V) may be prepared by passing chlorine into hot aqueous sodium hydroxide. Balance the equation for this reaction below.

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..... Cl_2 + ... NaOH → ..... NaCl + $NaClO_3$ + $3H_2O$

(3)

(Total 12 marks)

Q10.

(a) Complete the following table.

Particle	Relative charge	Relative mass
Proton		
Neutron		
Electron		

(3)

(b) An atom of element **Z** has two more protons and two more neutrons than an atom of $^{34}_{16}S$. Give the symbol, including mass number and atomic number, for this atom of **Z**.

_____

(2)

(c) Complete the electronic configurations for the sulphur atom, S, and the sulphide ion, S^{2-}.

S $1s^2$ _____

S^{2-} $1s^2$ _____

(2)

(d) State the block in the Periodic Table in which sulphur is placed and explain your answer.

Block _____

Explanation _____

(2)

(e) Sodium sulphide, Na_2S, is a high melting point solid which conducts electricity when molten. Carbon disulphide, CS_2, is a liquid which does not conduct electricity.

(i) Deduce the type of bonding present in Na_2S and that present in CS_2

Bonding in Na_2S _____

Bonding in CS_2 _____

(ii) By reference to all the atoms involved explain, in terms of electrons, how Na_2S is formed from its atoms.

_____

_____

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(iii) Draw a diagram, including all the outer electrons, to represent the bonding present in CS_2

(iv) When heated with steam, CS_2 reacts to form hydrogen sulphide, H_2S, and carbon dioxide.
Write an equation for this reaction.

_____

(7)

(Total 16 narks)

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Q1.

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.

_____

_____

_____

_____

(3)

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

_____

_____

_____

(2)

(Total 9 marks)

Q2.

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*.

_____

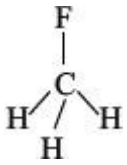
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_____

_____

(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.

_____

_____

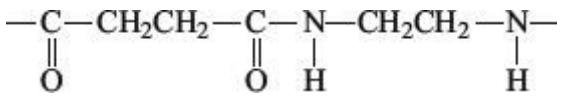
(3)

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(Total 11 marks)

Q3.

(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, $HOCH_2COOH$

_____

_____

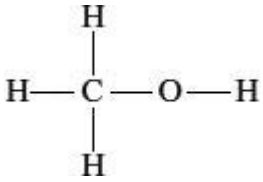
_____

(2)

(Total 5 marks)

Q4.

(a) Methanol has the structure



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

_____

_____

_____

(2)

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(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)

Q5.

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)

Q6.

(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.

_____

_____

_____

_____

_____

_____

_____

_____

_____

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_____

_____

_____

_____

_____

(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)

Q7.

(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)

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(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)

Q8.

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 $CH_3COOH(l)$

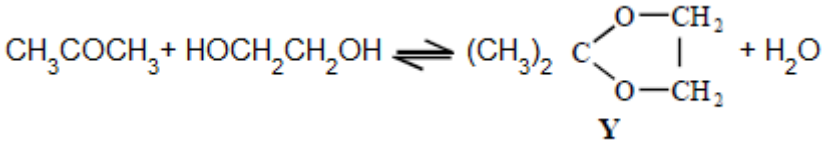
D $CH_3OH(l)$

(Total 1 mark)

Q9.

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

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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)

Q10.

(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.

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_____

(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)

Q11.

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.

_____

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(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)

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Q12.

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)

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Q1.

This question is about compounds containing fluorine.

(a) Draw the shape of a molecule of krypton difluoride (KrF_2).
Include in your answer any lone pairs of electrons that influence the shape.
Name the shape produced by the atoms in a KrF_2 molecule and suggest a bond angle.

Name of shape _____

Bond angle _____

(3)

(b) There are two lone pairs of electrons on the oxygen atom in a molecule of oxygen difluoride (OF_2).

Explain how the lone pairs of electrons on the oxygen atom influence the bond angle in oxygen difluoride.

_____

_____

_____

_____

_____

_____

_____

(2)

(c) Silicon tetrafluoride (SiF_4) is a tetrahedral molecule.

Deduce the type of intermolecular forces in SiF_4
Explain how this type of intermolecular force arises and why no other type of intermolecular force exists in a sample of SiF_4

Intermolecular forces in SiF_4 _____

Explanation _____

_____

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_____

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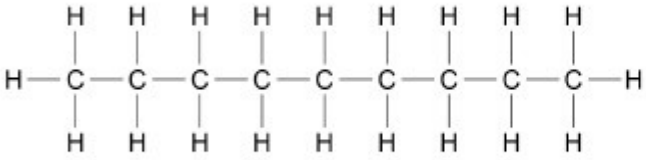
(3)

(Total 8 marks)

Q2.

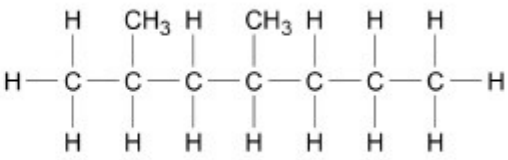
The alkanes nonane and 2,4-dimethylheptane are structural isomers with the molecular formula C_9H_{20}
They are found in crude oil and can be separated by fractional distillation.
Both can be used in fuels or cracked to form other products.

nonane



boiling point 151 °C

2,4-dimethylheptane



boiling point 134 °C

(a) State the general formula of an alkane containing n carbon atoms.
Deduce an expression for the relative molecular mass (M_r) of an alkane in terms of n.

General formula _____

Expression _____

(2)

(b) Explain why nonane has a higher boiling point than 2,4-dimethylheptane.

_____

_____

_____

_____

_____

_____

(2)

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(c) Give an equation for the complete combustion of nonane.

_____

(1)

(d) Nonane is often found in fuel for jet engines. Combustion in jet engines produces pollutants including nitrogen monoxide (NO).

Explain how this nitrogen monoxide is formed.

_____

_____

_____

_____

_____

(2)

(e) Nonane can be cracked to form large quantities of propene.

Name the type of cracking used.

_____

(1)

(f) The main use of propene, formed from cracking, is to make poly(propene).

Draw the repeating unit of poly(propene).

(1)

(Total 9 marks)

Q3.

Which compound has the highest boiling point?

A butanal ⬭

B butan-2-ol ⬭

C but-2-ene ⬭

D 1-fluorobutane ⬭

(Total 1 mark)

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Q4.

The oxidation of propan-1-ol can form propanal and propanoic acid.
The boiling points of these compounds are shown in the table.

Compound	Boiling point / °C
propan-1-ol	97
propanal	49
propanoic acid	141

In a preparation of propanal, propan-1-ol is added dropwise to the oxidising agent and the aldehyde is separated from the reaction mixture by distillation.

(a) Explain, with reference to intermolecular forces, why distillation allows propanal to be separated from the other organic compounds in this reaction mixture.

(3)

(b) Give **two** ways of maximising the yield of propanal obtained by distillation of the reaction mixture.

1. _____

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_____

_____

2. _____

_____

_____

_____

_____

_____

(2)

(c) Describe how you would carry out a simple test-tube reaction to confirm that the sample of propanal obtained by distillation does **not** contain any propanoic acid.

_____

_____

_____

_____

_____

_____

(2)

(d) A student carried out an experiment to determine the enthalpy of combustion of ethanol.
Combustion of 457 mg of ethanol increased the temperature of 150 g of water from 25.1 °C to 40.2 °C

Calculate a value, in kJ mol^{-1}, for the enthalpy of combustion of ethanol in this experiment.
Give your answer to the appropriate number of significant figures.

(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

Enthalpy of combustion _____ kJ mol^{-1}

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(3)

(e) A mixture of isomeric alkenes is produced when pentan-2-ol is dehydrated in the presence of hot concentrated sulfuric acid. Pent-1-ene is one of the isomers produced.

Name and outline a mechanism for the reaction producing pent-1-ene.

Name of mechanism _____

Mechanism

(4)

(f) A pair of stereoisomers is also formed in the reaction in **part (e)**.

Name the less polar stereoisomer formed.
Explain how this type of stereoisomerism arises.

Name _____

Explanation _____

_____

_____

_____

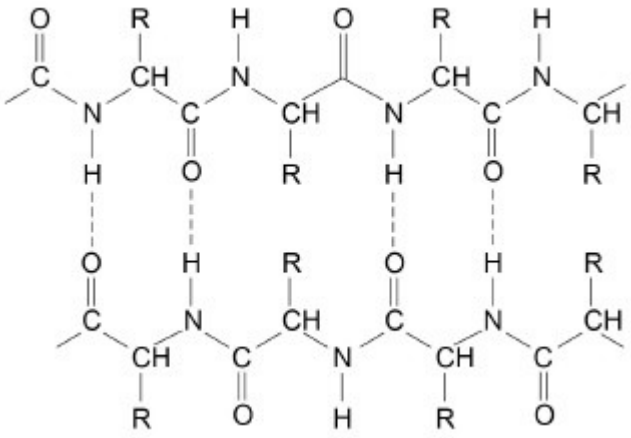
(2)

(Total 16 marks)

Q5.

Use the Data Booklet to help you answer this question about amino acids.
The diagram shows parts of two polypeptide chains in a beta-pleated sheet of a protein.

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(a) The polypeptide chains are held together by hydrogen bonding as shown in the diagram.

Explain how these hydrogen bonds form.

_____

_____

_____

_____

_____

(2)

(b) A different type of bond can form between two polypeptide chains when the chains each contain the amino acid cysteine.

Complete the structure to show the bond that forms between the side chains of two cysteine molecules.



(1)

(c) The type of bond in **part (b)** between two polypeptide chains influences the three-dimensional structure of the protein.

Name this type of protein structure.

_____

(1)

(d) Draw the structure of the zwitterion of a dipeptide formed by alanine and serine.

(2)

(Total 6 marks)

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Q6.

This question is about intermolecular forces.

(a) Give the meaning of the term electronegativity.

_____

_____

_____

(1)

(b) Explain how permanent dipole-dipole forces arise between hydrogen chloride molecules.

_____

_____

_____

_____

_____

_____

(2)

(c) Complete the table by naming the shape of each molecule.

Place a tick (✔) in the final column if the molecule has a permanent dipole.

Molecule	**Name of shape**	**Tick (✔) if molecule has a permanent dipole**
SiH_4		
PH_3		
$BeCl_2$		
CH_3Cl		

(4)

(Total 7 marks)

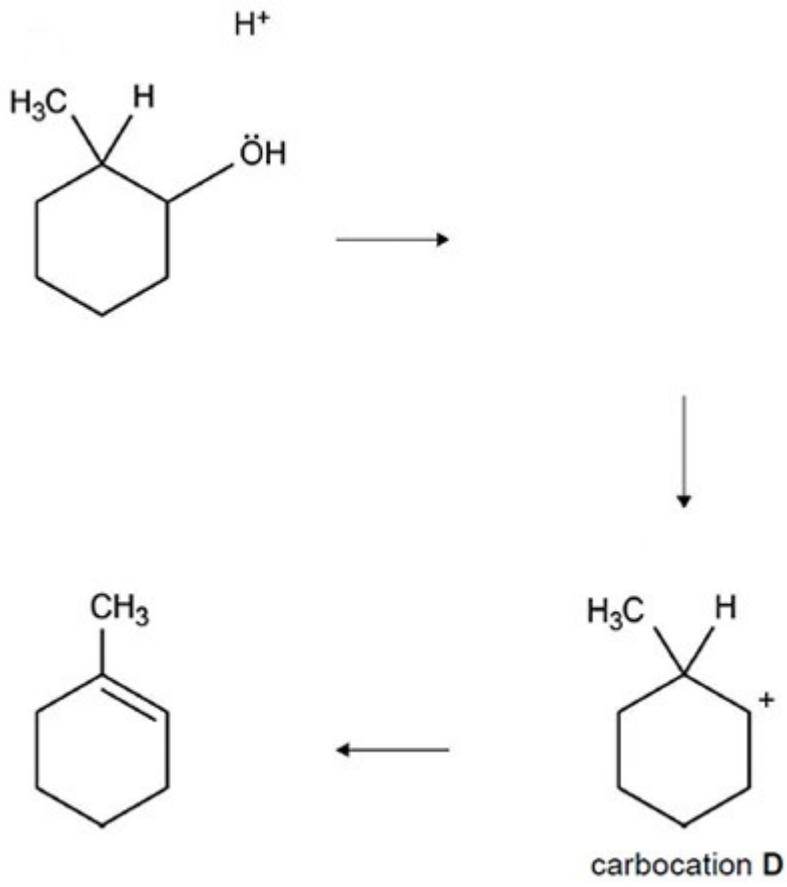
Q7.

