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.

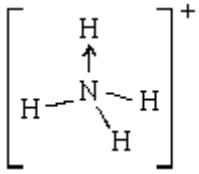
(4)

(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?

_____

_____

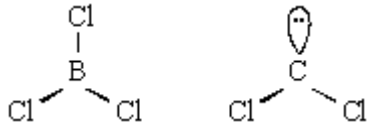
(2)

(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)

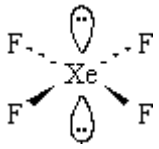
(b) Give the name which describes the shape of molecules having bond angles of 109° 28'.
Give an example of one such molecule.

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^-

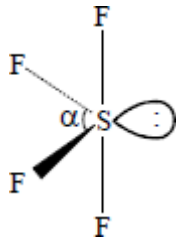
C ClF_2^-

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.

(a) **4**LiH + $AlCl_3$ → $LiAlH_4$ + **3**LiCl

1

(b) H^- = $1s^2$ **or** $1s_2$

1

(c) Tetrahedral or diagram

(Not distorted tetrahedral)

1

(Equal) <u>repulsion</u>

1

between four <u>bonding</u> pairs / <u>bonds</u>

(Not repulsion between H atoms loses M2 and M3)

(Not 'separate as far as possible')

('4' may be inferred from a correct diagram)

1

(d) Dative (covalent) or coordinate

1

Lone pair **or** non-bonding pair of electron **or** both e^-

1

QoL Donated from H^- to Al **or** shared between H and Al

(tied to M2)

(Not 'from H atom') (Not 'to Al ion') (Not 'e^-s transferred')

1

[8]

Q2.

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

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

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

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

*The explanation **must** be based on **<u>intermolecular</u>** forces/attractions*

Note: if the explanation is <u>clearly</u> <u>intramolecular</u> = CE

4

(b) Electron <u>pair</u> **or** lone <u>pair</u> donated **(1)**

Do not accept 'donation of electrons'

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

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

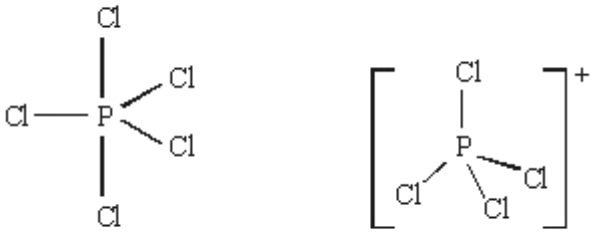
Ignore missing charge

2

(c)

4

PCl_5 PCl_4^+



(1) **(1)**

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

Bond Angle(s) 90° and 120° **(1)**

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

Bond angle(s) 109 or 109.5° **(1)**

[10]

Q3.

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

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

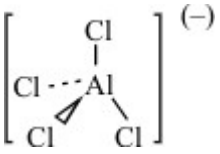


Wrong symbols - no diagram mark

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

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

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



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

QoL may be awarded here also

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Mark all points independently

8

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

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

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

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

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

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

4

[12]

Q4.

(a) (i) Covalent **(1)**

(ii) Co-ordinate **(1)** (or dative)

(iii) Both / two / pair electrons come from nitrogen **(1)**

(iv) 4 bonding / electron pairs **(1)**

repel equally **(1)**

OR are identical

as far apart as possible **(1)**

OR to position of minimum repulsion

tetrahedron **(1)**

7

(b) Power (or ability) of an element / atom to attract electron pair/electrons/ an electron/electron density **(1)**

in a covalent bond **(1)**

Allow attract from, withdraw in, do not allow remove from, withdraw from.

2

(c) (i) Electron deficient **(1)**

Or small, slight, partial positive charge

(ii) H < N **(1)**

2

[11]

Q5.

(a) (i) 3 (bonding) pairs of electrons **(1)**

allow 3 bonds

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repel equally **(1)** *(or as much as possible)*

Or get as far apart as possible

(ii) *Predicted bond angle:* 118° *(allow 117 - 119°)* ***(1)***
Explanation: lone pair ***(1)***
repels more than bonding pair ***(1)***

Allow EXP if ∠ < 118°
but C.E. = 0 if ∠ ≥ 120°

5

(b) *Name of shape:* Tetrahedral **(1)**
Example: CH_4 etc **(1)**

Allow correct ion

2

(c) (i) 90° **(1)**

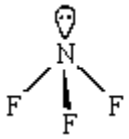
(ii) lone pairs (or they) repel more than bonding pairs (or most) **(1)**
(so are) as far apart as possible **(1)**

Mark independently

(iii) square planar **(1)**

allow square

4

(d) 

3 bonds + 1 lone pair **(1)**
correct shape **(1)**
(
only give this mark if first mark also given

Penalise sticks (i.e. N-) once but N must be shown

2

[13]

Q6.

C

[1]

Q7.

A

[1]

Q8.

C

[1]

Q9.

C

[1]

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Q1.

This question was, in general, also poorly answered. Of those candidates who attempted part (a), most were successful; however, a surprisingly large number of candidates made no attempt to balance the equation. Whilst, in part (b), most candidates gave the correct electronic arrangement for the hydride ion; $1s^0$ and $1s^12s^1$ were quite common errors. Candidates encountered many problems in deducing the shape of the $AlCl_4^-$ ion, with *trigonal planar*, *square planar* and *distorted tetrahedral* being the most common errors. Some candidates drew diagrams to illustrate their answer, many of which showed a lone pair on the Al atom. The explanation was frequently incomplete, or incorrectly referred to repulsions between *hydrogen atoms* or *hydride ions*, rather than between four bonding electron pairs. In part (d), many candidates were able to identify the bonding as dative/coordinate but then simply described, in general terms, the formation of such a bond. References to the donation of a lone pair from the hydride ion to the aluminium atom were relatively rare.

Q2.

This question produced many good answers. In part (a)(i), electronegativity was frequently quoted as the required property of the atoms. A reference to the 'high electronegativity of fluorine and chlorine' was accepted here but vague references to 'high electronegativity of the atoms' was not. Errors included simple references to 'unequal sharing', which did not address the question, and arguments based on the number of protons present in the nuclei. Many candidates provided acceptable explanations in part (a)(ii) but many confused attempts were also seen. Most candidates attributed the difference in boiling points to differences in the strength of intermolecular attractions but the types of attraction present in the two systems were quite frequently confused. It was not always clear that the forces described were intermolecular in nature. In part (b), the origin of a co-ordinate bond was well known, however, some candidates confused the direction of electron pair donation. The quality of drawing seen in part (c) varied considerably. Most diagrams proved to be acceptable but some were very poor. In some cases, the use of dotted lines and wedges to show the direction of the bonds was more of a hindrance than a help. It is recommended that candidates who intend to use these devices practice them beforehand. Some diagrams, especially that of $AlCl_4^-$ showed a lone pair, while other diagrams clearly indicated a planar structure. Most candidates were able to deduce the appropriate bond angles, but errors were not uncommon.

Q3.

The quality of answers offered by candidates in part (a) varied considerably. There were some very good and clear diagrams of the species but there were many poor ones also. A considerable number of the diagrams for the $AlCl_4^-$ ion showed a lone pair of electrons and some candidates described the dative bond as being a lone pair. The suggestion of a bond angle of 107° in the $AlCl_4^-$ ion was quite common. A few diagrams of the structure of SF_6 also contained lone pairs, nd in some cases bond angles of 60° or 120° were quoted. References to repulsion between fluorine or chlorine atoms are unacceptable but were still rather common. A considerable number of candidates performed a calculation to determine the number of electron pairs present in the species. Often, there was no indication of whether pairs were bonding or non-bonding pairs and in some instances candidates quoted such figures without reference to electrons at all. In many cases, explanations were rambling and lacking in precision. Few candidates attributed the regular shapes of the species to equal repulsion between specified numbers of bonding pairs, and so the marks allocated for the explanation of the shapes were frequently not earned.

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Some interesting answers to part (b) were seen. Many candidates experienced some difficulty in applying their understanding of 'changes of *state*' and '*behaviour of gases*' (specification section 10.3.4) in this somewhat novel context. While many correctly deduced that the energy required to vaporise the solvent was taken from the skin and so induced cooling, few candidates attempted to explain the meaning of the term *volatile solvent*. The spreading of the fragrant molecules by *diffusion* was frequently reported but few candidates attempted to explain why the fragrance would be detected *after a while*, rather than instantaneously.

Q4.

Most candidates gained high marks for this question. Parts (a) (i) to (iii) were usually correct but a surprising number of the weaker candidates suggested that N → H represented a hydrogen bond. Full marks for part (a) (iv) were seldom awarded. Despite the instruction about electron pairs in the question, some candidates referred to repulsion between hydrogen atoms rather than between electron pairs. Answers to parts (b) and (c) were of good quality.

Q5.

This question was answered better than question 2 but not as well as question 1. In part (a)(i) answers were usually incomplete. In this part and in part (a)(ii), weak candidates often referred to repulsion between chlorine atoms rather than between bonding and non-bonding electron pairs. Parts (b) and (c) (i) were usually correct but candidates had more difficulty answering part (c)(iii) where they did not recognise the square planar shape. Part (d) was usually correct.

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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.

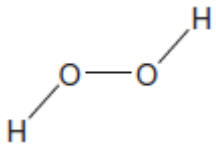
_____

(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 _____

_____

_____

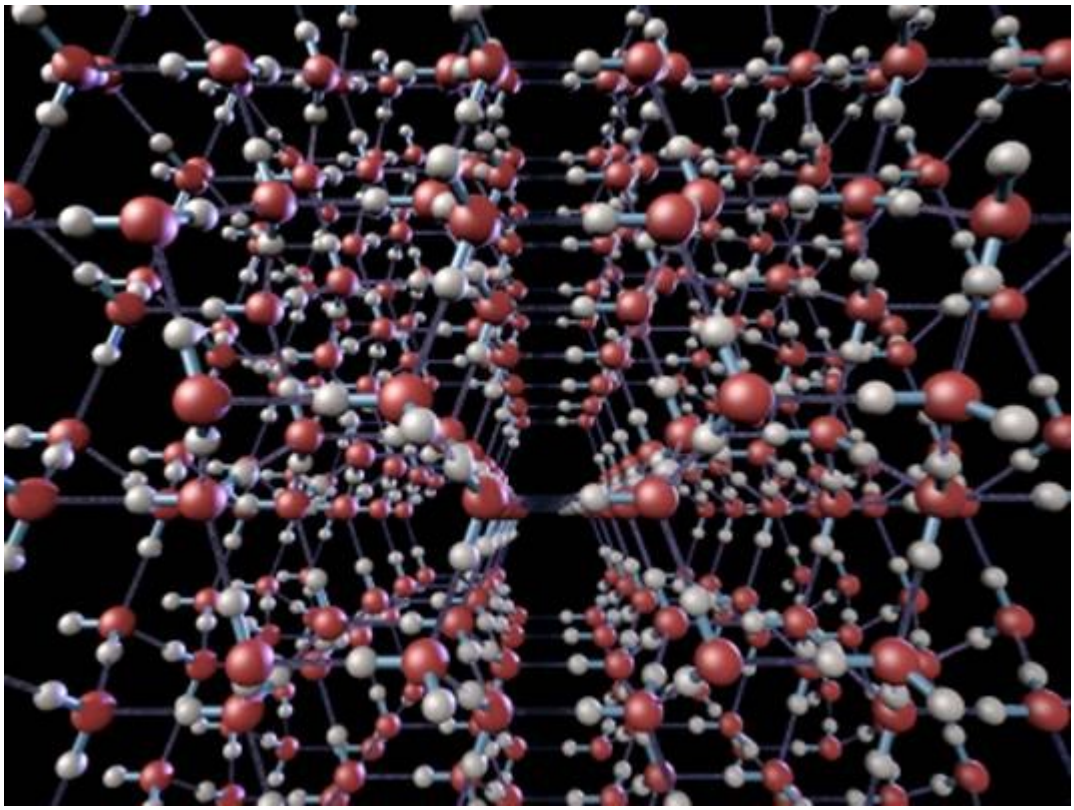
(2)

(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**.

_____

_____

_____

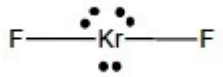
_____

(3)

(Total 9 marks)

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Q1.

(a) 

Allow diagram with 2 bonds <u>and</u> 3 lone pairs

1

<u>Linear</u>

1

<u>180°</u>

1

(b) Lone pairs repel more than bond pairs

1

Allow idea of reducing bond angle

bond angle will be lower (than regular tetrahedral angle) / bond angle of 103-106°

1

(c) Van der Waals forces

Allow London forces, dispersion forces, induced dipole-dipole

Apply List for M1.