Alcohols undergo dehydration in the presence of concentrated phosphoric acid, via a carbocation intermediate, to form alkenes.

(a) Complete the mechanism for the conversion of 2-methylcyclohexanol into 1-methylcyclohexene via carbocation **D** by drawing

- the structure of the missing intermediate
- all necessary curly arrows.

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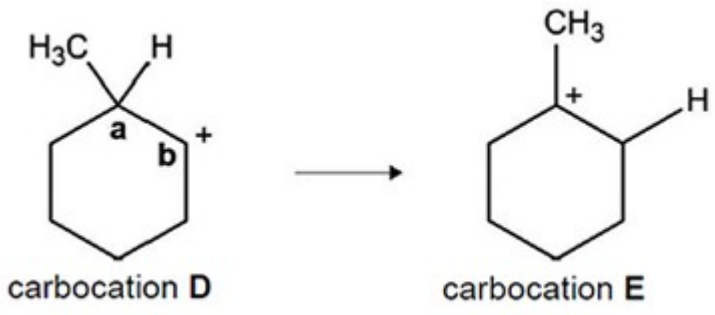


(4)

(b) Draw the structure of a different cyclic alkene formed from carbocation **D**.

(1)

(c) Carbocation **D** can undergo a type of reaction called a rearrangement to form carbocation **E**. In this reaction, a hydrogen atom and its bonding pair of electrons move from carbon **a** to carbon **b** as shown in the diagram below.



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Use your knowledge of carbocations to explain why this rearrangement takes place.

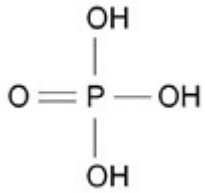
(2)

(d) As a result of the rearrangement in part (c), a third alkene is formed in this reaction.

Draw the structure of this third alkene.

(1)

(e) Cyclohexene is prepared by the dehydration of cyclohexanol using concentrated phosphoric acid as a catalyst. The structure of concentrated phosphoric acid is shown.



Identify the factors that influence the boiling points of each of the compounds in this reaction mixture. State how and explain why cyclohexene can be separated from the reaction mixture.

(6)

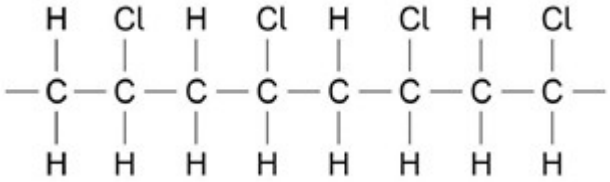
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(Total 14 marks)

Q8.

Chloroethene can be polymerised to form poly(chloroethene), commonly known as PVC. This polymer can be used to make pipes, window frames and electrical insulation. Plasticisers can be added to change the properties of PVC

A section of poly(chloroethene) is shown.



(a) Chloroethene has a melting point of −154 °C

All types of PVC melt at temperatures over 100 °C

Explain why PVC melts at a higher temperature than chloroethene.

_____

_____

_____

_____

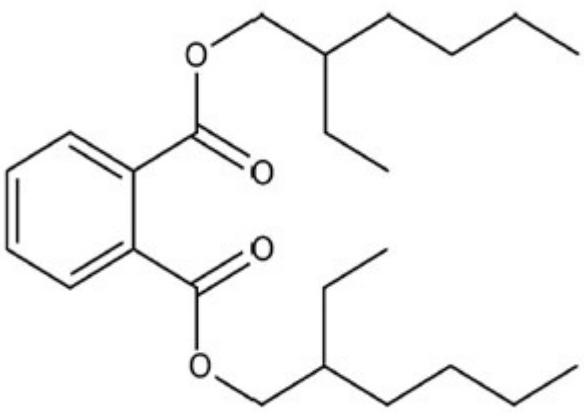
_____

_____

_____

(2)

(b) This structure shows a molecule that has been used as a plasticiser in PVC.



Deduce the number of hydrogen atoms in this molecule.

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_____

(1)

(c) Use your understanding of the properties of PVC to explain whether you would expect to find a plasticiser in the PVC used to insulate electrical cables.

_____

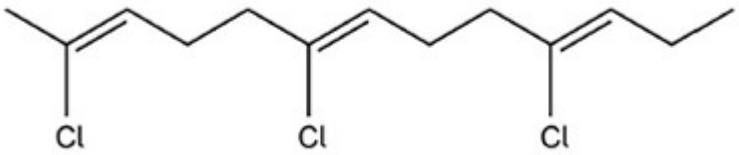
_____

_____

_____

(1)

(d) A section of the polymer poly(chloroprene), a synthetic rubber, is shown.



Draw the **displayed** formula for the repeating unit of poly(chloroprene).

(1)

(Total 5 marks)

Q9.

Which compound has the highest boiling point?

A $CH_3CH_2CH_2OH$ ⬭

B CH_3CH_2CHO ⬭

C CH_3COCH_3 ⬭

D CH_3COOCH_3 ⬭

(Total 1 mark)

Q10.

This question is about elements in Group 7 of the Periodic Table and their compounds.

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(a) Bromine (Br_2), strontium chloride ($SrCl_2$) and iodine monochloride (ICl) all have similar M_r values.

Suggest, with reasons, the order of melting points for these three substances.

(6)

(b) Write an equation for the reaction of chlorine with cold water.

State a reason why chlorine is added to drinking water, and suggest a disadvantage of treating water in this way.

Equation

Reason

Disadvantage

(3)

(c) Bromine reacts with phosphorus to form phosphorus tribromide.

Write an equation for this reaction and draw the shape of the phosphorus tribromide molecule formed.

Suggest the bond angle in phosphorus tribromide.

Equation

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Shape

Bond angle _____

(3)

(d) Phosphorus pentabromide in the solid state consists of PBr_4^+ and Br^- ions.

Draw the shape of the PBr_4^+ ion and suggest its bond angle.

Shape

Bond angle _____

(2)

(Total 14 marks)

Q11.

Halogenoalkanes such as 1,1,2-trichloro-1,2,2-trifluoroethane were used as coolants in refrigerators until the late 1980s. Their use was then banned and alternative coolants were used instead.

(a) Draw the displayed formula of 1,1,2-trichloro-1,2,2-trifluoroethane.

(1)

(b) 1,1,2-Trichloro-1,2,2-trifluoroethane was banned for use as a refrigerant because it damaged the ozone layer.

Write **three** equations to show how this compound is involved in damaging the ozone layer.

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_____

_____

_____

(3)

(c) State the role of chlorine atoms in the reactions in part **(b)**.

_____

(1)

(d) Inevitably, some coolant escapes from refrigerators.

Deduce which of the following coolants, **A**, **B** or **C**, would cause least environmental damage to the atmosphere.

$CHCl_2CHClF$	CF_3CH_2F	CF_3CCl_2F
A	**B**	**C**

Coolant _____

(1)

(e) Give the IUPAC name of compound **B** in part **(d)**.

_____

(1)

(f) The boiling point of iodomethane (CH_3I) is higher than that of fluoromethane (CH_3F) even though the electronegativity of iodine is less than that of fluorine.

Explain why iodomethane has the higher boiling point by considering the forces that act between CH_3I molecules and comparing these forces with the forces between the CH_3F molecules.

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 10 marks)

Q12.

This question is about the element iodine and its compounds.

(a) Iodine is in Group 7 of the Periodic Table.

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Complete the electron configuration of an iodine atom.

[Kr] _____

(1)

(b) Part of the structure of an iodine crystal is shown in the diagram.



Use your knowledge of structure and bonding to explain why the melting point of iodine is low (113.5 °C) and why that of hydrogen iodide is very low (–50.8 °C).

(6)

(c) State why iodine does **not** conduct electricity.

_____

_____

_____

(1)

(d) Deduce an equation for the formation of hydrogen iodide from its elements.

_____

(1)

(e) The triiodide ion is formed when an iodine molecule is bonded to an iodide ion.

What is the formula of ammonium triiodide?

Tick (✔) **one** box.

NH_3I_3 ☐

NH_3I_4 ☐

NH_4I ☐

NH_4I_3 ☐

(1)

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(f) Draw the shape of the IF_3 molecule and the shape of the IF_4^- ion.
Include any lone pairs of electrons that influence each shape.

(2)

(g) Deduce the oxidation state of iodine in the following species.

$Ba(IO_3)_2$

_____

$[H_4IO_6]^-$

_____

(2)

(Total 14 marks)

Q13.

Which statement about intermolecular forces is **not** correct?

A	Intermolecular forces exist between all simple molecules.	⬭
B	Hydrogen bonding occurs between HBr molecules.	⬭
C	Hydrogen bonding is the strongest intermolecular force in liquid ethanol.	⬭
D	Hydrogen bonds occur between C=O and H−N in proteins.	⬭

(Total 1 mark)

Q14.

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)

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Q15.

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

A HF ⬭

B NH_3 ⬭

C CH_3COOH ⬭

D CHF_3 ⬭

(Total 1 mark)

Q16.

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)

Q17.

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.

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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)

Q18.

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

ethanol $\longrightarrow$ ethanal $\longrightarrow$ 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.

(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.

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(Total 16 marks)

Q19.

Which compound has the highest boiling point?

A C_2H_4 ⬭

B C_2H_6 ⬭

C CH_3NH_2 ⬭

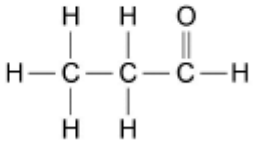
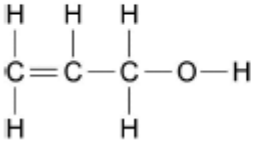
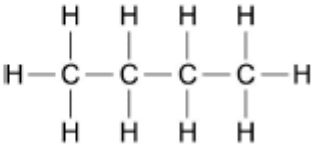
D CH_3F ⬭

(Total 1 mark)

Q20.

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

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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.

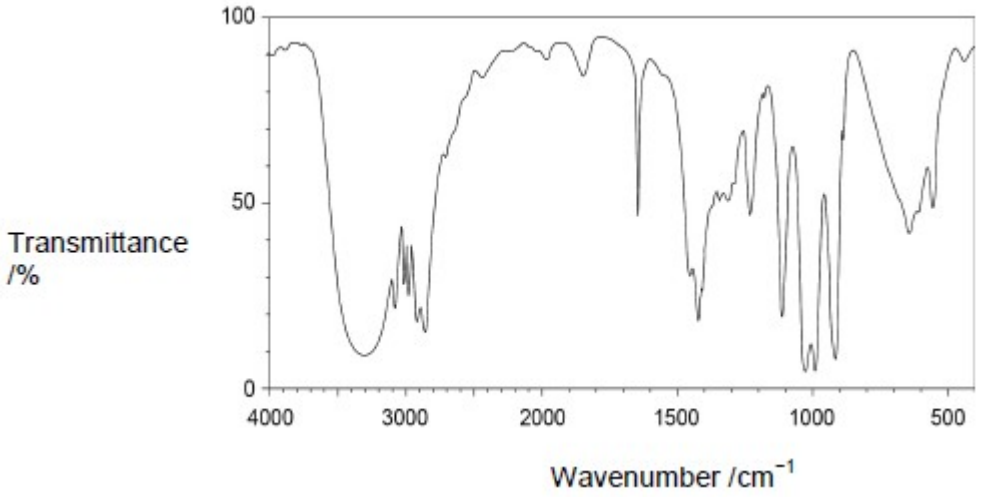
_____

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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.

_____

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(6)
(Total 10 marks)

Q21.

(a) Van der Waals' forces exist between all molecules.

Explain how these forces arise.

(3)

(b) The table shows the boiling points of methanol (CH_3OH) and methanethiol (CH_3SH).

Compound	Boiling point / °C
Methanol	65
Methanethiol	6

(i) Explain, in terms of their intermolecular forces, why the boiling points of these compounds are different.

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_____

_____

_____

(3)

(ii) Suggest how a mixture of methanol and methanethiol could be separated.

_____

_____

(1)

(c) Suggest why methaneselenol (CH_3SeH) has a higher boiling point than methanethiol (CH_3SH).

_____

_____

_____

_____

(2)

(d) Sulfur forms many molecular compounds with the halogens.

(i) Draw the shape of an SF_6 and of an SF_4 molecule.
Include any lone pairs that influence the shape.
State the bond angle(s) in SF_6 and in SF_4.
Name the shape of SF_6.

	SF_6	**SF_4**
Shape		
Bond angle(s)		
Name of shape		

(6)

(ii) SCl_2 reacts with NaF to form SF_4 and S_2Cl_2 and one other product.

Write an equation for the reaction.

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_____

(2)

(Total 17 marks)

Q22.

Compounds **A**, **B**, **C** and **D** are isomers with the molecular formula $C_4H_{10}O$
They all have a broad absorption in their infrared spectra in the range 3230–3550 cm^{-1}.

(a) Use **Table A on the data sheet** to identify the bond and the functional group present responsible for this absorption.

_____

(1)

(b) Compounds **A** and **B** are both straight-chain compounds.
A can be oxidised to form **P**.
B can be oxidised to form **Q**.
P and **Q** are isomers with molecular formula C_4H_8O

Tollens' reagent and Fehling's solution can be used to distinguish between isomers **P** and **Q**. The results shown in the table are obtained.

Compound	Observation with Tollens' reagent	Observation with Fehling's solution
P	No visible change	No visible change
Q	Silver mirror formed	Brick-red precipitate formed

Use the information about compounds **P** and **Q** to identify compounds **A** and **B**.
Explain your answer with reference to the functional groups in **P** and **Q**.

Identity of **A** _____

Identity of **B** _____

Explanation _____

_____

_____

_____

(3)

(c) Isomer **C** is resistant to oxidation.
Isomer **C** reacts to form compound **R** that has an absorption in its infrared spectrum in the range 1620–1680 cm^{-1}.

State the bond that causes the absorption in the range 1620–1680 $^{-1}$.

Give the displayed formula of isomer **C**.

Identify the reagent and give **one** reaction condition needed to convert **C** into **R**.

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Bond _____

Displayed formula of **C**

Reagent _____

Condition _____

(4)

(d) Compound **D** is a branched-chain isomer that can be oxidised to form compounds **S** and **T**.

(i) Compound **S** is obtained by distilling it off as it forms during the oxidation. Compound **T** is formed when the oxidation takes place under reflux.

Identify the functional groups in **S** and **T**.

Explain, with reference to intermolecular forces, why it is possible to obtain compound **S** but not **T** from the reaction mixture by distilling off **S** as soon as it forms.

_____

_____

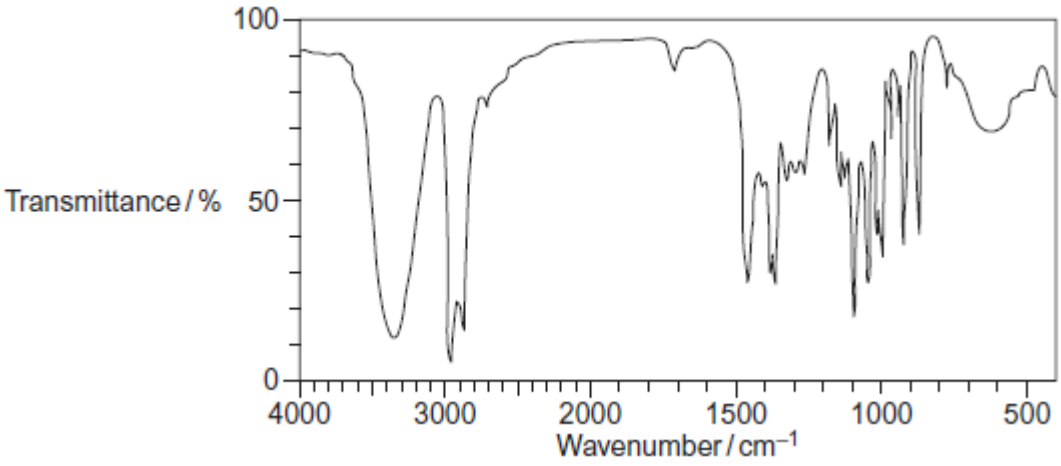
_____

_____

_____

(3)

(ii) A student claims to have oxidised compound **D**.
The infrared spectrum of the product obtained by the student is shown.



Suggest two ways in which the spectrum shows that compound **D** has **not** been oxidised.

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_____

_____

_____

_____

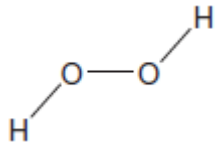
_____

(2)

(Total 13 marks)

Q23.

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.

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(3)

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

_____

_____

_____

_____

_____

(2)

(Total 7 marks)

Q24.

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

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

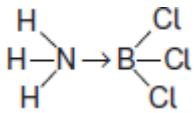
_____

(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.

_____

_____

_____

(1)

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(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.**

_____

_____

_____

_____

(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)

Q25.

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.

_____

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_____

_____

_____

(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.

_____

_____

_____

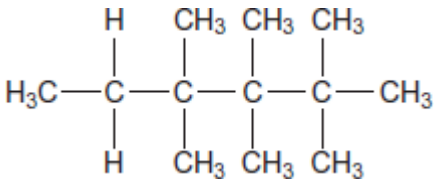
_____

_____

(2)

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(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.

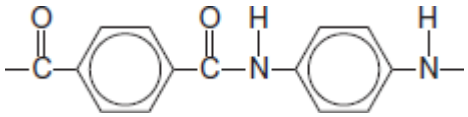
_____

(1)

(Total 16 marks)

Q26.

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.

_____

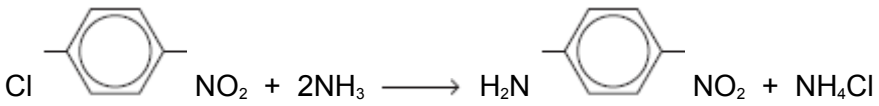
(1)

(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**.

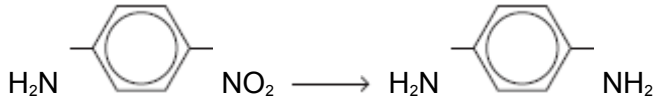
Stage **1**



X

Stage **2**

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(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)

Q27.

Fritz Haber, a German chemist, first manufactured ammonia in 1909.

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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)

Q28.

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.

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(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)

Q29.

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

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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.

_____

_____

_____

_____

_____

(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.

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Explain, in terms of bonding, why the boiling point of fluorine is very low.

_____

_____

_____

(2)

(Total 15 marks)

Q30.

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

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

_____

_____

_____

(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 NHF_2

_____

(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.

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$$NHF_2 + BF_3 \longrightarrow F_2HNBF_3$$

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 _____

_____

_____

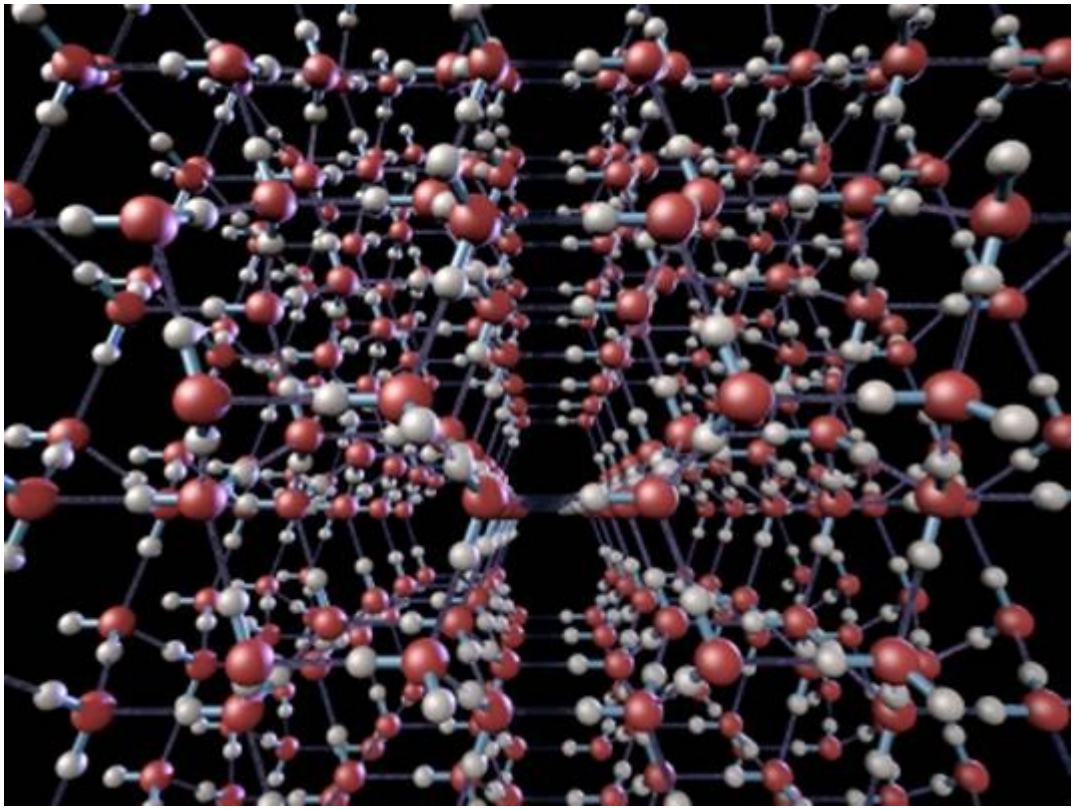
(2)

(Total 10 marks)

Q31.

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)

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(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)

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

_____

(1)

(Total 9 marks)

Q32.

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 _____

_____

_____

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_____

(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)

Q33.