Allow M2 if vdW mentioned in M1, otherwise CE=0

1

(Uneven distribution of electrons in) one molecule <u>induces</u> dipole in neighbouring/another/nearby <u>molecule</u>

1

symmetrical molecule / dipoles cancel

OR

no hydrogens bonded to F (N or O), therefore no hydrogen bonding

1

[8]

Q2.

This question is marked using Levels of Response. Examiners should apply a 'best-fit' approach to the marking.	
Level 3 5-6 marks	All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 and then stage 3. Coherent communication requires that there is a

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	comparison between the types of bonding and that the bonding is correct for each substance.
Level 2 3-4 marks	All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows some progression from stage 1 to stage 2 and then stage 3.
Level 1 1-2 marks	Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR only one stage is covered but the explanation is generally correct and virtually complete. Answer shows some progression between two stages
Level 0 0 marks	Insufficient correct chemistry to gain a mark.

Indicative chemistry content. Contradictions (eg molecules, IMFs, covalent bonding,) negate statements.

Stage 1 - **Na**
1a) Na has metallic bonding
1b) there is attraction/ bonding between the positive nucleus/ ion and the delocalised electrons in Na
1c) Na has a giant/lattice structure

Stage 2 – **NaBr or NaI**
2a) Ionic bonding in NaBr and/or NaI
2b) There is attraction/ bonding between the + and – ions in NaBr and/or NaI
2c) NaBr and/or NaI have a giant/lattice structure

Stage 2 – **comparison of bonding**
3a) The ionic bonds are stronger (or wtte) than the metallic bonds
3b) there is stronger attraction (or wtte) between the + and – ions in NaBr than in NaI
3c) since the Br^- ion is smaller than the I– ion

6

(b) **M1** $Na + H_2O \rightarrow NaOH + ½ H_2$

Allow multiples

1

M2 (Mass Na = 0.250 g so moles Na = 0.250/23.0) = 0.0109

CE: If not divided by 23, max 3/5 calculation marks – M3, M4 and M5

AE: If not divided by 1000 and final answer is 1.33 × 10^5 cm^3 4/5

1

M3 moles H_2 = 5.43 × 10^{-3} to 5.45 × 10^{-3}

M3 = M2 /2

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CE: If incorrect ratio used max 3/5 calculation marks – M2, M4 and M5

1

M4 T = 298 (K) and P = 101000 (Pa)

1

M5 V = nRT/P or (5.435 × 10^{-3} × 8.31 × 298)/101000 or 1.33 × 10^{-4} (m^3)

1

M6 V = 133 – 134 cm^3

Allow to 2 significant figures or more

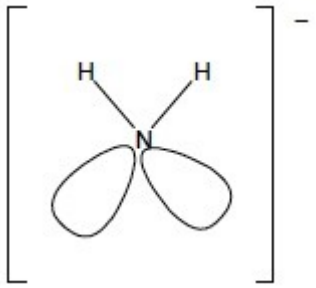
1

(c) Conc = 0.0109/ 500 × 10^{-3} = 0.0217-0.022 (mol dm^{-3})

Allow M2 from question (b)

1

(d) **M1**



Ignore charge and brackets

1

M2 104.5°

Allow 104-106

1

M3 (4) electron pairs repel to be as far apart as possible

1

M4 lp/lp repulsion> lp/bp repulsion (> bp/bp repulsion)

For M4 allow lone pairs repel more than bonding pairs

Mark independently

1

[16]

Q3.

B

[1]

Q4.

(a) Power of an atom to attract a pair of electrons in a covalent bond.

Allow power of an atom to attract a bonding/shared pair of electrons

Allow power of an atom to withdraw electron density from a covalent bond

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Not lone pair Not Element

1

(b) Difference in electronegativity leads to bond polarity

If chloride (ions) mentioned then CE = 0

1

(dipoles don't cancel therefore the molecule has an overall permanent dipole) and there is an attraction between $\partial+$ on one molecule and $\partial-$ on another

partial charges should be correct if shown and can score M2 from diagram

1

(c)

SiH_4	**Tetrahedral**		1 shape & no tick
PH_3	**Pyramidal (trigonal) Allow tetrahedral**	✓	1 shape & tick
$BeCl_2$	**Linear**		1 shape & no tick
CH_3Cl	**(Distorted)Tetrahedral**	✓	1 shape & tick

If shapes are drawn rather than named then penalise first mark gained

4

[7]

Q5.

C

[1]

Q6.

A

[1]

Q7.

(a) $SrCl_2$> ICl > Br>

If wrong can award 1 for one in the correct 'position'

2

$SrCl_2$ strong ionic bonds / (strong electrostatic attraction between opposite ions)

1

Lattice so many strong bonds to overcome

1

ICl has dipole-dipole between molecules – weaker than ionic bonds

1

Br_2 has van der Waals forces between molecules – much weaker

Accept London / dispersion / induced dipole forces

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1

(b) $Cl_2 + H_2O \rightleftharpoons HCl + HClO$

OR *$2Cl_2 + 2H_2O \rightleftharpoons O_2 + 4HCl$*

OR $Cl_2 + H_2O \rightleftharpoons 2H^+ + Cl^- + ClO^-$

1

Kills bacteria

1

Wasteful as most potable water not used for drinking - used in washing clothes etc

OR Some people suffer eye irritation / Some people find the taste unpleasant

OR can react with organic compounds to produce harmful substances

Allow 'it is potentially toxic as it can be if over concentrated'

1

(c) $6Br_2 + P_4 \longrightarrow 4PBr_3$

Accept 4P for P_4

1

Pyramidal shown in a diagram (but the name of the shape isn't needed)

1

100–108°

Actual value is 101° (hence larger range of values allowed)

1

(d) Tetrahedral shown in a diagram (but the name of the shape isn't needed)

1

109.5°

Accept 109° or 109°28'

1

[14]

Q8.

C

[1]

Q9.

(a) [Kr] $5s^2\ 4d^{10}5p^5$

1

(b) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3
All stages are covered and the explanation of each stage is correct and complete.

Answer communicates the whole explanation coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

5-6 marks

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Level 2
All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies **OR** two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression through the stages. Some steps in each stage may be out of order and incomplete.

3-4 marks

Level 1
Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, **OR** only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

Level 0
Insufficient correct chemistry to warrant a mark.

0 marks

Indicative Chemistry content

Stage 1

I_2 is molecular.

HI is molecular.

Stage 2

IMF hold the molecules together.

There are weak IMF forces hence the melting point is low in both substances.

I_2 bigger molecule than HI so I_2 has more electrons.

Stage 3

Therefore stronger van der Waals between molecules in I_2 that need more energy to break causing the melting point to be higher.

HI also shows permanent dipole-dipole attraction between molecules but these forces are less than the vdW forces in iodine.

6

(c) No delocalised electrons or ions

1

(d) $\frac{1}{2}H_2 + \frac{1}{2}I_2 \longrightarrow HI$

Allow multiples

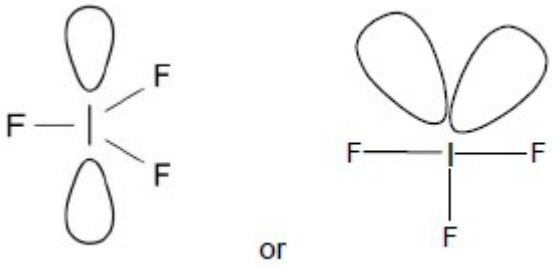
1

(e) NH_4I_3

1

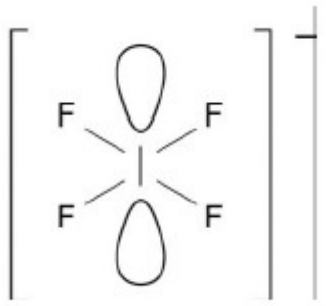
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(f)



Allow any shape with 3 bond pairs and 2 lone pairs

1



Allow any shape with 4 bond pairs and 2 lone pairs (e.g. lone pairs in equatorial positions)

1

(g) +5

1

+7

1

[14]

Q10.

(a) $C(s) + 2F_2(g) \longrightarrow CF_4(g)$

State symbols essential

1

(b) Around carbon there are 4 bonding pairs of electrons (and no lone pairs)

1

Therefore, these repel equally and spread as far apart as possible

1

(c) $\Delta H = \Sigma\ \Delta_f H$ products $- \Sigma\ \Delta_f H$ reactants or a correct cycle

1

Hence = (2 × –680) + (6 × –269) – (x) = –2889

1

x = 2889 – 1360 – 1614 = –85 (kJ mol^{-1})

1

Score 1 mark only for +85 (kJ mol^{-1})

(d) Bonds broken = 4(C–H) + 4(F–F) = 4 × 412 + 4 × F–F

Bonds formed = 4(C–F) + 4(H–F) = 4 × 484 + 4 × 562

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Both required

1

$-1904 = [4 \times 412 + 4(F–F)] – [4 \times 484 + 4 \times 562]$

$4(F–F) = -1904 – 4 \times 412 + [4 \times 484 + 4 \times 562] = 632$

1

$F–F = 632 / 4 = 158$ (kJ mol^{-1})

1

The student is correct because the F–F bond energy is much less than the C–H or other covalent bonds, therefore the F–F bond is weak / easily broken

Relevant comment comparing to other bonds

(Low activation energy needed to break the F–F bond)

1

[10]

Q11.

B

[1]

Q12.

(a) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 then stage 3.

Level 3
5 – 6 marks

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows progression from stage 1 to stage 3.

Level 2
3 – 4 marks

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete

Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

Level 1
1 – 2 marks

Insufficient correct chemistry to gain a mark.

Level 0
0 marks

Indicative chemistry content

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Stage 1: Electrons round P
- P has 5 electrons in the outside shell
- With 3 electrons from 3 fluorine, there are a total of 8 electrons in outside shell
- so 3 bond pairs, 1 non-bond pair

Stage 2: Electron pair repulsion theory
- Electron pairs repel as far as possible
- Lone pair repels more than bonding pairs

Stage 3: Conclusions
- Therefore, tetrahedral / trigonal pyramidal shape
- With angle of 109(.5)° decreased to 107°

6

(b) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^7$

Allow correct numbers that are not superscripted

1

(c) Too many electrons in d sub-shell / orbitals

1

(d) Tetrahedral (shape)

1

109.5°

Allow 109°

1

[10]

Q13.

(a) Correct diagram of NH_3 including LP on N

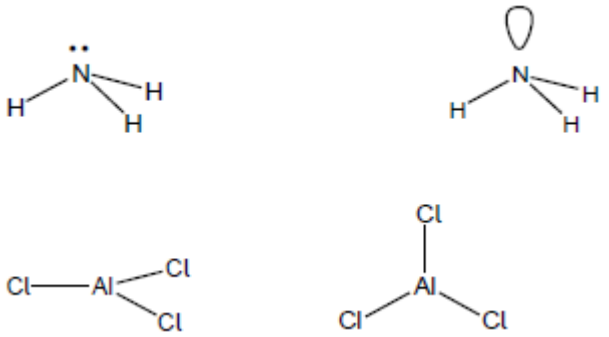
1

Correct diagram of $AlCl_3$

1

Bond angles in range 106-108° and bond angle of 120°

1



Ignore shape names

(b) Dative (covalent) /co-ordinate bond

Wrong bond CE=0 but mark on if covalent quoted

1

Shared pair of / both electrons come from the $N(H_3)$

1

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(c) Aluminium is now surrounded by 4 electron pairs/bonds or is tetrahedral

Independent

1

Therefore Cl-Al-Cl bond angle decreases / changes
(from 120° in $AlCl_3$) to allow range 107-111° in H_3NAlCl_3

1

[7]

Q14.