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)

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(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 _____

_____

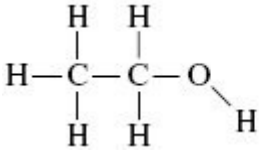
_____

(3)

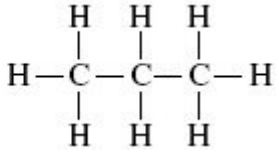
(Total 13 marks)

Q34.

(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 _____

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Explanation _____

(2)

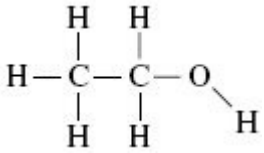
(ii) State the strongest type of intermolecular force present in each compound.

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.

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(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)

Q35.

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)

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Q1.

Solution **A** contains the compound $[Cu(H_2O)_6]Cl_2$

(a) State the type of bonding between the oxygen and hydrogen in this compound.

_____

(1)

(b) State why the chloride ions in this compound are **not** considered to be ligands.

_____

_____

_____

(1)

(c) An excess of ammonia was added to a sample of solution **A** to form solution **B**.

Write an ionic equation for the reaction that occurs when solution **A** is converted into solution **B** and state the colour of solution **B**.

Equation

_____

_____

Colour _____

(2)

(d) Aqueous sodium carbonate was added to another sample of solution **A** to form a blue-green solid **C**.

Identify the blue-green solid **C**.

_____

(1)

(e) Reagent **D** was added to another sample of solution **A** to form a yellow-green solution.

Identify reagent **D** and write an ionic equation for the reaction that occurs when the yellow-green solution is formed from solution **A**.

Identity of reagent **D**

_____

Equation

_____

_____

(2)

(f) Explain why colorimetry cannot be used to determine the concentration of solutions containing $[CuCl_2]^-$

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In your answer refer to the electron configuration of the metal ion.

_____

_____

_____

_____

(2)

(Total 9 marks)

Q2.

Which of these statements best describes a dative covalent bond?

A A pair of electrons shared between two atoms where each atom has donated one electron. ⬭

B A pair of electrons shared between two atoms where one atom has donated two electrons. ⬭

C Two pairs of electrons shared between two atoms where each atom has donated one electron. ⬭

D Two pairs of electrons shared between two atoms where each atom has donated two electrons. ⬭

(Total 1 mark)

Q3.

Which type of bond is formed between N and B when a molecule of NH_3 reacts with a molecule of BF_3?

A Ionic. ⬭

B Covalent. ⬭

C Co-ordinate. ⬭

D Van der Waals. ⬭

(Total 1 mark)

Q4.

Ammonia reacts with aluminium chloride as shown by the equation:

$$NH_3 + AlCl_3 \longrightarrow H_3NAlCl_3$$

(a) Draw diagrams to illustrate the shapes of NH_3 molecules and of $AlCl_3$ molecules.

Include in your diagrams any lone pairs of electrons that influence the shape.

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Indicate the values of the bond angles.

(3)

(b) Name the type of bond formed between N and Al in H_3NAlCl_3 and explain how this bond is formed.

Type of bond _____

Explanation _____

_____

_____

_____

(2)

(c) Explain how the value of the Cl-Al-Cl bond angle in $AlCl_3$ changes, if at all, on formation of the compound H_3NAlCl_3

_____

_____

_____

_____

(2)

(Total 7 marks)

Q5.

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

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

_____

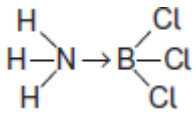
(1)

(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.

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(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.

_____

_____

_____

(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.**

_____

_____

_____

_____

(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.

_____

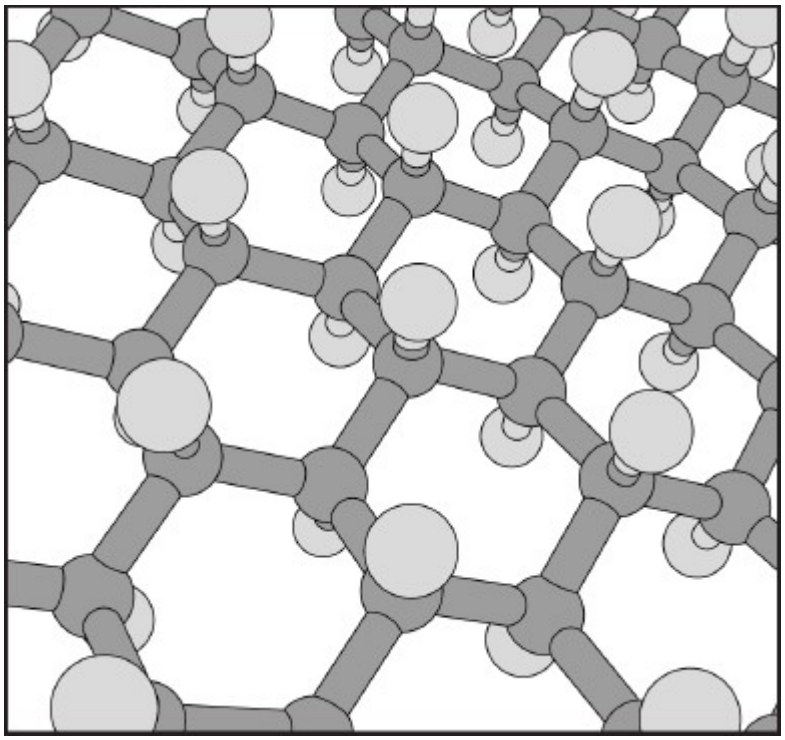
(1)

(Total 9 marks)

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Q6.

In 2009 a new material called graphane was discovered. The diagram shows part of a model of the structure of graphane. Each carbon atom is bonded to three other carbon atoms and to one hydrogen atom.



(a) Deduce the type of crystal structure shown by graphane.

_____

(1)

(b) State how two carbon atoms form a carbon–carbon bond in graphane.

_____

_____

(1)

(c) Suggest why graphane does **not** conduct electricity.

_____

_____

(1)

(d) Deduce the empirical formula of graphane.

_____

(1)

(Total 4 marks)

Q7.

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Aluminium and thallium are elements in Group 3 of the Periodic Table.
Both elements form compounds and ions containing chlorine and bromine.

(a) Write an equation for the formation of aluminium chloride from its elements.

_____

(1)

(b) An aluminium chloride molecule reacts with a chloride ion to form the $AlCl_4^-$ ion.

Name the type of bond formed in this reaction. Explain how this type of bond is formed in the $AlCl_4^-$ ion.

Type of bond _____

Explanation _____

_____

_____

(2)

(c) Aluminium chloride has a relative molecular mass of 267 in the gas phase.

Deduce the formula of the aluminium compound that has a relative molecular mass of 267

_____

(1)

(d) Deduce the name or formula of a compound that has the same number of atoms, the same number of electrons and the same shape as the $AlCl_4^-$ ion.

_____

(1)

(e) Draw and name the shape of the $TlBr_5^{2-}$ ion.

Shape of the $TlBr_5^{2-}$ ion.

Name of shape _____

(2)

(f) (i) Draw the shape of the $TlCl_2^+$ ion.

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(1)

(ii) Explain why the $TlCl_2^+$ ion has the shape that you have drawn in part (f)(i).

_____

_____

_____

(1)

(g) Which **one** of the first, second or third ionisations of thallium produces an ion with the electron configuration [Xe] $5d^{10}6s^1$?

Tick (✓) one box.

First ☐

Second ☐

Third ☐

(1)

(Total 10 marks)

Q8.

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 _____

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_____

(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)

Q9.

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^-

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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.

_____

_____

_____

_____

_____

(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.

_____

_____

_____

(2)

(Total 15 marks)

Q10.

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

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

_____

_____

_____

(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 NHF_2

_____

(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 _____

_____

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_____

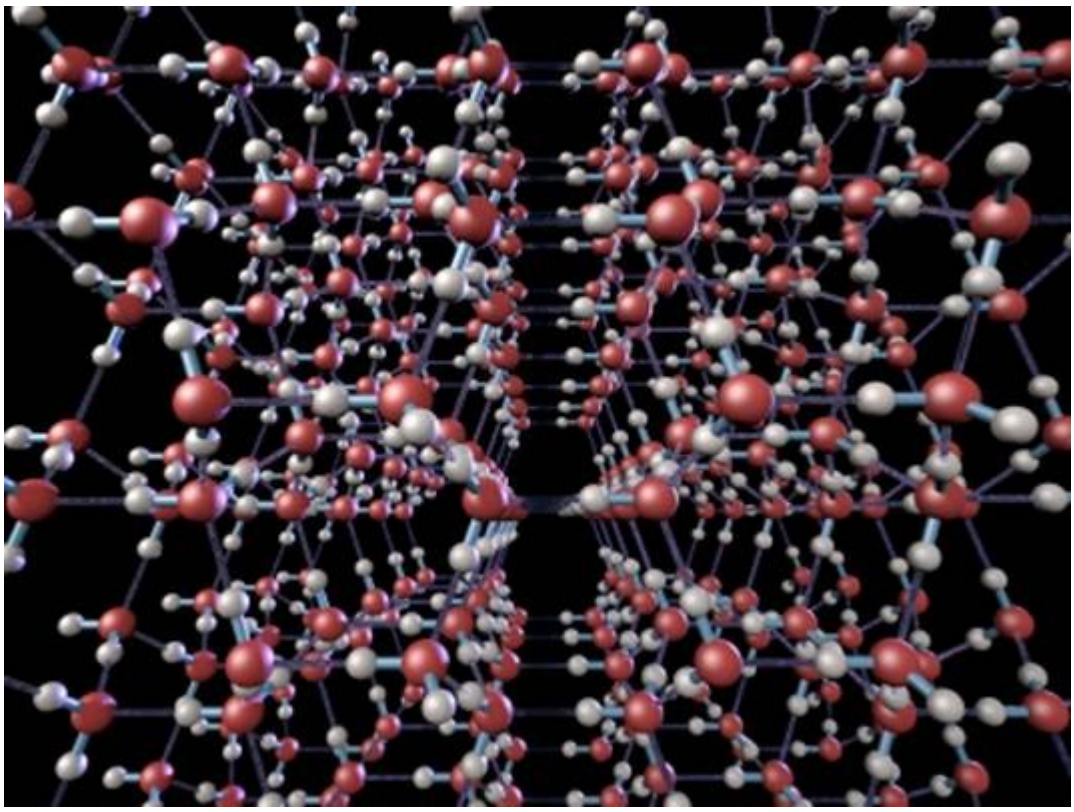
(2)

(Total 10 marks)

Q11.

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

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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)

Q12.

Fluorine forms many compounds that contain covalent bonds.

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(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.

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

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)

Q13.

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

_____

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_____

(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 _____

_____

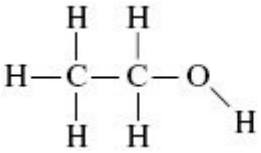
_____

(3)

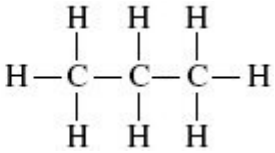
(Total 13 marks)

Q14.

(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 _____

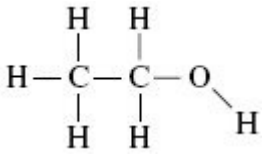
Liquid propane _____

(2)

(b) Ethanol dissolves in water. Draw a diagram to show how one molecule of ethanol

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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)

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(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)

Q15.

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.

_____

_____

_____

_____

_____

(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 _____

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_____

_____

(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)

Q16.