(a) Electron movement in first molecule / temporary dipole

Allow description

1

Induces a dipole in another molecule

Allow description

1

(Induced-temporary) attraction or δ+ attracts δ- in different/adjacent molecules

M3 dependent on M1 <u>and</u> M2

Allow electrostatic attraction

M3 could be scored in diagram

If other type of force / metallic / ionic / polar bonds / permanent dipoles / difference in electronegativity mentioned CE = 0

1

(b) (i) (Methanol) H-bonds / hydrogen bonding

1

(Methanethiol) dipole-dipole forces or van der Waals

1

H-bonds are a strong<u>er</u> / are the strongest IMF

Allow H-bonds require more energy to overcome

If M1 and M2 not scored, allow 1 for methanol has stronger IMFs

If breaking covalent bonds then CE=0

1

(ii) (Fractional) distillation

Allow description

Do not allow heating unqualified

1

(c) (Methaneselenol is a) bigger molecule / larger Mr / larger no of electrons / Se bigger atom

1

With <u>stronger/more</u> <u>vdw</u> forces <u>between molecules</u>

If breaking covalent bonds then CE=0

1

(d) (i)

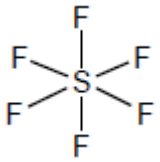


Diagram showing 6 bond pairs

1

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(Bond angle) 90° for SF_6

Ignore 180°

1

Octahedral

1

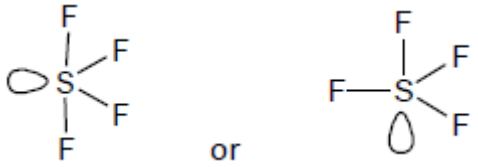


Diagram showing 4 bond pairs <u>and 1 lone pair</u>

1

(Bond angles) for SF_4

If shape of SF_4 is not based on 4 bond pairs <u>and 1 lone pair</u> cannot score M4 or M5

Any **two** from:
Allow 85 – 89°

Do not allow 90°

Allow 100 – 119°

Do not allow 120°

Allow 170 – 179°

Do not allow 180°

2

(ii) NaCl (as product in any equation)

1

$3\ SCl_2 + 4\ NaF \rightarrow SF_4 + S_2Cl_2 + 4\ NaCl$

Allow multiples

Ignore states

1

[17]

Q15.

(a) Silicon / Si

If not silicon then CE = 0 / 3

1

<u>covalent</u> (bonds)

M3 dependent on correct M2

1

Strong or many of the (covalent) bonds need to be <u>broken</u> / needs a lot of energy to <u>break</u> the (covalent) bonds

Ignore hard to break

1

(b) Argon / Ar

If not argon then CE = 0 / 3. But if Kr chosen, lose M1 and allow M2+M3

1

Large(st) number of protons / large(st) nuclear charge

Ignore smallest atomic radius

1

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Same amount of shielding / same number of shells / same number of energy levels

Allow similar shielding

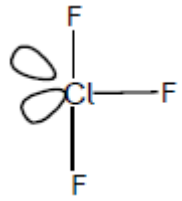
1

(c) Chlorine / Cl

*Not Cl_2, Not C**L**, Not Cl^2*

1

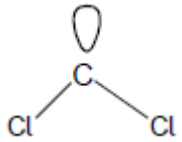
(d) (i)



Or any structure with 3 bonds and 2 lone pairs

Ignore any angles shown

1



Or a structure with 2 bonds and 1 lone pair

1

(ii) Bent / v shape

Ignore non-linear, angular and triangular

Apply list principle

1

(iii) $\frac{1}{2}Cl_2 + \frac{3}{2}F_2 \longrightarrow ClF_3$

No multiples

Ignore state symbols

1

[11]

Q16.

(a) 94−105.5°

1

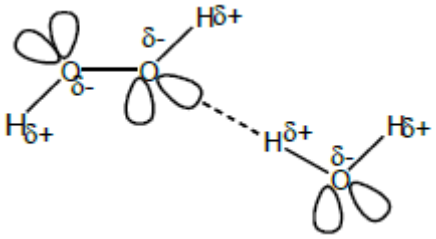
(b) (i) Hydrogen bond(ing) / H bonding / H bonds

Not just hydrogen

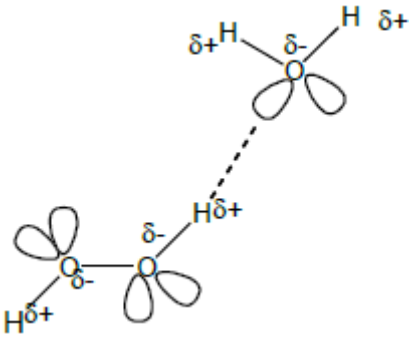
1

(ii)

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OR



1 mark for all lone pairs

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

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

3

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

Mark independently

1

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

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

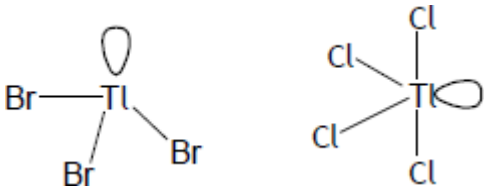
If breaking covalent bonds CE = 0

1

[7]

Q17.

(a)



Mark is for correct number of bonds and lone pair in each case.

Ignore charges if shown.

2

Pyramidal / trigonal pyramid

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Allow tetrahedral.

1

107°

Allow 107 to 107.5°.

1

(b) M1 Ionic

CE = 0 / 3 if not ionic.

1

M2 Oppositely charged ions / Tl^+ and Br^- ions

If molecules / intermolecular forces / metallic bonding, CE=0.

1

M3 <u>Strong attraction</u> between ions

M3 dependent on M2.

Allow 'needs a lot of energy to break / overcome' instead of 'strong'.

1

(c) $Tl + \frac{1}{2}Br_2 \longrightarrow TlBr$

Allow multiples.

Ignore state symbols even if incorrect.

1

[8]

Q18.

(a) $Al + 1.5Cl_2 \rightarrow AlCl_3$

Accept multiples.

Also $2Al + 3Cl_2 \rightarrow Al_2Cl_6$

Ignore state symbols.

1

(b) Coordinate / dative (covalent)

If wrong CE=0/2 if covalent mark on.

1

<u>Electron pair on Cl^- donated to Al</u>(Cl_3)

QoL

Lone pair from Cl^- not just Cl

Penalise wrong species.

1

(c) Al_2Cl_6 or $AlBr_3$

Allow Br_3Al or Cl_6Al_2

Upper and lower case letters must be as shown.

Not $2AlCl_3$

1

(d) $SiCl_4$ / silicon tetrachloride

Accept silicon(4) chloride or silicon(IV) chloride.

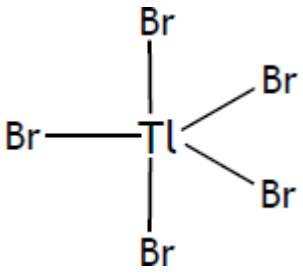
Upper and lower case letters must be as shown.

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Not silicon chloride.

1

(e)



Accept shape containing 5 bonds and no lone pairs from Tl to each of 5 Br atoms.

Ignore charge.

1

Trigonal bipyramid(al)

1

(f) (i) Cl — Tl — Cl

Accept this linear structure only with no lone pair on Tl

1

(ii) (Two) bonds (pairs of electrons) repel equally / (electrons in) the bonds repel to be as far apart as possible

Dependent on linear structure in (f)(i).

Do not allow electrons / electron pairs repel alone.

1

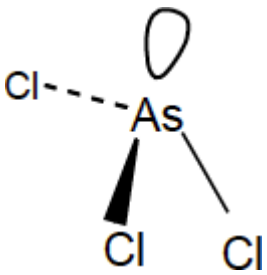
(g) Second

1

[10]

Q19.

(a)



Mark is for 3 As-Cl bonds and 1 lone pair

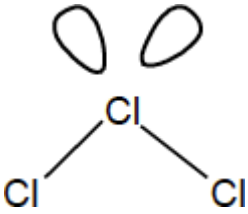
1

(Trigonal) pyramid(al) / tetrahedral

Allow triangular pyramid

1

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Mark is for 2 Cl-Cl bonds and 2 lone pairs
Do not penalise if + not shown

1

Bent / V-shaped / triangular

Not trigonal

1

(b) There are 4 bonds or 4 pairs of electrons (around As)

Can show in a diagram. If lone pair included in shape, CE = 0 / 2

1

(Electron pairs / bonds) repel equally

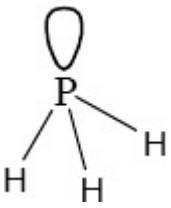
QoL

1

[6]

Q20.

(a)



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

1

(b) Coordinate / dative

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

1

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

Do not allow a generic description of a coordinate bond.

1

(c) 109.5° / 109½ / 109° 28☐

Allow answers in range between 109° to 109.5°

1

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

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

Do not allow phosphine is not very electronegative.

1

[5]

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Q21.

(a) P = 100 000 (Pa) and V = 5.00 x 10^{-3} (m^3)

M1 is for correctly converting P and V in any expression or list Allow 100 (kPa) and 5 (dm^3) for M1.

1

$$n = \frac{PV}{RT} = \frac{100\ 000 \times 5.00 \times 10^{-3}}{8.31 \times 298}$$

M2 is correct rearrangement of PV = nRT

1

= 0.202 moles (of gas produced)

This would score M1 and M2.

Therefore $\frac{0.202}{5}$ = 0.0404 moles B_2O_3

M3 is for their answer divided by 5

1

Mass of B_2O_3 = 0.0404 x 69.6

M4 is for their answer to M3 x 69.6

1

= <u>2.81</u> (g)

M5 is for their answer to 3 sig figures.

2.81 (g) gets 5 marks.

1

(b) B + 1.5 Cl_2 → BCl_3

Accept multiples.

1

<u>3</u> bonds

1

Pairs repel <u>equally</u>/ by the <u>same amount</u>

Do not allow any lone pairs if a diagram is shown.

1

(c) (i) 43.2/117.3 (= 0.368 moles BCl_3)

1

0.368 x 3 (= 1.105 moles HCl)

Allow their BCl_3 moles x 3

1

Conc HCl = $\frac{1.105 \times 1000}{500}$

Allow moles of HCl × 1000 / 500

1

= <u>2.20 to 2.22</u> mol dm^{-3}

Allow 2.2

Allow 2 significant figures or more

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1

(ii) $H_3BO_3 + 3NaOH \rightarrow Na_3BO_3 + 3H_2O$

Allow alternative balanced equations to form acid salts.

Allow $H_3BO_3 + NaOH \rightarrow NaBO_2 + 2H_2O$

1

(d) $\frac{10.8}{120.3}(\times 100)$

Mark is for both M_r values correctly as numerator and denominator.

1

8.98(%)

Allow 9(%).

1

Sell the HCl

1

(e) Alternative method

Cl = 86.8%

Cl = 142 g

1

B Cl

$\frac{13.2}{10.8}$ $\frac{86.8}{35.5}$

B *Cl*

$\frac{21.6}{10.8}$ $\frac{142}{35.5}$

1

1.22 *2.45 or ratio 1:2 or BCl_2*

2:4 ratio

1

BCl_2 has M_r of 81.8 so
81.8 x 2 = 163.6
Formula = B_2Cl_4

B_2Cl_4

Allow 4 marks for correct answer with working shown.

Do not allow $(BCl_2)_2$

1

[20]

Q22.

(a) Covalent

If not covalent CE = 0/2

If dative covalent CE = 0/2

If blank mark on

Ignore polar

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If number of pairs of electrons specified, must be 3

1

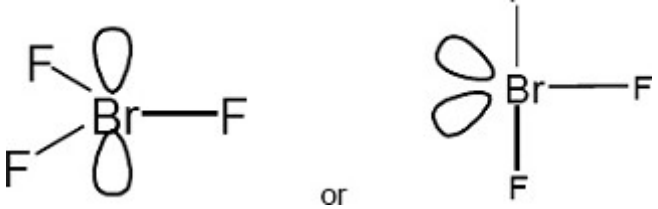
Shared <u>pair</u>(s) of electrons / one electron from Br and one electron from F

Not 2 electrons from 1 atom

Not shared pair between ions/molecules

1

(b) (i)



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

Penalise Fl

1

BrF_3 if trigonal planar shown = 120°

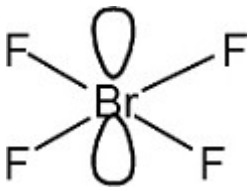
Allow 84 – 90° or 120° and ignore 180°

or if T shape shown 84 – 90°

Irrespective of shape drawn

1

(ii)



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

Allow Fl

1

BrF_4^- 90°

Only

Ignore 180°

1

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

If molecules, IMF, metallic, CE =0

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

Ignore atoms

1

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

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1

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

If ions mentioned they must be correct

Strong bonds between + and – ions =3/3

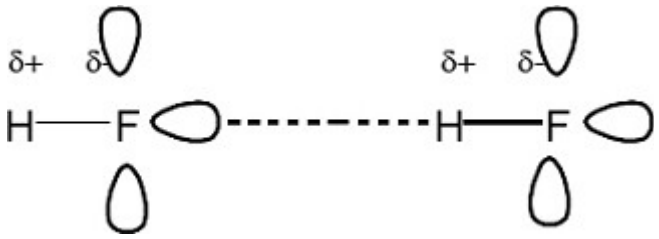
1

(d) (i) Hydrogen bonds/hydrogen bonding/H bonds/H bonding

Not just hydrogen

1

(ii)



One mark for 4 partial charges

One mark for 6 lone pairs

One mark for H bond from the lone pair to the Hδ+

Allow Fl

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

CE = 0/3 if incorrect molecules shown.

3

(e) vdw / van der Waals forces between molecules

QoL

Not vdw between HF molecules, CE = 0/2

vdw between atoms, CE = 0/2

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

1

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

1

[15]

Q23.

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

1

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

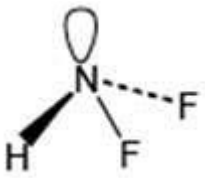
1

Stronger VdW intermolecular forces = M2

If stated VdW between atoms lose M2

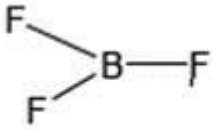
(b) (i)

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

1



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

1

NHF_2 shape - pyramidal / trigonal pyramid

Accept tetrahedral / triangular pyramid

1

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

Not triangular or triangular planar

1

(ii) 107°

Allow 106-108°

1

(c) Hydrogen bonds

Allow H-Bonds

Not just Hydrogen

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

1

(d) Coordinate / dative covalent / dative

If covalent mark on

If ionic / metallic CE = 0

1

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

Direction of donation needed here

1

[10]

Q24.

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

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

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CE if holes filled with air, O_2 etc

CE if macromolecule

CE if <u>atoms</u> further apart (since ambiguous)

Ignore spaces filled with H_2O

Ignore reference to H bonds

Allow better tessellation in liquid water

1

(b) (i) Hydrogen bonding

Allow H bonds

Do not allow 'hydrogen' only but mark on

1

(ii) Van der Waals'/VdW

Allow London forces, dispersion forces, temporary induced dipole forces

1

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

Not H Bonds are strong (needs comparison)

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

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

1

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

1

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

do not insist on the + sign

Allow triangular pyramid

Not square pyramid

Ignore bond angles in structure

M2 independent of M1

1

(ii) 107°

Allow range 106 – 108°

Ignore °(C)

1

(iii) NH_3/ammonia

Contradictions (eg NH_4 ammonia) CE = 0

1

(d) 3

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

1

[9]

Q25.

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

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

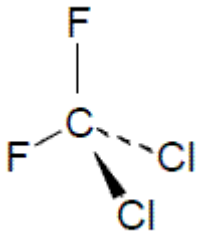
1

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

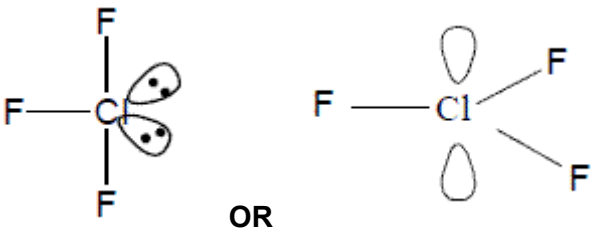
1

Only
Ignore state symbols even if wrong

(b)

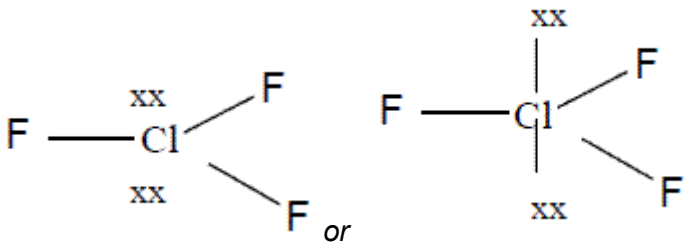


1



OR

Allow any structure with 4 bp
In $CClF_2$, watch for Cl in centre- it must be C
Ignore wrong bond angles
Representations of lone pairs allowed are the two examples shown with or without the electrons in the lobe.
Also they can show the lone pair for either structure by two crosses/dots or a line with two crosses/dots on it e.g.



Or a structure with 3 bp and 2 lp

1

(c) Dipole – dipole

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

1

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

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

1

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

CE if lone pair is from B

1

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

Must have the – sign on the F ie F^-
Ignore Fl^-
M3 dependent on M2

1

(ii) 109° to 109.5°

1

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

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

1

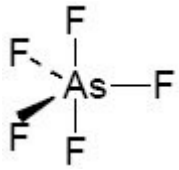
= 54.3%

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

1

[11]

Q26.



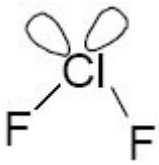
Mark M1 – M5 independently
M1 for 5 bond pairs around As
Do not penalise A for As or Fl for F

1

trigonal/triangular bipyramid(al)

Allow trigonal dipyramid

1



M3 for 2 bond pairs to F and 2 lone pairs
Lone pairs can be shown as lobes with or without electrons or as xx or

$\underline{x}$ -
x

1

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Bent/V shape/non-linear/triangular/angular

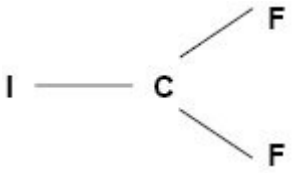
Bent-linear = contradiction
Do not allow trigonal

1

104° – 106°

1

(For candidates who thought this was ClF_2^+ which contained iodine allow



Trigonal/triangular planar

Not just triangular

120°

[5]

Q27.

(a) $2s^2\ 2p^6$;

If ignored the $1s^2$ given and written $1s^2 2s^2 2p^6$ mark as correct
Allow capitals and subscripts

1

(b) (i) $Na^+(g) \rightarrow Na^{2+}(g) + e^{(-)}$;

One mark for equation and one mark for state symbols

$Na^+(g) + e^{(-)} \rightarrow Na^{2+}(g) + 2e^{(-)}$;

M2 dependent on M1
Allow $Na^+(g) - e^{(-)} \rightarrow Na(g)$
Allow $X^+(g) \rightarrow X^{2+}(g) + e$ = 1 mark

2

(ii) $Na^{(2+)}$ requires loss of e^- from a 2(p) orbital or 2nd energy level or 2nd shell and $Mg^{(2+)}$ requires loss of e^- from a 3(s) orbital or 3rd energy level or 3rd shell / $Na^{(2+)}$ loses e from a lower (energy) orbital/ or vice versa;

Not from 3p

1

Less shielding (in Na);

Or vice versa for Mg

1

$e^{(-)}$ closer to nucleus/ more attraction (of electron to nucleus) (in Na);

M3 needs to be comparative

1

(iii) Aluminium /Al;

1

(c) Decreases;

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If not decreases CE = 0
If blank, mark on

1

Increasing nuclear charge/ increasing number of protons;

1

Electrons in same shell or level/ same shielding/ similar shielding;

1

(d) Answer refers to Na;

Allow converse answers relating to Mg.

Na fewer protons/smaller nuclear charge/ fewer delocalised electrons;

Allow Mg is 2+ and Na is +.
If vdw CE = 0.

1

Na is a bigger ion/ atom;

1

Smaller attraction between nucleus and delocalised electrons;

If mentioned that charge density of Mg^{2+} is greater then allow first 2 marks.
(ie charge / size / attraction).
M3 allow weaker metallic bonding.

1

(e) (Bent) shape showing 2 lone pairs + 2N−H bond pairs;

Atoms must be labelled.
Lone pairs can be with or without lobes.

1

Bent / v shape/ triangular;

Not tetrahedral.
Allow non-linear.
Bent-linear = contradiction.

1

(f) Ne has full sub-levels/ can't get any more electrons in the sub-levels/ Ne has full shells;

Not $2s^2\ 2p^6$ alone.
Not stable electron configuration.

1

[16]

Q28.

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

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

1

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

Not distort
Not remove electrons

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1

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

1

Hydrogen bonds/H bonds;

Not just hydrogen

1

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

Insufficient to say N= 3.1 and H = 2.1

1

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

Not N becomes (fully) negative or vice versa

1

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

QWC
Can score M2 and 3 from a diagram

1

(d) Co-ordinate/dative;

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

1

Both electrons/ lone pair (on P/PH_3)

Not lone pair on hydrogen

1

Shares/donated from P(H_3)/ to H(δ+);

1

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

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

1

Pyramidal/tetrahedral/ trigonal pyramidal;

Not bipyramidal/triangular

1

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

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

1

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

Accept multiples

1

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[14]

Q29.

(a) NaCl is ionic

1

cubic lattice

1

ions placed correctly

1

electrostatic attraction between ions

1

Covalent bonds between atoms in water

1

Hydrogen bonding between water molecules

1

Tetrahedral representation showing two covalent and two hydrogen bonds

1

2 hydrogen bonds per molecule

1

Attraction between ions in sodium chloride is very strong

1

Covalent bonds in ice are very strong

1

Hydrogen bonds between water molecules in ice are much weaker

1

Consequently, less energy is required to break the hydrogen bonds in ice to form separate water molecules than to break the ionic bonds in sodium chloride and make separate ions

1

(b)

Mark Range	The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question **Descriptor** an answer will be expected to meet most of the criteria in the level descriptor
3	– claims supported by an appropriate range of evidence – good use of information or ideas about chemistry, going beyond those given in the question – argument well structured with minimal repetition or irrelevant points – accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling
2	– claims partially supported by evidence – good use of information or ideas about chemistry given in the

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	question but limited beyond this – the argument shows some attempt at structure – the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling
0-1	– valid points but not clearly linked to an argument structure – limited use of information or ideas about chemistry – unstructured – errors in spelling, punctuation and grammar or lack of fluency

4 bonding electron pairs **1**

and one lone pair **1**

repel as far apart as possible QWC **1**

lone pair - bond pair repulsion > bp—bp QWC **1**

pushes S-F bonds closer together **1**

shape is trigonal bipyramidal with lone pair either axial or equatorial QWC **1**

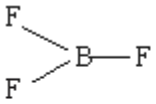
angles <90 **1**

and < 120 **1**

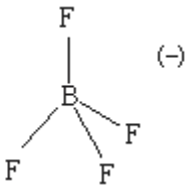
[20]

Q30.

(i)



(1)



(1)

[Do not allow shapes which show a lone pair] **2**

BF_3 Trigonal planar/planar triangular
[Not plane triangle] **1**

BF_4^- Tetrahedral
[Not distorted tetrahedral] **1**

Equal repulsion between (4) bonding pairs/bonds/bonding electrons **1**

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109(½)°

1

(ii) Lone pair donated / both electrons supplied by <u>one atom</u>

1

from F^- (to B)

[ignore missing charge or fluorine or 'atom']

1

dative/dative covalent/coordinate bonding

1

[9]

Q31.

A

[1]

Q32.

(penalty for sig fig error =1 mark per question)

(a) neutron: relative mass = 1 relative charge = 0

(not 'neutral')

1

electron: relative mass = 1/1800 → 0/negligible *or*

5.56 × 10–4 → 0 relative charge = –1

1

(b) $^{17}O/O^{17}$ mass number (*Do not accept 17.0*)

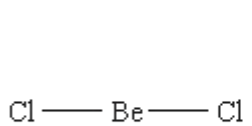
1

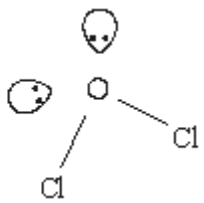
oxygen symbol 'O'

(if 'oxygen' + — 'mass number = 17'(1))
(if 'oxygen'+ — 'mass number = 17'(0))
(if at N^0 given but ≠ 8, treat as 'con' for M2)
(if lp on Be, diagram = 0)
(ignore bond angles)
(not dot and cross diagrams)

1

(c)





2

QoL Linear **(1)** bent / V-shaped / angular **(1)**

(mark name and shape independently)
(accept (distorted) tetrahedral)

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(if balls instead of symbols, lose M1 – can award M2)
(penalise missing 'Cl' once only)
(not 'non-linear')

2

(d) M_r ($Mg(NO_3)_2$ = 58(.3) *(if At N⁰ used, lose M1 and M2)*

1

moles $Mg(OH)_2$ = 0.0172 (conseq on wrong M2) (answer to 3+ s.f.)

1

moles HCl = 2 × 0.0172 = 0.0344 *or* 0.0343 (mol) *(process mark)*

1

vol HCl = $\frac{0.0343 \times 1000}{1}$ = 34.3 – 34.5 (cm^3) *(unless wrong unit)*
*(if candidate **used** 0.017 or 0.0171 lose M2)*
(just answer with no working, if in range = (4).
if, say, 34 then =(2))
(if not 2:1 ratio, lose M3 and M4)
(if work on HCl, CE = 0/4)

1

[12]

Q33.