The equation below shows the reaction between boron trifluoride and a fluoride ion.

$$BF_3 + F^- \rightarrow BF_4^-$$

(i) Draw diagrams to show the shape of the BF_3 molecule and the shape of the BF_4^- ion. In each case, name the shape. Account for the shape of the BF_4^- ion and state the bond angle present.

_____

_____

_____

_____

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(6)

(ii) In terms of the electrons involved, explain how the bond between the BF_3 molecule and the F^- ion is formed. Name the type of bond formed in this reaction.

(3)

(Total 9 marks)

Q17.

Phosphorus and nitrogen are in Group V of the Periodic Table and both elements form hydrides. Phosphine, PH_3, reacts to form phosphonium ions, PH_4^+, in a similar way to that by which ammonia, NH_3, forms ammonium ions, NH_4^+

(a) Give the name of the type of bond formed when phosphine reacts with an H^+ ion. Explain how this bond is formed.

Type of bond _____

Explanation _____

(3)

(b) Draw the shapes, including any lone pairs of electrons, of a phosphine molecule and of a phosphonium ion.
Give the name of the shape of the phosphine molecule and state the bond angle found in the phosphonium ion.

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PH_3 PH_4^+

Shape of PH_3 _____ *Bond angle in PH_4^+* _____

(4)

(Total 7 marks)

Q18.

Lithium hydride, LiH, is an ionic compound containing the hydride ion, H^-
The reaction between LiH and aluminium chloride, $AlCl_3$, produces the ionic compound $LiAlH_4$

(a) Balance the equation below which represents the reaction between LiH and $AlCl_3$

$$LiH + AlCl_3 \rightarrow LiAlH_4 + LiCl$$

(1)

(b) Give the electronic configuration of the hydride ion, H^-

_____

(1)

(c) Predict the shape of the AlH_4^- ion. Explain why it has this shape.

Shape _____

Explanation _____

_____

_____

(3)

(d) A bond in AlH_4^- can be represented by H → Al

Name this type of bond and explain how it is formed.

Type of bond _____

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Explanation _____

_____

_____

(3)

(Total 8 marks)

Q19.

(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^+

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Bond angle(s) _____ *Bond angle(s)* _____

(4)

(Total 10 marks)

Q20.

(a) Complete the following table.

Particle	Relative charge	Relative mass
Proton		
Neutron		
Electron		

(3)

(b) An atom of element **Z** has two more protons and two more neutrons than an atom of $^{34}_{16}S$. Give the symbol, including mass number and atomic number, for this atom of **Z**.

_____

(2)

(c) Complete the electronic configurations for the sulphur atom, S, and the sulphide ion, S^{2-}.

S $1s^2$ _____

S^{2-} $1s^2$ _____

(2)

(d) State the block in the Periodic Table in which sulphur is placed and explain your answer.

Block _____

Explanation _____

(2)

(e) Sodium sulphide, Na_2S, is a high melting point solid which conducts electricity when molten. Carbon disulphide, CS_2, is a liquid which does not conduct electricity.

(i) Deduce the type of bonding present in Na_2S and that present in CS_2

Bonding in Na_2S _____

Bonding in CS_2 _____

(ii) By reference to all the atoms involved explain, in terms of electrons, how Na_2S is formed from its atoms.

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_____

_____

(iii) Draw a diagram, including all the outer electrons, to represent the bonding present in CS_2

(iv) When heated with steam, CS_2 reacts to form hydrogen sulphide, H_2S, and carbon dioxide.
Write an equation for this reaction.

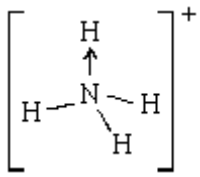
_____

(7)

(Total 16 narks)

Q21.

(a) An ammonium ion, made by the reaction between an ammonia molecule and a hydrogen ion, can be represented as shown in the diagram below.



(i) Name the type of bond represented in the diagram by N—H

_____

(ii) Name the type of bond represented in the diagram by N→H

_____

(iii) In terms of electrons, explain why an arrow is used to represent this N→H bond.

_____

_____

(iv) In terms of electron pairs, explain why the bond angles in the NH_4^+ ion are all 109° 28’

_____

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_____

_____

_____

(7)

(b) Define the term *electronegativity*.

_____

_____

(2)

(c) A bond between nitrogen and hydrogen can be represented as $\overset{\delta-}{\text{N}}\!\!-\!\!\overset{\delta+}{\text{H}}$

(i) In this representation, what is the meaning of the symbol $\delta+$?

_____

(ii) From this bond representation, what can be deduced about the electronegativity of hydrogen relative to that of nitrogen?

_____

_____

(2)

(Total 11 marks)

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Q1.

This question is about compounds containing fluorine.

(a) Draw the shape of a molecule of krypton difluoride (KrF_2).
Include in your answer any lone pairs of electrons that influence the shape.
Name the shape produced by the atoms in a KrF_2 molecule and suggest a bond angle.

Name of shape _____

Bond angle _____

(3)

(b) There are two lone pairs of electrons on the oxygen atom in a molecule of oxygen difluoride (OF_2).

Explain how the lone pairs of electrons on the oxygen atom influence the bond angle in oxygen difluoride.

_____

_____

_____

_____

_____

_____

_____

(2)

(c) Silicon tetrafluoride (SiF_4) is a tetrahedral molecule.

Deduce the type of intermolecular forces in SiF_4
Explain how this type of intermolecular force arises and why no other type of intermolecular force exists in a sample of SiF_4

Intermolecular forces in SiF_4 _____

Explanation _____

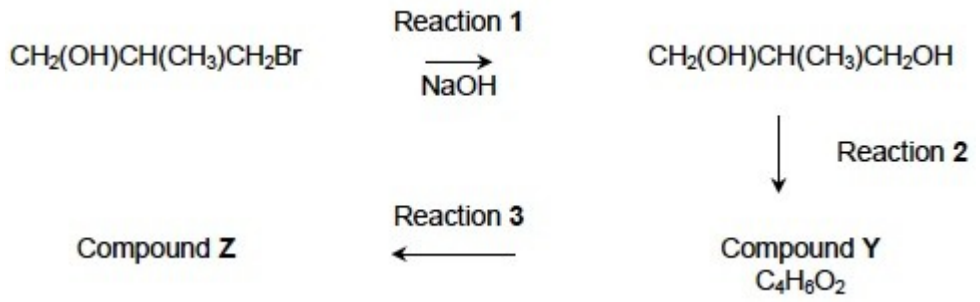
_____

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(3)
(Total 8 marks)

Q2.

Halogenoalkanes are useful compounds in synthesis. A reaction pathway is shown.



(a) Give the IUPAC name for $CH_2(OH)CH(CH_3)CH_2Br$

(1)

(b) Reaction **1** occurs via a nucleophilic substitution mechanism.

Explain why the halogenoalkane is attacked by the nucleophile in this reaction.

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_____

_____

_____

_____

(3)

(c) The infrared spectrum of Compound **Y** shows a significant absorption in the range 1680–1750 cm^{-1}

Draw the displayed formula of Compound **Y**.

(1)

(d) Compound **Z** has the empirical formula C_3H_4NO

Give the structure of Compound **Z**.

Suggest the reagent for Reaction **3**.

Structure

Reagent for Reaction **3** _____

(2)

(Total 7 marks)

Q3.

Which molecule does **not** have a permanent dipole?

A CH_3Br ⬭

B CH_2Br_2 ⬭

C $CHBr_3$ ⬭

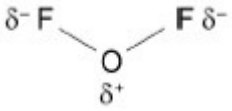
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D CBr_4 ⬭

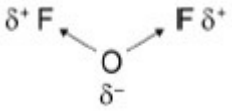
(Total 1 mark)

Q4.

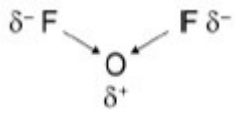
Which diagram shows the correct bonding and correct bond polarity in a molecule of oxygen difluoride?

A 

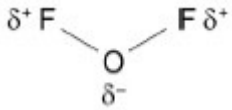
⬭

B 

⬭

C 

⬭

D 

⬭

(Total 1 mark)

Q5.

This question is about intermolecular forces.

(a) Give the meaning of the term electronegativity.

_____

_____

_____

(1)

(b) Explain how permanent dipole-dipole forces arise between hydrogen chloride molecules.

_____

_____

_____

_____

_____

_____

(2)

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(c) Complete the table by naming the shape of each molecule.

Place a tick (✔) in the final column if the molecule has a permanent dipole.

Molecule	Name of shape	Tick (✔) if molecule has a permanent dipole
SiH_4		
PH_3		
$BeCl_2$		
CH_3Cl		

(4)

(Total 7 marks)

Q6.

Which molecule does **not** have a permanent dipole?

A CH_3Cl ⬭

B $CHCl_3$ ⬭

C CF_4 ⬭

D $CHCl_2F$ ⬭

(Total 1 mark)

Q7.

Which molecule is the least polar?

A Bromomethane ⬭

B Dibromomethane ⬭

C Tribromomethane ⬭

D Tetrabromomethane ⬭

(Total 1 mark)

Q8.

Which of these atoms has the highest electronegativity?

A Na ⬭

B Mg ⬭

C Cl ⬭

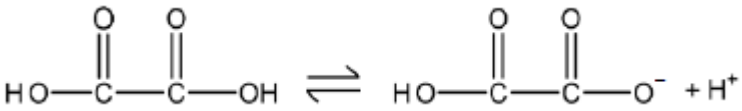
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D Ar ⬭

(Total 1 mark)

Q9.

Ethanedioic acid is a weak acid.
Ethanedioic acid acts, initially, as a monoprotic acid.



(a) Use the concept of electronegativity to justify why the acid strengths of ethanedioic acid and ethanoic acid are different.

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(b) A buffer solution is made by adding 6.00×10^{-2} mol of sodium hydroxide to a solution containing 1.00×10^{-1} mol of ethanedioic acid ($H_2C_2O_4$).
Assume that the sodium hydroxide reacts as shown in the following equation and that in this buffer solution, the ethanedioic acid behaves as a monoprotic acid.

$$H_2C_2O_4(aq) + OH^-(aq) \longrightarrow HC_2O_4^-(aq) + H_2O(l)$$

The dissociation constant K_a for ethanedioic acid is 5.89×10^{-2} mol dm^{-3}.

Calculate a value for the pH of the buffer solution.
Give your answer to the appropriate number of significant figures.

pH = _____

(5)

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(c) In a titration, the end point was reached when 25.0 cm^3 of an acidified solution containing ethanedioic acid reacted with 20.20 cm^3 of 2.00 $\times 10^{-2}$ mol dm^{-3} potassium manganate(VII) solution.

Deduce an equation for the reaction that occurs and use it to calculate the original concentration of the ethanedioic acid solution.

Equation _____

Calculation

Original concentration = _____ mol dm^{-3}

(4)

(Total 15 marks)

Q10.

Which molecule has the largest dipole?

A ClF_3 ⬭

B BF_3 ⬭

C SF_6 ⬭

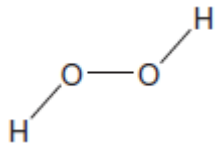
D CF_4 ⬭

(Total 1 mark)

Q11.

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

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(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)

Q12.

The following table shows the electronegativity values of the elements from lithium to fluorine.

	Li	Be	B	C	N	O	F
Electronegativity	1.0	1.5	2.0	2.5	3.0	3.5	4.0

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

_____

_____

_____

(2)

(ii) Suggest why the electronegativity of the elements increases from lithium to fluorine.