(a) dative / coordinate (covalent) bond;

1

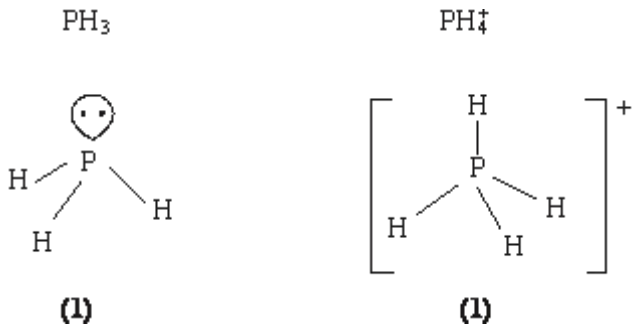
Lone/non-bonding pair / both electrons;

1

(donated) from P to H^+;

1

(b)



(1) (1)

pyramidal *OR* trigonal pyramid 109($^{1/2}$)°;
(accept tetrahedral)

4

[7]

Q34.

B

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[1]

Q35.

(a) (i) $2Na + 2NH_3 \rightarrow 2NaNH_2 + H_2$

(or multiples)

1

(ii) (Missing 'H' penalise once only) [NOT dot-and-cross diagrams]



1

[NOT 90° / 180° angles] (need 2 lp & 'bent' shape)

1

(iii) <u>107°</u>

1

(iv) More lone pairs on NH_2^-, than on NH_3

1

Lone pairs repel more than bonding pairs

Must be comparison

(Mark separately)
[NOT repulsion between atoms or between bonds]

1

(b) (i) <u>Simplest ratio of atoms of each element</u> in a compound / substance / species / entity / molecule

1

(ii)

	Mg	N	O
$\frac{16.2}{(24)}$	$\frac{16.2}{24.3}$	$\frac{18.9}{14}$	$\frac{64.9}{16}$
(0.675)	0.667	1.37	4.06
	1	2	6

MgN_2O_6

(Mark M1 first. If any wrong A_r used = CE = 0)
(Accept $Mg(NO_3)_2$ for M3 if above working shown)

1

[9]

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Q1.

(a) A good number of students realised that the KrF_2 molecule has three lone pairs around the krypton but few were able to appreciate that this is a linear molecule. Some students did not show any lone pairs on their diagrams.

(b) Most students understood that lone pairs reduce the bond angle in a molecule so this was answered well.

(c) A good number of students realised that the intermolecular forces were van der Waals' but were unable to describe accurately how these forces arise or why other intermolecular forces are not present between SiF_4 molecules. Only 4.9% of students gained full marks.

Q2.

(a) This levels-of-response question discriminated very well, with approximately one third of students scoring marks in each of the three levels. Some excellent answers were seen. Some students, however, answered very well initially but then used wrong terminology, for example wrong bonding and/or intermolecular forces in all/some of the substances, and showed contradictions in their answers.

(b) Unfortunately, the equation was often seen with sodium oxide as the product rather than sodium hydroxide. In the calculation, many students did not use the 2:1 ratio from the equation, leading to an answer of 267 cm^3. However, this part of the question also discriminated well, with over 25% of students gaining full marks; most students scored some marks and less than 3% scored zero.

(c) Just under half of the students (48.5%) gave a correct answer; the commonest error was to multiply the amount, in moles, by volume rather than dividing by volume.

(d) This part discriminated well, though only a few students (7%) scored full marks. The structure often had the wrong number of lone pairs and/or the wrong bond angle. That lone pair-lone pair repulsion is greater than bond pair-bond pair repulsion was known by the majority of students.

Q3.

While 72% of students gave the correct answer, D and A were chosen with almost equal frequency as incorrect responses.

Q4.

(a) This was a straightforward definition that was reasonably well known, with 51.8% of students successful.

(b) The second mark was rarely scored, perhaps showing that students had not read the question carefully enough. The best answers often included a good diagram to shown the interaction between molecules.

(c) The shapes were quite well known, but the link with overall polarity less so. This question was a good discriminator, with almost even proportions of students scoring 0, 1, 2, 3 and 4 marks.

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Q5.

Although 55.5% of students got this correct, a surprising number thought that methane (A) has a 90º bond angle – it was the most popular distractor.

Q6.

Many students (45%) could suggest the most likely bond angle around the oxygen atom in ethanol.

Q13.

The fairly familiar shapes here proved quite easy for many students and the rest of the question also proved to be quite accessible except for (c) where many were unable to explain the change in the Cl-Al-Cl bond angle.

Q14.

Students struggled to explain how van der Waals' forces arise between molecules. Most scored a mark by referring to 'electron movement' but did not go on to explain that a dipole is induced in an adjacent molecule. Many answers were based on the difference in electronegativity. Most students correctly explained the difference in boiling points between methanol and methanethiol and between methaneselenol and methanethiol. On occasions the quality of students' language was poor either stating that boiling results in all bonds breaking or indicating that the O-H bond in methanol was broken. For this reason a statement that the relevant forces act 'between molecules' is necessary to gain credit. Nearly all students answered part (b)(ii) correctly. The shape and bond angles of SF_6 proved a good discriminator. Some students were not able to deduce the correct number of lone pairs around SF_4 and others did not appreciate the effect of the single lone pair on the bond angles. In part (d)(ii) most students were able to deduce NaCl as the missing product but not all were able to balance the equation. Multiples were accepted.

Q15.

The students who selected the correct element in part (a) generally went on to score full marks. However a large number thought that argon had the highest melting point and therefore did not score any marks. In part (b) the majority of students selected argon and gave an explanation of their choice. If the answer was correct the most common problem was missing the shielding factor necessary for the third mark. Part (c) was answered correctly by most students. The shape of ClF_3 was found easier to draw than CCl_2 in part (d)(i) and the name of the shape in (d)(ii) was answered correctly by many students. The most common error in part (d)(iii) was to write an equation to produce two moles rather than one mole as stated in the question.

Q16.

There were several different angles given in part (a) but the majority of students gave the correct one. The type of intermolecular force in part (b)(i) was very well answered. There were many students who scored full marks on the diagram in part (b)(ii) showing the lone pairs as lobes, two crosses or two dots. It should be stressed that students who choose to use dots should ensure that they are bold and clear. Some students however failed to score full marks since they did not have the correct number of lone pairs on each of the oxygen atoms. Partial charges, if seen, were generally correct. Several students did not read the question and used two water molecules instead of what was required. Answers to part (c) were generally quite poor and showed that students did not really understand the concept of electronegativity; many tried to compare the electronegativity of molecules rather than atoms. The students who correctly stated that the electronegativity of sulphur

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was lower than oxygen could often not explain the relevance of electronegativity difference to hydrogen bonding being absent between the molecules.

Q17.

Answers to part (a) showed that there are still many students who cannot work out the correct shape of an unknown molecule. The main error was drawing the incorrect number of lone pairs and this led to an incorrect name and angle in the molecules. As always, this type of question discriminated very well. In part (b), many students could not identify the correct type of bonding and, therefore, could not score any marks. Many others who could identify the correct bonding then contradicted themselves by referring to intermolecular forces in the crystalline solid.

Despite the formula TlBr being given, many students could not write a balanced equation in part (c). Many did not realise that bromine is a diatomic molecule and others showed the formation of the product from ions.

Q18.

The equation in part (a) was given correctly by only a few students. Far too many students could not give the correct formula for aluminium chloride. The type of bonding in part (b) was well answered but many students thought that the pair of electrons originated from the Cl atom or from the Al atom. In part (e), the majority of students gave a correct structure and formula. Incorrect answers were due to the insertion of lone pairs of electrons. The linear shape in part (f) was generally answered well but the explanation of the shape often did not refer to repulsion between the bonding electron pairs. The majority of students scored the mark in part (g), realising that the outer electrons are removed first during successive ionisations.

Q19.

Most students were able to draw the shape of the arsenic trichloride molecule and correctly describe its shape in part (a). The most common error was to include two lone pairs in $AsCl_3$. Students struggled more with the shape of the Cl^{3+} ion with many thinking it was linear or cyclic. A few students lost marks due to only showing dot and cross diagrams without further clarification. In part (b), a large number of students supported their answer with a diagram of the new structure but failed to understand that there would be equal repulsion between the four bonds. Many students did not realise that the lone pair became a dative bond or thought that if the lone pair was removed there would be no repulsion in the molecule. Other students described repulsion between atoms rather than repulsion between bonding electrons.

Q20.

The structure in part (a) was well answered. Part (b) was also answered well although a few students gave generic answers about co–ordinate bonds rather than specific answers to this question. Various bond angles were seen for part (c). In part (d), the idea of an electronegativity difference was often seen but then students often gave responses that were not specific to the molecule in the question. Many students lost marks by referring to the electronegativity of the phosphine molecule.

Q21.

The unstructured calculation in part (a) was attempted by all but a few students. Most students managed to score two marks. The most common errors were the incorrect conversion of pressure and volume into the appropriate units and a failure to divide the

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total moles of gas by five. The equation in part (b) was often incorrect with many examples of B_2 and atomic chlorine given. The students who knew that there were three bonding pairs of electrons often did not realise that the repulsions of the bonding pairs were equal. The calculation in part (c)(i) was reasonably well answered. Many students scored the first two marks but then incorrectly multiplied by 500/1000. Very few produced the expected equation in part (c)(ii) although the alternative equations were often seen. Many examples of the incorrect formulae '$NaBO_3$' and 'NaB' in unbalanced equations were also seen. Part (d) was well answered by the majority of students. A wide variety of methods were seen that could score full marks in part (e). The first three marks were usually obtained but the final mark proved elusive. Many students suggested that the molecular formula was $2BCl_2$ rather than the correct answer, B_2Cl_4.

Q22.

Part (a) was generally answered well although many students did not refer to a shared pair of electrons in the covalent bond. The required number of bond pairs and lone pairs in parts (b)(i) and (ii) were reasonably well known although many students did not appreciate that the lone pairs would repel each other and the bond pairs as far apart as possible and hence lost the marks for the bond angles. Some students incorrectly gave B as the symbol for bromine. The answers to part (c) differentiated well. Weaker students generally scored zero due to chemical errors. Where students identified ionic bonding, marks were lost by not stating oppositely charged ions or by referring to incorrect ions eg K^+ and F^-. The type of intermolecular force in part (d)(i) was well known. Weaker students did not know the formula HF in part (d)(ii) and many students lost marks due to careless omissions of the partial charges or the lone pairs. Students generally realised that van der Waals' forces were present in fluorine and hence the boiling point was low. However many answers did not refer to van der Waals' forces acting between molecules and some answers referred incorrectly to the breaking of weak covalent bonds.

Q23.

Many candidates answered part (a) well but there were a significant number who did not make it clear that the van der Waals forces were between the molecules. Part (b)(i) differentiated well. There were many examples of the wrong number of lone pairs in both molecules and a frequent occurrence of bi-pyramids in candidates' answers. The angle in part (b)(ii) generated a range of values although the answer to part (c) was given correctly by a majority of candidates. Part (d) was generally well done although several candidates gave the wrong direction for the donation of the lone pair.

Q24.

Part (a) proved a difficult question with many candidates failing to refer to molecules. Of those that did many thought that the space between the molecules was filled with air or oxygen. Many considered hydrogen bonds but not the effect on the spacing between the molecules. Intermolecular forces in part (b) were generally well known although a few thought incorrectly that there are dipole-dipole forces between methane molecules. In part (b)(iii), many candidates stated that hydrogen bonds were strong but then failed to make the comparison between the intermolecular forces in the two molecules. The shape in part (c)(i) was generally well attempted but less able candidates included two or no lone pairs of electrons. Many candidates thought that the ion was planar, but of those who correctly stated the shape as tetrahedral many followed with a bond angle of 109° in part (c)(ii) showing that they had not taken account of the lone pair of electrons in the molecule. The identification of the molecule in part (c)(iii) proved difficult and many candidates suggested ions rather than a molecule. Part (d) was not well answered.

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Q25.

In part (a)(i) many candidates omitted the word ‘pair’ from their answer and hence did not score the mark. The equation in part (a)(ii) was not answered well since many candidates failed to read the question, which asked for an equation to produce one mole of product. Other errors included not giving the correct formulae for chlorine or fluorine molecules. Candidates found the first structure in part (b) relatively easy, but answers for the structure of ClF_3 often included the wrong number of lone pairs of electrons. Part (c) was answered well. The idea of co-ordinate bonding was generally well known but the explanation in part (d)(i) was not. Many candidates thought that the lone pair originated from the B rather than the F^-. A large range of answers was seen in part (d)(ii) with 107.5 being the most popular incorrect answer. If candidates understood the concept of atom economy then they generally scored 2 marks in part (e).

Q26.