_____

_____

_____

(2)

(b) State the type of bonding in lithium fluoride.
Explain why a lot of energy is needed to melt a sample of solid lithium fluoride.

Bonding _____

Explanation _____

_____

_____

(3)

(c) Deduce why the bonding in nitrogen oxide is covalent rather than ionic.

_____

_____

(1)

(d) Oxygen forms several different compounds with fluorine.

(i) Suggest the type of crystal shown by OF_2

_____

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(1)

(ii) Write an equation to show how OF_2 reacts with steam to form oxygen and hydrogen fluoride.

_____

(1)

(iii) One of these compounds of oxygen and fluorine has a relative molecular mass of 70.0 and contains 54.3% by mass of fluorine.

Calculate the empirical formula and the molecular formula of this compound. Show your working.

Empirical formula _____

_____

_____

_____

_____

_____

Molecular formula _____

_____

(4)

(Total 14 marks)

Q13.

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

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

_____

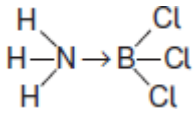
(1)

(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.

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

_____

_____

_____

(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.**

_____

_____

_____

_____

(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)

Q14.

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*.

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_____

_____

_____

(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.

_____

_____

_____

_____

_____

(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 _____

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(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)

Q15.

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*.

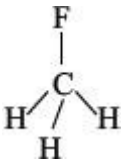
_____

_____

_____

(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.

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_____

_____

_____

_____

(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.

_____

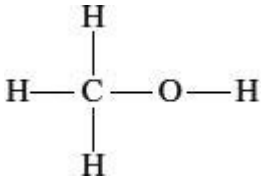
_____

(3)

(Total 11 marks)

Q16.

(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.

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_____

_____

_____

_____

(3)

(Total 5 marks)

Q17.

(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^+

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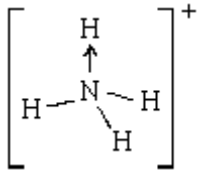
Bond angle(s) _____ *Bond angle(s)* _____

(4)

(Total 10 marks)

Q18.

(a) An ammonium ion, made by the reaction between an ammonia molecule and a hydrogen ion, can be represented as shown in the diagram below.



(i) Name the type of bond represented in the diagram by N—H

_____

(ii) Name the type of bond represented in the diagram by N→H

_____

(iii) In terms of electrons, explain why an arrow is used to represent this N→H bond.

_____

_____

(iv) In terms of electron pairs, explain why the bond angles in the NH_4^+ ion are all 109° 28'

_____

_____

_____

_____

(7)

(b) Define the term *electronegativity*.

_____

_____

(2)

(c) A bond between nitrogen and hydrogen can be represented as $\overset{\delta-}{N}—\overset{\delta+}{H}$

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(i) In this representation, what is the meaning of the symbol δ+ ?

_____

(ii) From this bond representation, what can be deduced about the electronegativity of hydrogen relative to that of nitrogen?

_____

_____

(2)

(Total 11 marks)

Q19.

Which one of the following bond polarities is **not** correct?

A $\overset{\delta+}{C}-\overset{\delta-}{H}$ in ethane

B $\overset{\delta+}{C}-\overset{\delta-}{Br}$ in bromoethane

C $\overset{\delta+}{C}-\overset{\delta-}{O}$ in ethanol

D $\overset{\delta+}{C}=\overset{\delta-}{O}$ in ethanal

(Total 1 mark)

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Q1.

This question is about sodium and some of its compounds.

(a) Use your knowledge of structure and bonding to explain why sodium bromide has a melting point that is higher than that of sodium, and higher than that of sodium iodide.

(6)

(b) When 250 mg of sodium were added to 500 cm^3 of water at 25 °C a gas was produced.

Give an equation for the reaction that occurs.
Calculate the volume, in cm^3, of the gas formed at 101 kPa

The gas constant, R = 8.31 J K^{-1} mol^{-1}

Equation _____

Volume _____ cm^3

(6)

(c) Calculate the concentration, in mol dm^{-3}, of sodium ions in the solution produced in the reaction in **part (b)**.

Concentration _____ mol dm^{-3}

(1)

(d) Sodium reacts with ammonia to form the compound $NaNH_2$ that contains the NH_2^- ion.

Draw the shape of the NH_2^- ion.
Include any lone pairs of electrons that influence the shape.

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Predict the bond angle.
Justify your prediction.

Shape

Bond angle _____

Justification _____

_____

(4)

(Total 17 marks)

Q2.

Which is the correct crystal structure for the substance named?

	Substance	Structure	
A	Iodine	Simple molecular	○
B	Diamond	Ionic	○
C	Sodium chloride	Giant covalent	○
D	Graphite	Metallic	○

(Total 1 mark)

Q3.

This question is about some Period 3 elements and their oxides.

(a) Write an equation for the reaction of phosphorus with an excess of oxygen.

_____

(1)

(b) Describe a test you could carry out in a test tube to distinguish between sodium oxide and the product of the reaction in part (a)

_____

_____

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_____

_____

_____

_____

(3)

(c) State the type of crystal structure shown in silicon dioxide and in sulfur trioxide.

Silicon dioxide _____

Sulfur trioxide _____

(2)

(d) Explain why silicon dioxide has a higher melting point than sulfur trioxide.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(e) Write an equation for the reaction of sulfur trioxide with potassium hydroxide solution.

_____

_____

(1)

(f) Write an equation for the reaction of an excess of magnesium oxide with phosphoric acid.

_____

_____

(1)

(g) Draw the displayed formula of the undissociated acid formed when sulfur dioxide reacts with water.

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(1)

(Total 13 marks)

Q4.

This question is about the chemistry of some Group 2 elements.

(a) Write an equation for the reaction of calcium with water at 25 °C and predict a possible value for the pH of the solution formed.

Equation

_____

pH _____

(2)

(b) State the trend in solubility, in water, of the Group 2 sulfates from magnesium to barium.

_____

(1)

(c) State the trend in solubility, in water, of the Group 2 sulfates from magnesium to barium.

Reagent _____

Equation

_____

(2)

(d) Explain why the melting point of calcium sulfate is high.

_____

_____

_____

_____

_____

_____

_____

(2)

(Total 7 marks)

Q5.

This question is about the element iodine and its compounds.

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(a) Iodine is in Group 7 of the Periodic Table.

Complete the electron configuration of an iodine atom.

[Kr] _____

(1)

(b) Part of the structure of an iodine crystal is shown in the diagram.



Use your knowledge of structure and bonding to explain why the melting point of iodine is low (113.5 °C) and why that of hydrogen iodide is very low (–50.8 °C).

(6)

(c) State why iodine does **not** conduct electricity.

_____

_____

_____

(1)

(d) Deduce an equation for the formation of hydrogen iodide from its elements.

_____

(1)

(e) The triiodide ion is formed when an iodine molecule is bonded to an iodide ion.

What is the formula of ammonium triiodide?

Tick (✔) **one** box.

NH_3I_3 ☐

NH_3I_4 ☐

NH_4I ☐

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NH_4I_3 ☐

(1)

(f) Draw the shape of the IF_3 molecule and the shape of the IF_4^- ion.
Include any lone pairs of electrons that influence each shape.

(2)

(g) Deduce the oxidation state of iodine in the following species.

$Ba(IO_3)_2$

_____

$[H_4IO_6]^-$

_____

(2)
(Total 14 marks)

Q6.

The table shows some data about the elements bromine and magnesium.

Element	Melting point / K	Boiling point / K
Bromine	266	332
Magnesium	923	1383

In terms of structure and bonding explain why the boiling point of bromine is different from that of magnesium. Suggest why magnesium is a liquid over a much greater temperature range compared to bromine.

_____

_____

_____

_____

_____

_____

_____

_____

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_____

_____

_____

_____

_____

_____

(Total 5 marks)

Q7.

Which substance exists as a macromolecule?

A Cu ⬭

B SiO_2 ⬭

C P_4O_{10} ⬭

D MgO ⬭

(Total 1 mark)

Q8.

(a) Van der Waals' forces exist between all molecules.

Explain how these forces arise.

_____

_____

_____

_____

_____

(3)

(b) The table shows the boiling points of methanol (CH_3OH) and methanethiol (CH_3SH).

Compound	Boiling point / °C
Methanol	65
Methanethiol	6

(i) Explain, in terms of their intermolecular forces, why the boiling points of these compounds are different.

_____

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_____

_____

_____

_____

_____

(3)

(ii) Suggest how a mixture of methanol and methanethiol could be separated.

_____

_____

(1)

(c) Suggest why methaneselenol (CH_3SeH) has a higher boiling point than methanethiol (CH_3SH).

_____

_____

_____

_____

(2)

(d) Sulfur forms many molecular compounds with the halogens.

(i) Draw the shape of an SF_6 and of an SF_4 molecule.
Include any lone pairs that influence the shape.
State the bond angle(s) in SF_6 and in SF_4.
Name the shape of SF_6.

	SF_6	**SF_4**
Shape		
Bond angle(s)		
Name of shape		

(6)

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(ii) SCl_2 reacts with NaF to form SF_4 and S_2Cl_2 and one other product.

Write an equation for the reaction.

_____

(2)

(Total 17 marks)

Q9.

This question is about the periodicity of the Period 3 elements.

(a) State and explain the general trend in first ionisation energy across Period 3.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(b) Give one example of an element which deviates from the general trend in first ionisation energy across Period 3.

Explain why this deviation occurs.

_____

_____

_____

_____

_____

_____

_____

(3)

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(c) The table shows successive ionisation energies of an element **Y** in Period 3.

Ionisation number	1	2	3	4	5	6	7	8
Ionisation energy / kJ mol^{-1}	1000	2260	3390	4540	6990	8490	27 100	31 700

Identify element **Y**.

Explain your answer using data from the table.

_____

_____

_____

_____

_____

_____

(2)

(d) Identify the Period 3 element that has the highest melting point.

Explain your answer by reference to structure and bonding.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 13 marks)

Q10.

Silicon dioxide (SiO_2) has a crystal structure similar to diamond.

(a) Give the name of the type of crystal structure shown by silicon dioxide.

_____

(1)

(b) Suggest why silicon dioxide does **not** conduct electricity when molten.

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_____

_____

_____

(1)

(c) Silicon dioxide reacts with hydrofluoric acid (HF) to produce hexafluorosilicic acid (H_2SiF_6) and one other substance.

Write an equation for this reaction.

_____

(1)

(Total 3 marks)

Q11.

Some airbags in cars contain sodium azide (NaN_3).

(a) Sodium azide is made by reacting dinitrogen monoxide gas with sodium amide ($NaNH_2$) as shown by the equation.

$$2NaNH_2 + N_2O \longrightarrow NaN_3 + NaOH + NH_3$$

Calculate the mass of sodium amide needed to obtain 550 g of sodium azide, assuming there is a 95.0% yield of sodium azide.
Give your answer to 3 significant figures.

_____

_____

_____

_____

_____

_____

_____

_____

(5)

(b) If a car is involved in a serious collision, the sodium azide decomposes to form sodium and nitrogen as shown in the equation.

$$2NaN_3(s) \longrightarrow 2Na(s) + 3N_2(g)$$

The nitrogen produced then inflates the airbag to a volume of 7.50×10^{-2} m^3 at a pressure of 150 kPa and temperature of 35 °C.