A pleasing number of answers scoring full marks were seen. The structure of AsF_5 was generally well done although candidates struggled with the name of the shape. Generally the structure of ClF_2^+ was more demanding and many candidates only showed one lone pair. A large number of candidates thought that the ClF_2^+ ion was linear.

Fewer than 1% of candidates interpreted the ion as the difluoroiodomethyl cation, for which full credit was available.

Q27.

The electronic configuration in part (a) was generally well known. In part (b)(i) the removal of 2 electrons from the neutral atom was a common incorrect answer and in (b)(ii) many candidates missed the effect of change of shielding. Often candidates referred to s and p orbitals with no reference to the number of the principal energy level. Part (b)(iii) was disappointing and showed that many candidates find it difficult to apply concepts to different situations. Part (c) was generally well known although many candidates did not score the second explanation mark. In part (d) many candidates did not realise that metallic bonding, or an explanation of it, was required in the answer. Many thought that van der Waals forces were involved or mentioned losing electrons causing ionisation. In part (e) there were many unclear diagrams and many candidates had the wrong number of lone pairs of electrons. Answers to the shape of the molecule were often incorrect or contradictory e.g. bent-linear. Part (f) was well answered.

Q28.

The definition required in part (a) was generally well known. Common errors included reference to a single electron or omitting covalent bond. Part (b) was quite a good discriminator with many candidates merely giving ‘dipole-dipole interaction’ or just ‘hydrogen’. Part (c) also discriminated well. Many candidates relied upon attraction between the partial charges on the hydrogen and nitrogen neglecting the importance of the lone pair on the nitrogen atom. Most candidates knew about co-ordinate bonding and scored the first mark in part (d). The idea of sharing a pair of electrons was well known although the direction of donation was often wrong or unclear. Many scored both marks in part (e) and some good 3-D diagrams were seen. Candidates lost marks by omitting the H atoms, replacing the As with N or P and stating the shape as bipyramidal or planar. Part (f) proved difficult for weaker candidates. There were a few who failed to realise the significance of the negative signs and thought that AsH_3 had the higher boiling point and some referred to breaking covalent bonds rather than intermolecular forces. The equation in part (g) was usually correctly balanced.

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Q30.

Many of the diagrams in part (i) were poorly drawn, and many instances of one or more lone pairs of electrons being shown on the B atom were seen. Those candidates who tried to indicate the three-dimensional nature of the structures using wedges and dotted lines, frequently used them incorrectly. While many candidates correctly named the shapes of the species, it was not unusual for the shape of the BF_4 ion to be described as being *distorted tetrahedral.* In most instances, the correct bond angle was quoted for the BF_4" ion, however, bond angles of 107° or even 105° were quite frequently seen. An explanation for the shape of this ion was rarely attempted and, when it was, it was often given in terms of repulsion between Fluorine atoms rather than of bonding electron pairs. *Equal* repulsion was rarely seen. Part (ii) was quite well answered. Most candidates were able to show an understanding of dative covalent bonding, although a fair number of candidates predicted that there was a lone pair of electrons on boron which was donated to the fluoride ion when the bond was formed.

Q32.

On the whole, this question was well answered. The relative masses and charges of neutrons and electrons were generally well known but errors were not uncommon. Some candidates reversed the contents of the *mass* and *charge* columns, suggesting that they had rote learned a table with a different layout of columns.

Part (b) was quite well done but errors such as ^{17}Be, ^{13}O, $^{17.0}O$ and ^{16}O were not uncommon.

While many candidates correctly deduced the shapes of the molecules in part (c), the presence of a lone pair of electrons on the Be atom, or one/three lone pairs of electrons on the O atom, was quite common. The shape of the $BeCl_2$ molecule was well known but there was considerable confusion regarding the shape of the Cl_2O molecule. Many candidates gave *tetrahedral* as the shape of this molecule. While the distribution of electron pairs around the oxygen atom might be described as *tetrahedral*, this is not the shape produced by the atoms in the molecule. Many candidates described the shape in appropriately by using the terms *bent*, *V-shaped* and *angular*. The use of *tetrahedral* was accepted in this examination but this may not be the case in future examinations. A significant number of candidates used the term *bent linear* when describing the shape of Cl_2O molecules; this was treated as a contradiction and so earned no credit. A significant number of candidates attempted to show the shapes of these molecules using dot-and-cross diagrams; these were not accepted.

The calculation in part (d) was correctly performed by many candidates, but errors such as the use of incorrect *M*r values or the use of an incorrect mole ratio were quite common. A small but significant number of candidates assumed the use of a known mass of HCl and ignore the 1.00 g of $Mg(OH)_2$ stipulated in the question; such answered earned no credit.

Q33.

This question was, in general, quite well answered, although very low scores were not uncommon. Most candidates correctly identified the bonding in part (a) as being dative or coordinate. In some cases, the bond was incompletely described as being *covalent* but references to *hydrogen bonding, van der Waals' forces* and *ionic bonding* also appeared quite frequently. The explanation of the origin of this bond was less well done. Some candidates, having read about ammonia in the stem, quoted a nitrogen atom as being the source of the lone pair which formed the dative bond. Others clearly had little idea of how a dative bond is formed. It is worrying that a number of candidates thought that H^+ ions each have a lone pair that they can donate to the phosphorus atom. In part (b), the

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shapes of both species were usually clearly and accurately drawn. The most common errors were to omit the lone pair of electrons on the PH_3 molecule, to add extra lone pairs of electrons on either species and to show phosphine as either a trigonal planar shape or as 'T' shaped. Errors in the naming of the shape of phosphine molecule were quite common, with *bipyramidal* and *planar triangular* being the most common. There were also many errors in the bond angle quoted for the phosphonium ion, with 107°, 90° and multiple angles being frequently seen. While *tetrahedral* was accepted this year for the shape of phosphine, *pyramidal* is preferred; centres are asked to encourage candidates to use this term.

Q35.

The equation, in part (a) (i), was often correct but some candidates omitted hydrogen altogether, gave its formula as ‘H’ or failed to balance the equation correctly. In part (a) (ii), the shape of NH_3 was generally well known but it was not uncommon to see either no lone pairs, or two lone pairs, on the structure, or for a ‘T’ shape to be drawn. Fewer candidates drew an acceptable structure for the amide ion. The most frequently seen errors were drawings showing the ion as being linear or showing other than two lone pairs. Hydrogen atoms were omitted in some diagrams. The bond angle (107°) present in ammonia was generally well known but a significant number of candidates quoted 109 ½°; other incorrect angles were less frequently seen. The explanation in part (a) (iv) was often vague and unconvincing. Many candidates did not appreciate the significance of the second lone pair of electrons in the ion. Clear explanations of the differences in repulsion provided by bonding pairs and lone pairs were relatively rare. Descriptions of repulsions between lone pair electrons and hydrogen atoms or between bonds, rather than between bonding pairs of electrons, were quite common errors. In part (b) (i), answers were often incomplete, with words such as ‘simplest’, ‘atoms of and ‘each element’ being frequently omitted. The empirical formula calculation was generally well done, although the use of incorrect A_r values or the incorrect rounding of answers was not uncommon.

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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 marked using Levels of Response. Examiners should apply a 'best-fit' approach to the marking.	
Level 3 5-6 marks	All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 and then stage 3. Coherent communication requires that there is a comparison between the types of bonding and that the bonding is correct for each substance.
Level 2 3-4 marks	All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows some progression from stage 1 to stage 2 and then stage 3.
Level 1 1-2 marks	Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR only one stage is covered but the explanation is generally correct and virtually complete. Answer shows some progression between two stages
Level 0 0 marks	Insufficient correct chemistry to gain a mark.

Indicative chemistry content. Contradictions (eg molecules, IMFs, covalent bonding,) negate statements.

Stage 1 - **Na**
1a) Na has metallic bonding
1b) there is attraction/ bonding between the positive nucleus/ ion and the delocalised electrons in Na
1c) Na has a giant/lattice structure

Stage 2 – **NaBr or NaI**
2a) Ionic bonding in NaBr and/or NaI
2b) There is attraction/ bonding between the + and – ions in NaBr and/or NaI
2c) NaBr and/or NaI have a giant/lattice structure

Stage 2 – **comparison of bonding**
3a) The ionic bonds are stronger (or wtte) than the metallic bonds
3b) there is stronger attraction (or wtte) between the + and – ions in NaBr than in NaI

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3c) since the Br^- ion is smaller than the I^- ion

6

(b) **M1** $Na + H_2O \rightarrow NaOH + ½ H_2$

Allow multiples

1

M2 (Mass Na = 0.250 g so moles Na = 0.250/23.0) = 0.0109

CE: If not divided by 23, max 3/5 calculation marks – M3, M4 and M5

AE: If not divided by 1000 and final answer is 1.33×10^5 cm^3 4/5

1

M3 moles $H_2 = 5.43 \times 10^{-3}$ to 5.45×10^{-3}

M3 = M2 /2

CE: If incorrect ratio used max 3/5 calculation marks – M2, M4 and M5

1

M4 T = 298 (K) and P = 101000 (Pa)

1

M5 $V = nRT/P$ or $(5.435 \times 10^{-3} \times 8.31 \times 298)/101000$ or 1.33×10^{-4} (m^3)

1

M6 V = 133 – 134 cm^3

Allow to 2 significant figures or more

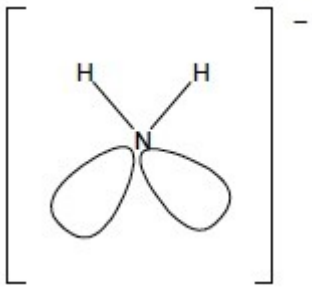
1

(c) Conc = $0.0109/ 500 \times 10^{-3} = 0.0217$-$0.022$ (mol dm^{-3})

Allow M2 from question (b)

1

(d) **M1**



Ignore charge and brackets

1

M2 104.5°

Allow 104-106

1

M3 (4) electron pairs repel to be as far apart as possible

1

M4 lp/lp repulsion> lp/bp repulsion (> bp/bp repulsion)

For M4 allow lone pairs repel more than bonding pairs

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Mark independently

1

[16]

Q2.

(a) (i) d (block) **OR** D (block)

Ignore transition metals / series.

Do not allow any numbers in the answer.

1

(ii) Contains positive (metal) ions or protons or nuclei and <u>delocalised / mobile / free / sea of</u> electrons

Ignore atoms.

1

<u>Strong attraction</u> between them or <u>strong metallic</u> bonds

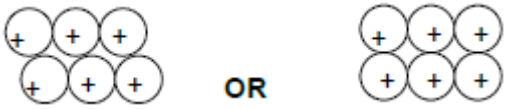
Allow 'needs a lot of energy to break / overcome' instead of 'strong'.

If strong attraction between incorrect particles, then CE = 0 / 2.

If molecules / intermolecular forces / covalent bonding / ionic bonding mentioned then CE=0.

1

(iii)



M1 is for regular arrangement of atoms / ions (min 6 metal particles).

M2 for + sign in each metal atom / ion.

Allow 2^+ sign.

2

(iv) <u>Layers / planes / sheets of atoms or ions</u> can slide over one another

QoL.

1

(b) (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8\ (4s^0)$

Only.

1

(ii) $NiCl_2.6H_2O$ + **6** $SOCl_2$ $\longrightarrow$ $NiCl_2$ + **6** SO_2 + **12** HCl

Allow multiples.

1

NaOH / NH_3 / $CaCO_3$ / CaO

Allow any name or formula of alkali or base.

Allow water.

1

[9]

Q3.

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(a) White powder / solid / ash / smoke

Ignore ppt / fumes

1

Bright / white light / flame

Allow glows white / glows bright

1

$Mg + H_2O \rightarrow MgO + H_2$

Ignore state symbols

Ignore reference to effervescence or gas produced

1

(b) Mg^{2+} / magnesium ion has higher charge than Na^+

Allow Mg^{2+} ions smaller / greater charge density than Na^+ ions

Allow Mg atoms smaller than Na (atoms)

Allow magnesium has more delocalised electrons

Must be a comparison

Ignore reference to nuclear charge

1

Attracts delocalised / free / sea of electrons more strongly / metal–metal bonding stronger / metallic bonding stronger

Wrong type of bonding (vdW, imf), mention of molecules CE = 0

1

(c) **Structure:** Macromolecular / giant molecule / giant covalent

Mark independently

1

Bonding: Covalent / giant covalent

1

Physical Properties:

Any **two** from: Hard/
Brittle / not malleable
Insoluble
Non conductor

Ignore correct chemical properties

Ignore strong, high boiling point, rigid

2

(d) **Formula:** P_4O_{10}

Mention of ionic or metallic, can score M1 only

1

Structure: Molecular

If macromolecular, can score M1 & M3 only

1

Bonding: Covalent / shared electron pair

1

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van der Waals' / dipole–dipole forces <u>between molecules</u>

Allow vdW, imf and dipole–dipole imf but do not allow imf alone

1

(e) $SO_2 + H_2O \rightarrow H^+ + HSO_3^-$

Products must be ions

Allow $SO_2 + H_2O \rightarrow 2H^+ + SO_3^{2-}$

Allow two equations showing intermediate formation of H_2SO_3 *that ends up as ions*

Ignore state symbols

Allow multiples

1

(f) $P_4O_{10} + 6MgO \rightarrow 2Mg_3(PO_4)_2$

OR $P_4O_{10} + 6MgO \rightarrow 6Mg^{2+} + {}_4PO_4^{3-}$

OR $P_2O_5 + 3MgO \rightarrow Mg_3(PO_4)_2$ etc

Ignore state symbols

Allow multiples

1

[15]

Q4.

(a) **M1 (could be scored by a correct mathematical expression**

*Correct answer to the calculation gains all of **M1**, **M2** and **M3***

M1 $\underline{\Delta H = \Sigma \Delta H_f \text{ (}\textbf{products}\text{)} - \Sigma \Delta H_f \text{ (}\textbf{reactants}\text{)}}$

Credit 1 mark for − 101 (kJ mol^{-1})

OR a <u>correct cycle of balanced equations</u>

M2 = − 1669 − 3(− 590)
= − 1669 + 1770
(This also scores M1)

M3 = **+ 101** (kJ mol^{-1})

Award 1 mark ONLY for − 101

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**)*
- *If no AE, check for a correct method; this requires either a correct cycle with 3Sr <u>and</u> 2Al OR a clear statement of **M1** which could be in words and scores **<u>only M1</u>***

M4 - Using powders
Any **one** from

- To <u>increase collision frequency / collisions in a given time / rate of</u>

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collisions

- To increase the surface contact / contact between the solids / contact between (exposed) particles

Ignore dividing final answer by 3

*Penalise **M4** for reference to molecules.*

5

M5 Major reason for expense of extraction
Any **one** from

- Aluminium is extracted by electrolysis ***OR*** aluminium extraction uses (large amounts of) electricity
- Reaction / process / It / the mixture requires heat
- It is endothermic

(b) Calcium has a higher melting point than strontium, because

Ignore general Group 2 statements.

Correct reference to size of cations / proximity of electrons
M1 (For Ca) delocalised electrons closer to cations / positive ions / atoms / nucleus
OR cations / positive ions / atoms are smaller
OR cation / positive ion / atom or it has fewer (electron) shells / levels

*Penalise **M1** if either of Ca or Sr is said to have more or less delocalised electrons OR the same nuclear charge.*

Ignore reference to shielding.

Relative strength of metallic bonding
M2 (Ca) has stronger attraction between the cations / positive ions / atoms / nucleus and the delocalised electrons
OR
stronger metallic bonding

(assume argument refers to Ca but credit converse argument for Sr)

***CE= 0** for reference to molecules or Van der Waals forces or intermolecular forces or covalent bonds.*

2

(c) **M1** $\mathbf{2}Mg + O_2 \longrightarrow \mathbf{2}MgO$

M2 $Mg + \mathbf{2}H_2O \longrightarrow Mg(OH)_2 + H_2$

Credit multiples of the equations.

M3 Magnesium hydroxide is used as an antacid / relieve indigestion (heartburn) / neutralise (stomach) acidity / laxative

*Not simply "milk of magnesia" in **M3***

3

[10]

Q5.

(a) (i) Increases

1

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(ii) Decreases

1

(iii) Increases

1

(b) Calcium has a higher melting point than strontium, because

CE = 0 for reference to molecules or intermolecular forces or covalent bonds

Correct reference to size of cations/proximity of electrons

M1 (For Ca) delocalised <u>electron(s) closer to cations / positive ions / nucleus</u>

Ignore "Van der Waals forces (between atoms)" but penalise if between "molecules"

OR <u>cations / positive ions / atoms are smaller</u>

OR <u>cation / positive ion / atom or it has fewer (electron) shells / levels</u>

Ignore general Group 2 statements

Answers must be specific

Relative strength of metallic bonding

M2 (For Ca) has <u>stronger</u> attraction between the <u>cations / positive ions / nucleus</u> and the <u>delocalised electron(s)</u>

Penalise M1 if Ca or Sr is said to have <u>more or less</u> delocalised electrons

OR

<u>stronger metallic bonding</u>

(assume argument refers to Ca but accept converse argument for Sr)

Ignore reference to shielding

2

(c) (i) Sulfuric acid / it contains <u>sulfate ions / SO_4^{2-}</u>

OR

Do not penalise an <u>additional</u> but incorrect formula for sulfate ion.

<u>Sulfuric acid</u> would form a (white) <u>precipitate</u>

If only the formula of the sulfate ion is given, it must be correct

1

(ii) $Ba^{2+} + SO_4^{2-} \longrightarrow BaSO_4$ ONLY

Ignore state symbols

No multiples

1

[7]

Q6.

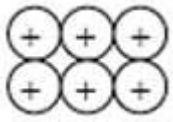
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(a) (i) Metallic

Allow body centred cubic

1

(ii)

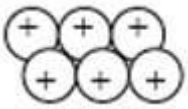


One mark for regular arrangement of particles. Can have a space between them

Do not allow hexagonal arrangement

1

OR



Na^+ Na^+ Na^+

Na^+ Na^+ Na^+

One mark for + in each

Ignore electrons

If it looks like ionic bonding then CE = 0/2

1

(b) (i) <u>Ionic</u>

CE = 0 for (b)(i) and (b)(ii) if not ionic

1

(ii) Strong (electrostatic) attraction

Any mention of IMF or molecules / metallic / covalent in (b)(ii) then CE 0/2

1

Between <u>oppositely</u> charged ions / particles

Or + and – ions

1

(c) Iodide / I^- bigger (ion) (so less attraction to the Na+ ion)

Need comparison

Do not allow iodine is a bigger atom

Ignore I^- has one more c^- shell

CE = 0 if IMF / covalent / metallic mentioned

1

[7]

Q7.

(a) Antacid

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OR

to neutralise acidity

OR

eases indigestion

Credit suitable reference to indigestion or to laxative or to relief of constipation

1

(b) **M1** Decrease in T decreases the <u>energy</u> of the <u>particles/ions/H^+/molecules</u>

M2 (also scores M1) Decrease in the number of/less particles/ions/ H^+/molecules with $E \geq E_{Act}$ or E ≥ minimum energy to react

*In **M1** and **M2,** credit "atoms" but ignore "calcium carbonate", ignore "calcium", ignore any ion formula except H^+*

M3 Few(er)/Less effective/productive/successful collisions

QoL

3

(c) (i) Strontium has a higher melting point than barium, because

Correct reference to size of cations/proximity of electrons
M1 (For Sr) delocalised <u>electrons closer to cations/positive ions/atoms/nucleus</u>

OR

cations/positive ions/atoms are smaller

OR

cation/positive ion/atom or it has fewer (electron) shells/levels

Ignore general Group 2 statements

Penalise M1 if Sr or Ba is said to have <u>more or less</u> delocalised electrons

Ignore reference to shielding

***CE = 0** for reference to molecules or intermolecular forces or covalent bonds*

Relative strength of metallic bonding
M2 (Sr) has <u>stronger</u> attraction between the <u>cations/positive ions/ atoms/nucleus</u> and the delocalised <u>electrons</u>

OR

<u>stronger metallic</u> bonding
(assume argument refers to Sr but accept converse argument for Ba) 2

Ignore "Van der Waals forces (between atoms)" but penalise if "between molecules"

(ii) $Sr + \mathbf{2}H_2O \rightarrow Sr(OH)_2 + H_2$

Or multiples

1

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(d) **2**Mg + $TiCl_4$ → **2**$MgCl_2$ + Ti

Or multiples

1

[9]

Q8.

(a) (i) Average/mean mass of 1 atom (of an element);

Average mass of 1 atom × 12.

1

Mass 1/12 atom of ^{12}C;

Mass 1 atom of ^{12}C.
QWC.

1

(ii) Other isotope = 46.0%;

1

$$107.9 = \frac{(54 \times 107.1) + (46 \times ?)}{100};$$

M2 whole expression.

1

108.8;

Answer 108.8 (3 marks).
Answer min 1 d.p..

1

Same electronic configuration/ same number of electrons (in outer shell)/ both have 47 electrons;

Ignore protons and neutrons unless incorrect.
Not just electrons determine chemical properties.

1

(b) Ionisation;

1

high energy electrons fired at sample;

Allow electron gun /blasted with electrons.

1

Acceleration;

1

With electric field/accelerating potential/potential difference;

Allow by negative plate.

1

Deflection;

1

With electromagnet/ magnet/ magnetic field;

M2 dependent on M1.
M4 dependent on M3.
M6 dependent on M5.

1

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(c) (Silver) metallic (bonding);

Vdw/molecules CE=0.

1

Regular arrangement of same sized particles;

1

+ charge in each ion;

Ignore multiple positive charges.
Candidates do not need to show delocalised electrons.

1

(d) Ionic (bonds);

1

Minimum 4 ions shown in 2D square arrangement placed Correctly;

Do not allow multiple charges on ions.

1

Further 3 ions shown correctly in a cubic lattice;

1

Strong (electrostatic) forces/bonds;

If vdw/molecules/covalent mentioned CE = 0 for M4 and M5.

1

Between + and – ions;

Accept between oppositely charged ions.

1

[20]

Q9.

(a) $2Al + 3CuCl_2 \rightarrow 2AlCl_3 + 3Cu$;

(accept multiples/fractions)

OR

$2Al + 3Cu^{2+} \rightarrow 2Al^{3+} + 3Cu$;

1

(b) (i) increases;

1

(ii) lower than expected / lower than Mg /

1

less energy needed to ionise; e^- removed from (3)p sub-level;

1

('e^- removed' may be implied)

of higher energy / further away from nucleus / shielded by 3s e^-s;

1

(c) $Al^+(g) \rightarrow Al^{2+}(g) + e^-$;

1

(d) trend: increases;

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1

more protons / higher charge on cation / more delocalised e^- / smaller atomic/ionic radius;
stronger attraction between (cat)ions and delocalised/free/mobile e^-

1

OR

stronger metallic bonding;

1

[9]

Q10.

(a) (i) positive ions **(1)**
(attract) delocalised electrons **(1)** *(or sea of or free or mobile)* **(1)**

Confusion with -ve ions
or ionic lattice C.E. = 0

(ii) more protons **(1)** (or Mg^{2+} more charge than Na^+)
attracts <u>delocalised</u> (or bonding) electrons more strongly **(1)**
Delocalised: can be brought forward from (a) (i)

OR more delocalised electrons (1)
Attacks positive ions more (1)
<u>Metallic</u> bonding is stronger scores one mark, only given if no other marks awarded

4

(b) macromolecular **(1)** *(or giant molecule etc)*
*covalent **(1)***
*<u>strong</u> covalent <u>bonds</u> **(1)***

or bonds require much energy to break

3

(c) delocalised *(OR free or sea of or mobile) electrons **(1)***

1

(d) Planes **(1)**
weak (bonds) forces between planes **(1)**

2

or v.dw forces between planes

[10]

Q11.

A

[1]

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Q1.

(a) This levels-of-response question discriminated very well, with approximately one third of students scoring marks in each of the three levels. Some excellent answers were seen. Some students, however, answered very well initially but then used wrong terminology, for example wrong bonding and/or intermolecular forces in all/some of the substances, and showed contradictions in their answers.

(b) Unfortunately, the equation was often seen with sodium oxide as the product rather than sodium hydroxide. In the calculation, many students did not use the 2:1 ratio from the equation, leading to an answer of 267 cm^3. However, this part of the question also discriminated well, with over 25% of students gaining full marks; most students scored some marks and less than 3% scored zero.

(c) Just under half of the students (48.5%) gave a correct answer; the commonest error was to multiply the amount, in moles, by volume rather than dividing by volume.

(d) This part discriminated well, though only a few students (7%) scored full marks. The structure often had the wrong number of lone pairs and/or the wrong bond angle. That lone pair-lone pair repulsion is greater than bond pair-bond pair repulsion was known by the majority of students.

Q2.