Calculate the minimum mass of sodium azide that must decompose.
(The gas constant R = 8.31 J K^{-1} mol^{-1})

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_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(c) Sodium azide is toxic. It can be destroyed by reaction with an acidified solution of nitrous acid (HNO_2) as shown in the equation.

$$2NaN_3 + 2HNO_2 + 2HCl \longrightarrow 3N_2 + 2NO + 2NaCl + 2H_2O$$

(i) A 500 cm^3 volume of the nitrous acid solution was used to destroy completely 150 g of the sodium azide.

Calculate the concentration, in mol dm^{-3}, of the nitrous acid used.

_____

_____

_____

_____

_____

_____

(3)

(ii) Nitrous acid decomposes on heating.

Balance the following equation for this reaction.

$$.....HNO_2 \longrightarrow .....HNO_3 + ...NO + ...H_2O$$

(1)

(d) Sodium azide has a high melting point.

Predict the type of bonding in a crystal of sodium azide.
Suggest why its melting point is high.

Type of bonding _____

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Reason for high melting point _____

_____

_____

_____

_____

(3)

(e) The azide ion has the formula N_3^-

(i) The azide ion can be represented as $N \equiv N - N^-$

One of these bonds is a co−ordinate bond.

On the following diagram, draw an arrowhead on one of the bonds to represent the direction of donation of the lone pair in the co−ordinate bond.

$$N \equiv N - N^-$$

(1)

(ii) Give the formula of a molecule that has the same number of electrons as the azide ion.

_____

(1)

(iii) Which is the correct formula of magnesium azide?

Tick (✓) **one** box.

Mg_3N ☐

MgN ☐

MgN_6 ☐

Mg_3N_2 ☐

(1)

(Total 21 marks)

Q12.

(a) Nickel is a metal with a high melting point.

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(i) State the block in the Periodic Table that contains nickel.

_____

(1)

(ii) Explain, in terms of its structure and bonding, why nickel has a high melting point.

_____

_____

_____

_____

_____

(2)

(iii) Draw a labelled diagram to show the arrangement of particles in a crystal of nickel.
In your answer, include at least six particles of each type.

(2)

(iv) Explain why nickel is ductile (can be stretched into wires).

_____

_____

_____

(1)

(b) Nickel forms the compound nickel(II) chloride ($NiCl_2$).

(i) Give the full electron configuration of the Ni^{2+} ion.

_____

(1)

(ii) Balance the following equation to show how anhydrous nickel(II) chloride can be obtained from the hydrated salt using $SOCl_2$
Identify **one** substance that could react with both gaseous products.

.....$NiCl_2.6H_2O(s)$ + ... $SOCl_2(g)$ ⟶ .....$NiCl_2(s)$ + ...$SO_2(g)$ + ...$HCl(g)$

Substance _____

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(2)
(Total 9 marks)

Q13.

Thallium is in Group 3 of the Periodic Table.
Thallium reacts with halogens to form many compounds and ions.

(a) Draw the shape of the $TlBr_3^{2-}$ ion and the shape of the $TlCl_4^{3-}$ ion.
Include any lone pairs of electrons that influence the shapes.

Name the shape made by the atoms in $TlBr_3^{2-}$ and suggest a value for the bond angle.

_____

(4)

(b) Thallium(I) bromide (TlBr) is a crystalline solid with a melting point of 480 °C.

Suggest the type of bonding present in thallium(I) bromide and state why the melting point is high.

_____

_____

_____

_____

_____

_____

(3)

(c) Write an equation to show the formation of thallium(I) bromide from its elements.

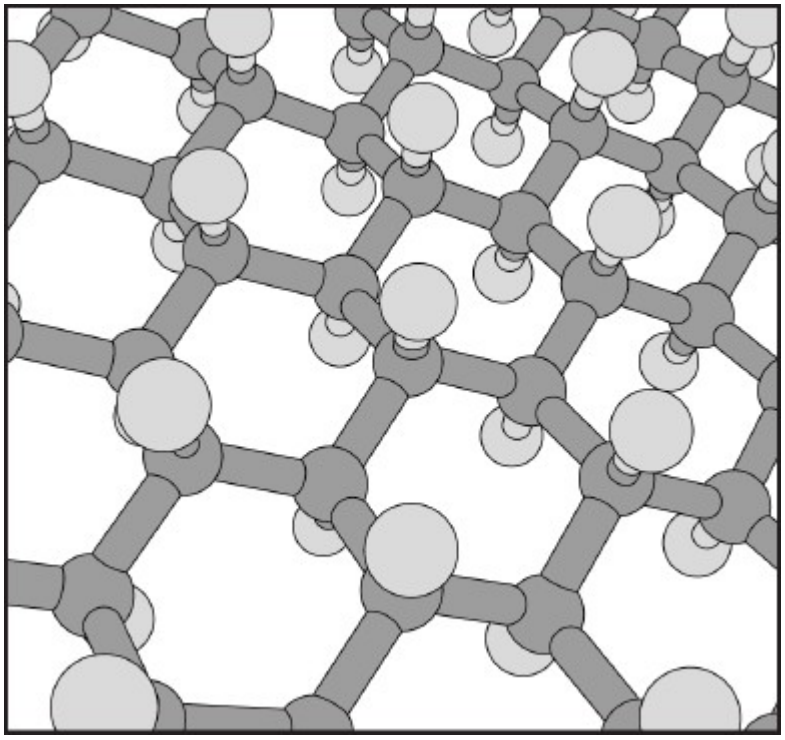
_____

(1)
(Total 8 marks)

Q14.

In 2009 a new material called graphane was discovered. The diagram shows part of a model of the structure of graphane. Each carbon atom is bonded to three other carbon atoms and to one hydrogen atom.

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(a) Deduce the type of crystal structure shown by graphane.

_____

(1)

(b) State how two carbon atoms form a carbon–carbon bond in graphane.

_____

_____

(1)

(c) Suggest why graphane does **not** conduct electricity.

_____

_____

(1)

(d) Deduce the empirical formula of graphane.

_____

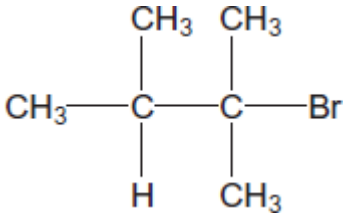
(1)

(Total 4 marks)

Q15.

(a) The structure of the bromoalkane **Z** is

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Give the IUPAC name for **Z**.

Give the general formula of the homologous series of straight-chain bromoalkanes that contains one bromine atom per molecule.

Suggest **one** reason why 1-bromohexane has a higher boiling point than **Z**.

(3)

(b) Draw the displayed formula of 1,2-dichloro-2-methylpropane.

State its empirical formula.

(2)

(Total 5 marks)

Q16.

The following table shows the electronegativity values of the elements from lithium to fluorine.

	Li	Be	B	C	N	O	F
Electronegativity	1.0	1.5	2.0	2.5	3.0	3.5	4.0

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

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_____

_____

_____

(2)

(ii) Suggest why the electronegativity of the elements increases from lithium to fluorine.

_____

_____

_____

(2)

(b) State the type of bonding in lithium fluoride.
Explain why a lot of energy is needed to melt a sample of solid lithium fluoride.

Bonding _____

Explanation _____

_____

_____

(3)

(c) Deduce why the bonding in nitrogen oxide is covalent rather than ionic.

_____

_____

(1)

(d) Oxygen forms several different compounds with fluorine.

(i) Suggest the type of crystal shown by OF_2

_____

(1)

(ii) Write an equation to show how OF_2 reacts with steam to form oxygen and hydrogen fluoride.

_____

(1)

(iii) One of these compounds of oxygen and fluorine has a relative molecular mass of 70.0 and contains 54.3% by mass of fluorine.

Calculate the empirical formula and the molecular formula of this compound.
Show your working.

Empirical formula _____

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_____

_____

_____

_____

_____

Molecular formula _____

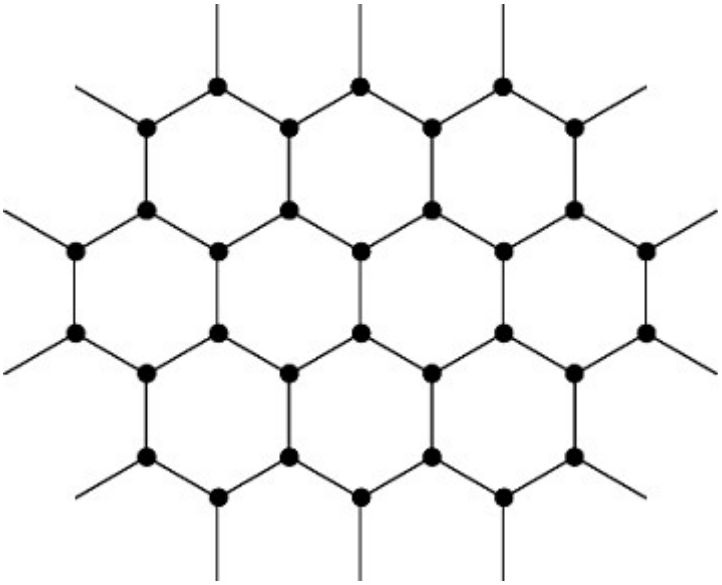
_____

(4)

(Total 14 marks)

Q17.

(a) Graphene is a new material made from carbon atoms. It is the thinnest and strongest material known. Graphene has a very high melting point and is an excellent conductor of electricity.
Part of the structure of graphene is illustrated in the diagram.



(i) Deduce the type of crystal structure shown by graphene.

_____

(1)

(ii) Suggest why graphene is an excellent conductor of electricity.

_____

_____

_____

_____

(2)

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(iii) Explain, in terms of its structure and bonding, why graphene has a high melting point.

_____

_____

_____

_____

(2)

(b) Titanium is also a strong material that has a high melting point. It has a structure similar to that of magnesium.

(i) State the type of crystal structure shown by titanium.

_____

(1)

(ii) Explain, in terms of its structure and bonding, why titanium has a high melting point.

_____

_____

_____

_____

(2)

(c) Titanium can be hammered into objects with different shapes that have similar strengths.

(i) Suggest why titanium can be hammered into different shapes.

_____

_____

(1)

(ii) Suggest why these objects with different shapes have similar strengths.

_____

_____

(1)

(d) Magnesium oxide (MgO) has a melting point of 3125 K.
Predict the type of crystal structure in magnesium oxide and suggest why its melting point is high.

Type of crystal structure _____

Explanation _____

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_____

_____

_____

(3)

(Total 13 marks)

Q18.

Trends in physical properties occur across all Periods in the Periodic Table.
This question is about trends in the Period 2 elements from lithium to nitrogen.

(a) Identify, from the Period 2 elements lithium to nitrogen, the element that has the largest atomic radius.

_____

(1)

(b) (i) State the general trend in first ionisation energies for the Period 2 elements lithium to nitrogen.

_____

(1)

(ii) Identify the element that deviates from this general trend, from lithium to nitrogen, and explain your answer.

Element _____

Explanation _____

_____

_____

(3)

(c) Identify the Period 2 element that has the following successive ionisation energies.

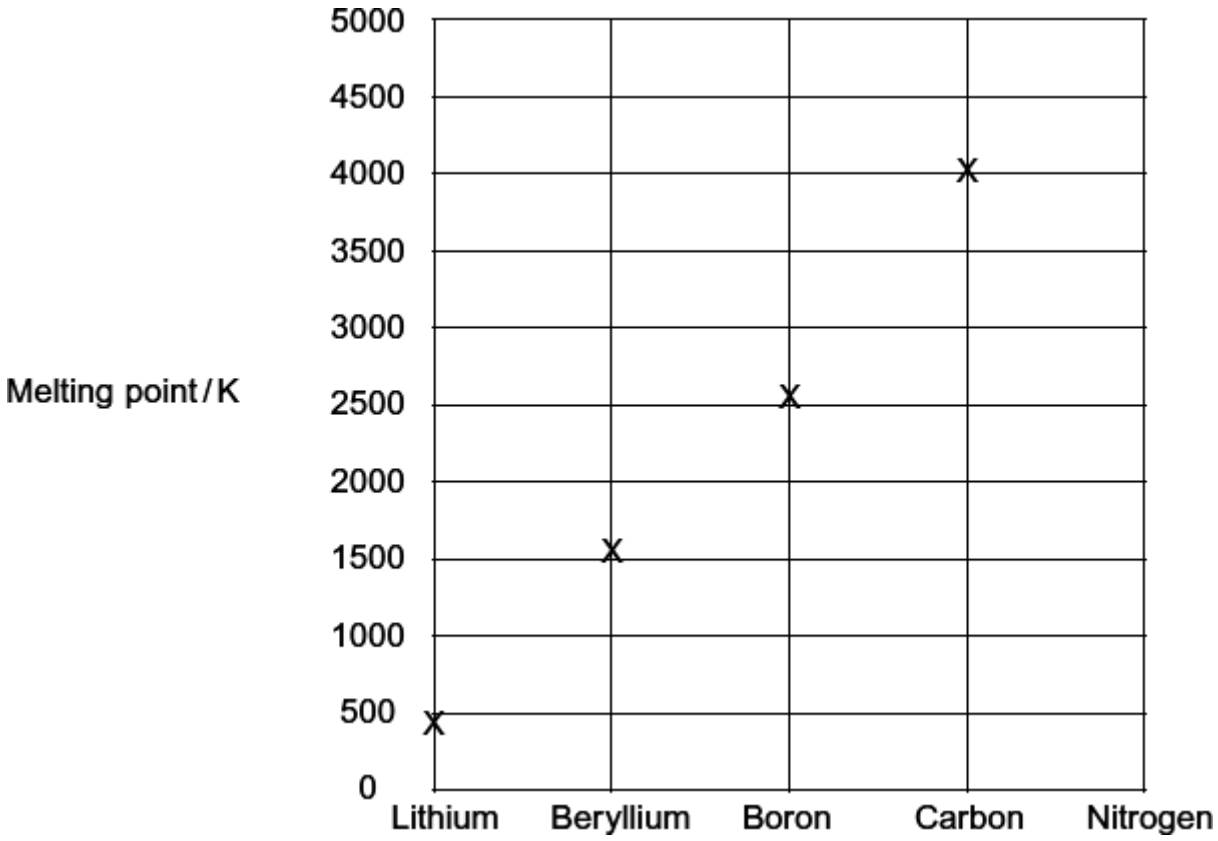
	First	Second	Third	Fourth	Fifth	Sixth
Ionisation energy / kJ mol^{-1}	1090	2350	4610	6220	37 800	47 000

_____

(1)

(d) Draw a cross on the diagram to show the melting point of nitrogen.

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(1)

(e) Explain, in terms of structure and bonding, why the melting point of carbon is high.

_____

_____

_____

_____

_____

(3)

(Total 10 marks)

Q19.

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.

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

(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.

_____

_____

_____

_____

_____

(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.

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(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.

_____

_____

_____

(2)

(Total 15 marks)

Q20.

There are several types of crystal structure and bonding shown by elements and compounds.

(a) (i) Name the type of bonding in the element sodium.

_____

(1)

(ii) Use your knowledge of structure and bonding to draw a diagram that shows how the particles are arranged in a crystal of sodium.
You should identify the particles and show a minimum of six particles in a two-dimensional diagram.

(2)

(b) Sodium reacts with chlorine to form sodium chloride.

(i) Name the type of bonding in sodium chloride.

_____

(1)

(ii) Explain why the melting point of sodium chloride is high.

_____

_____

_____

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_____

(2)

(c) The table below shows the melting points of some sodium halides.

	NaCl	NaBr	NaI
Melting point /K	1074	1020	920

Suggest why the melting point of sodium iodide is lower than the melting point of sodium bromide.

_____

_____

(1)

(Total 7 marks)

Q21.

Iodine and graphite are both solids. When iodine is heated gently a purple vapour is seen. Graphite will not melt until the temperature reaches 4000 K. Graphite conducts electricity but iodine is a very poor conductor of electricity.

(a) State the type of crystal structure for each of iodine and graphite.

_____

_____

_____

_____

(2)

(b) Describe the structure of and bonding in graphite and explain why the melting point of graphite is very high.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

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(c) Explain why iodine vaporises when heated gently.

_____

_____

_____

_____

(2)

(d) State why iodine is a very poor conductor of electricity.

_____

_____

(1)

(Total 9 marks)

Q22.

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.

_____

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_____

(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)

Q23.

(a) Complete the electronic configuration for the sodium ion, Na^+
$1s^2$ _____

(1)

(b) (i) Write an equation, including state symbols, to represent the process for which the energy change is the second ionisation energy of sodium.

_____

(2)

(ii) Explain why the second ionisation energy of sodium is greater than the second ionisation energy of magnesium.

_____

_____

_____

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_____

(3)

(iii) An element **X** in Period 3 of the Periodic Table has the following successive ionisation energies.

	First	Second	Third	Fourth
Ionisation energies / kJ mol^{-1}	577	1820	2740	11600

Deduce the identity of element **X**.

_____

(1)

(c) State and explain the trend in atomic radius of the Period 3 elements from sodium to chlorine.

Trend _____

Explanation _____

_____

_____

(3)

(d) Explain why sodium has a lower melting point than magnesium.

_____

_____

_____

_____

(3)

(e) Sodium reacts with ammonia to form the compound $NaNH_2$ which contains the NH_2^- ion. Draw the shape of the NH_2^- ion, including any lone pairs of electrons.
Name the shape made by the three atoms in the NH_2^- ion.

Shape of NH_2^-

Name of shape _____

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(2)

(f) In terms of its electronic configuration, give **one** reason why neon does not form compounds with sodium.

_____

(1)

(Total 16 marks)

Q24.

(a) (i) Define the term *relative atomic mass* (A_r) of an element.

_____

_____

_____

_____

(2)

(ii) A sample of the metal silver has the relative atomic mass of 107.9 and exists as two isotopes. In this sample, 54.0% of the silver atoms are one isotope with a relative mass of 107.1

Calculate the relative mass of the other silver isotope.

State why the isotopes of silver have identical chemical properties.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(b) The isotopes of silver, when vaporised, can be separated in a mass spectrometer.

Name the **three** processes that occur in a mass spectrometer before the vaporised isotopes can be detected.

State how each process is achieved.

_____

_____

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(6)

(c) State the type of bonding involved in silver.

Draw a diagram to show how the particles are arranged in a silver lattice and show the charges on the particles.

(3)

(d) Silver reacts with fluorine to form silver fluoride (AgF).

Silver fluoride has a high melting point and has a structure similar to that of sodium chloride.

State the type of bonding involved in silver fluoride.

Draw a diagram to show how the particles are arranged in a silver fluoride lattice and show the charges on the particles.

Explain why the melting point of silver fluoride is high.

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(5)

(Total 20 marks)

Q25.

(a) Describe the bonding in, and the structure of, sodium chloride and ice. In each case draw a diagram showing how each structure can be represented. Explain, by reference to the types of bonding present, why the melting point of these two compounds is very different.

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(12)

(b) Explain how the concept of bonding and non-bonding electron pairs can be used to predict the shape of, and bond angles in, a molecule of sulfur tetrafluoride, SF_4. Illustrate your answer with a diagram of the structure.

(8)

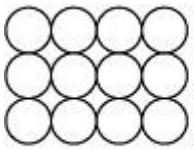
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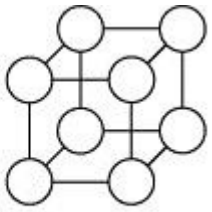
Q26.

At room temperature, both sodium metal and sodium chloride are crystalline solids which contain ions.

(a) On the diagrams for sodium metal and sodium chloride below, mark the charge for each ion.



Sodium metal



Sodium chloride

(2)

(b) (i) Explain how the ions are held together in solid sodium metal.

_____

_____

(ii) Explain how the ions are held together in solid sodium chloride.

_____

_____

(iii) The melting point of sodium chloride is much higher than that of sodium metal. What can be deduced from this information?

_____

_____

(3)

(c) Compare the electrical conductivity of solid sodium metal with that of solid sodium chloride. Explain your answer.

Comparison _____

_____

Explanation _____

_____

_____

(3)

(d) Explain why sodium metal is malleable (can be hammered into shape).

_____

_____

(1)

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(e) Sodium chlorate(V), $NaClO_3$, contains 21.6% by mass of sodium, 33.3% by mass of chlorine and 45.1% by mass of oxygen.

(i) Use the above data to show that the empirical formula of sodium chlorate(V) is $NaClO_3$

_____

_____

_____

_____

_____

(ii) Sodium chlorate(V) may be prepared by passing chlorine into hot aqueous sodium hydroxide. Balance the equation for this reaction below.

..... Cl_2 + ... NaOH → ..... NaCl + $NaClO_3$ + $3H_2O$

(3)

(Total 12 marks)

Q27.

Phosphorus exists in several different forms, two of which are white phosphorus and red phosphorus. White phosphorus consists of P_4 molecules, and melts at 44°C. Red phosphorus is macromolecular, and has a melting point above 550°C.

Explain what is meant by the term *macromolecular*. By considering the structure and bonding present in these two forms of phosphorus, explain why their melting points are so different.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(Total 5 marks)

Q28.

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Diamond and graphite are both forms of carbon.
Diamond is able to scratch almost all other substances, whereas graphite may be used as a lubricant. Diamond and graphite both have high melting points.

Explain each of these properties of diamond and graphite in terms of structure and bonding. Give **one** other difference in the properties of diamond and graphite.

(Total 9 marks)

Q29.

Iodine and diamond are both crystalline solids at room temperature. Identify one similarity in the bonding, and one difference in the structures, of these two solids. Explain why these two solids have very different melting points.

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_____

_____

_____

_____

_____

_____

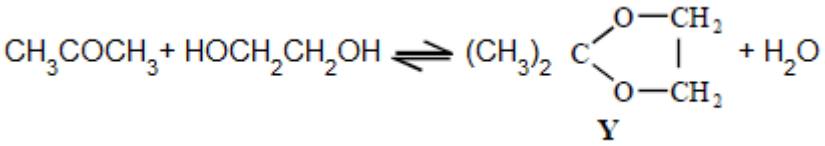
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_____

(Total 6 marks)

Q30.

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



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)

Q31.

(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.

_____

_____

_____

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(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)

Q32.

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

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(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.

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_____

_____

(3)

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

_____

_____

_____

(2)

(Total 17 marks)

Q33.

(a) (i) Describe the bonding in a metal.

_____

_____

_____

(ii) Explain why magnesium has a higher melting point than sodium.

_____

_____

_____

(4)

(b) Why do diamond and graphite both have high melting points?

_____

_____

_____

_____

(3)

(c) Why is graphite a good conductor of electricity?

_____

(1)

(d) Why is graphite soft?

_____

_____

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(2)

(Total 10 marks)

Q34.

Which one of the following does **not** contain any delocalised electrons?

A poly(propene)

B benzene

C graphite

D sodium

(Total 1 mark)

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