This question was generally quite well answered. In part (a)(i), most students knew the correct block in the Periodic Table although some seemed to think that the name ‘Transition Metals’ was enough to identify the d block. In part (a)(ii), the biggest issue was the omission of ‘positive’ when describing ions and ‘delocalised’ when describing the electrons involved in the bonding. The diagrams in part (a)(iii) generally scored highly but some were untidy and failed to show a regular arrangement of ions. Surprisingly, many students did not refer to layers of atoms / ions sliding in part (a)(iv) and therefore did not score the mark. Answers to part (b)(i) were disappointing and showed that students could not write the electron configuration of ions in the d block. Balancing the equation proved difficult but a good number of students did this well and many students could suggest a suitable substance in part (b)(ii).

Q3.

Few students scored all three marks for part (a) and even the highest-scoring students often gave only one correct observation. Weaker students often suggested incorrectly that it would be possible to see a gas being evolved and also wrote an incorrect equation showing formation of magnesium hydroxide rather than the oxide. In part (b), metallic bonding was not explained well by most students, often being confused with ionic bonding or intermolecular forces. In part (c), very few students scored more than three marks, often being unable to give a correct second physical property of silicon dioxide. Incorrect answers usually involved misreading the question and giving ‘high melting point’ or suggesting a chemical property. The formula, structure and bonding for phosphorus(V) oxide were usually correct in part (d) but only the highest-scoring students gave correct equations in parts (e) and (f). In part (e), a very common error was to write an equation with sulfur trioxide rather than sulfur dioxide.

Q4.

The whole of this question was relatively straightforward and it was pleasing to see the majority of students gain at least 3 marks in part (a) and over 40% gain both marks in part (b).

In part (c), too many students failed to balance their equations or could not write the correct formula for magnesium hydroxide. Fewer than half of all students gained all three marks.

Q5.

Part (a) involved a simple format but the chemical demand did not diminish and only 70% of the students wrote the correct response in part (a)(i). The correct use of chemical names and terminology was required in part (b). Part (c) was generally well answered.

Q6.

Part (a) was generally well done with the most common error being to assume ionic bonding showing circles with + and – signs in them. Very few did not show the required minimum of 6 particles. The type of bonding in sodium chloride was well known in part (b) and the explanation was answered well by a large number of candidates.

Part (c) proved more difficult and only the more able candidates were able to give a correct answer. Weaker candidates did not refer to the halide ions at all and some referred to electronegativity.

Q7.

All parts of this question discriminated well. It is a matter of concern that more than half the candidates were unable to write a correct equation for the reaction of magnesium with titanium(IV) chloride.

Q8.

Many candidates produced good answers here but it must be stressed that the definition of relative atomic mass must be absolutely correct for the award of both marks. Many candidates left out ‘average’ mass or the factor of 12.

Having to find the RAM of one of the isotopes challenged many of those who were unable to manipulate the equation but candidates regularly scored the first two marks and only lost the third calculation mark due to lack of dexterity with rearranging and algebra. The idea of isotopes having the same electron arrangement was generally well known although lots of answers included references to protons and/or neutrons.

Part (b) was well answered with the most common error being the confusion of electric and magnetic field. The processes were very well known. In part (c) there was confusion over metallic and ionic bonding. In part (d) most candidates had the idea of a 3D lattice but errors arose from multiple charges or negative charges on the Ag or like charges next to each other at some point in the lattice. Most candidates realised that ionic bonding was present, but some then contradicted their answers by mentioning intermolecular forces.

Q9.

While less able, (or less well prepared,) candidates struggled with this question, the majority coped quite well. The equation in part (a) was usually correct, although it was not unusual to see Al_2, Al^{3+} or Cu_2 in the equation, or for the equation to be incorrectly balanced. Most candidates correctly identified an increase in ionisation energy across the

group; however, the explanations in part (b)(ii) were frequently vague and unconvincing. In particular, statements that the electron in aluminium as *easier to remove,* rather than making direct reference to the lower ionisation energy of aluminium, failing to specify the 3p electron as being the first electron to be removed from aluminium or vaguely referring to extra shielding, were quite common. In part (c) some candidates did not start their equation with Al^+ ions and many more either omitted the state symbols completely or used the wrong one. The majority of candidates correctly identified a rising trend in the melting point of the three metals in part (d) but the explanations offered were diverse and frequently incomplete or wrong. Those candidates who did correctly attribute the trend to an increase in proton number or to the number of delocalised electrons often proceeded no further, or simply referred, without explanation, to an increase in metallic bonding. Many explanations were poor, and references to *molecules, ionic bonding, van der Waals' forces* and even *hydrogen bonding* were frequently seen.

Q10.

This question was answered well by the majority of candidates. Common errors or misconceptions were limited to parts (a)(i) and (ii). Here it was not uncommon for candidates to be confused between metallic and ionic bonding.

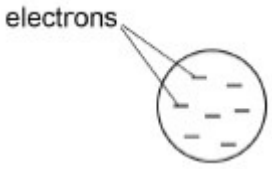
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Q1.

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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_____

_____

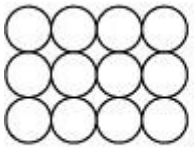
(5)

(Total 20 marks)

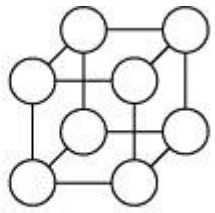
Q9.

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.

(a) Assume current model unless otherwise stated.

Statement about the nucleus:
(Central) nucleus contains protons and neutrons.

Allow "protons and neutrons are in the centre of the atom"

1

Statement about electrons
Electrons are now arranged in energy levels/shells/orbitals

Ignore "mostly empty space"

Ignore electrons surround / orbit nucleus

Allow additional statement about neutrons but must be separate from statement about nucleus to score

e.g.

no neutrons in plum pudding / neutrons now recognised

1

(b) $1s^2 2s^2 2p^3$

Ignore commas, capitals and subscripts

Allow $1s^2 2s^2 2px^1 2py^1 2pz^1$

1

(c) (R is N (nitrogen))

Formula Be_3N_2

Accept Be_3R_2 only if stated R = nitrogen

Accept N_2Be_3

1

[4]

Q2.

This question is marked using Levels of Response. Examiners should apply a 'best-fit' approach to the marking.	
Level 3 5-6 marks	All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 and then stage 3. Coherent communication requires that there is a comparison between the types of bonding and that the bonding is correct for each substance.
Level 2	All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies

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3-4 marks	OR two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows some progression from stage 1 to stage 2 and then stage 3.
Level 1 1-2 marks	Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR only one stage is covered but the explanation is generally correct and virtually complete. Answer shows some progression between two stages
Level 0 0 marks	Insufficient correct chemistry to gain a mark.

Indicative chemistry content. Contradictions (eg molecules, IMFs, covalent bonding,) negate statements.

Stage 1 - **Na**
1a) Na has metallic bonding
1b) there is attraction/ bonding between the positive nucleus/ ion and the delocalised electrons in Na
1c) Na has a giant/lattice structure

Stage 2 – **NaBr or NaI**
2a) Ionic bonding in NaBr and/or NaI
2b) There is attraction/ bonding between the + and – ions in NaBr and/or NaI
2c) NaBr and/or NaI have a giant/lattice structure

Stage 2 – **comparison of bonding**
3a) The ionic bonds are stronger (or wtte) than the metallic bonds
3b) there is stronger attraction (or wtte) between the + and – ions in NaBr than in NaI
3c) since the Br^- ion is smaller than the I^- ion

6

(b) **M1** $Na + H_2O \rightarrow NaOH + \frac{1}{2} H_2$

Allow multiples

1

M2 (Mass Na = 0.250 g so moles Na = 0.250/23.0) = 0.0109

CE: If not divided by 23, max 3/5 calculation marks – M3, M4 and M5

AE: If not divided by 1000 and final answer is 1.33 × 10^5 cm^3 4/5

1

M3 moles H_2 = 5.43 × 10^{-3} to 5.45 × 10^{-3}

M3 = M2 /2

CE: If incorrect ratio used max 3/5 calculation marks – M2, M4 and M5

1

M4 T = 298 (K) and P = 101000 (Pa)

1

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M5 V = nRT/P or (5.435 × 10^{-3} × 8.31 × 298)/101000 or 1.33 × 10^{-4} (m^3)

1

M6 V = 133 – 134 cm^3

Allow to 2 significant figures or more

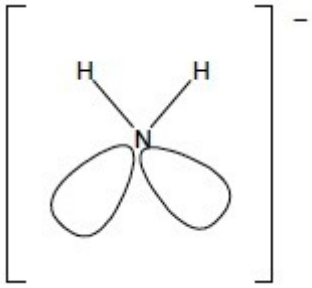
1

(c) Conc = 0.0109/ 500 × 10^{-3} = 0.0217-0.022 (mol dm^{-3})

Allow M2 from question (b)

1

(d) **M1**



Ignore charge and brackets

1

M2 104.5°

Allow 104-106

1

M3 (4) electron pairs repel to be as far apart as possible

1

M4 lp/lp repulsion> lp/bp repulsion (> bp/bp repulsion)

For M4 allow lone pairs repel more than bonding pairs

Mark independently

1

[16]

Q3.

B

[1]

Q4.

B

[1]

Q5.

(a) M1 550 × $\frac{100}{95}$ = 579 g would be 100% mass

Allow alternative methods.

There are 4 process marks:

1

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M2 So $\frac{579}{65}$ = 8.91 moles NaN_3

or

M1 $\frac{550}{65}$ = 8.46 moles NaN_3 (this is 95%)

M2 So 100% would be 8.46 × $\frac{100}{95}$ = 8.91 moles NaN_3

1: mass ÷ 65

2: mass or moles × 100 / 95 or × 1.05

3: moles NaN_3 × 2

4: moles $NaNH_2$ × 39

1

Then M3 Moles $NaNH_2$ = 8.91 × 2 = (17.8(2) moles)

1

M4 mass $NaNH_2$ = 17.8(2) × 39

1

M5 693 or 694 or 695 (g)

If 693, 694 or 695 seen to 3 sig figs award 5 marks

1

(b) M1 308 K and 150 000 Pa

1

M2 n = $\frac{PV}{RT}$ or $\frac{150\ 000 \times 7.5 \times 10^{-2}}{8.31 \times 308}$

1

M3 = 4.4(0) or 4.395 moles N_2

Allow only this answer but allow to more than 3 sig figs

1

M4 Moles NaN_3 = 4.395 × $\frac{2}{3}$ (= 2.93)

M4 is for M3 × $\frac{2}{3}$

1

M5 Mass NaN_3 = (2.93) × 65

M5 is for moles M4 × 65

1

M6 = 191 g

Allow 190 to 191 g allow answers to 2 sig figs or more

1

(c) (i) 150 / 65 = 2.31 moles NaN_3 or 2.31 moles nitrous acid

1

Conc = 2.31 × $\frac{1000}{500}$

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M2 is for M1 × 1000 / 500

1

4.6(1) or 4.6(2) (mol dm^{-3})

Only this answer

1

(ii) $3HNO_2 \longrightarrow HNO_3 + 2NO + H_2O$

Can allow multiples

1

(d) Ionic

If not ionic then CE = 0 / 3

1

Oppositely charged ions / Na^+ and N_3^- ions

Penalise incorrect ions here but can allow M3

1

Strong attraction between (oppositely charged) ions / lots of energy needed to overcome (strong) attractions (between ions)

M3 dependent on M2

1

(e) (i) $N \equiv N \longrightarrow N^-$

Only

1

(ii) CO_2 / N_2O / BeF_2 / HN_3

Allow other correct molecules

1

(iii) MgN_6

Only

1

[21]

Q6.

(a)

Method 1	Method 2
Mass of H_2O = 4.38−2.46	Percentage of H_2O = 44%
(= 1.92 g)	

If there is an AE in M1 then can score M2 and M3

If M_r incorrect can only score M1

1

$ZnSO_4$	H_2O	ZnSO4	H2O
2.46	1.92	56	44
161.5	18	161.5	18

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1

(0.0152		0.107)	(0.347		2.444)
(1	:	7)	(1	:	7)
x = 7			x = 7		

If x = 7 with working then award 3 marks.
Allow alternative methods.
If M1 incorrect due to AE, M3 must be an integer.

1

(b) Moles HCl = 0.12(0)

1

mol $ZnCl_2$ = 0.06(0) ***OR*** 0.12 / 2

1

If M2 incorrect then CE and cannot score M2, M3 and M4.

mass $ZnCl_2$ = 0.06 × 136.4
Allow 65.4 + (2 × 35.5) for 136.4

1

= 8.18(4) (g) ***OR*** 8.2 (g)
Must be to 2 significant figures or more.
Ignore units.

1

(c) Moles $ZnCl_2$ = $\frac{10.7}{136.4}$ (= 0.0784)

1

OR moles Zn = 0.0784

Mass Zn reacting = 0.0784 × 65.4 = (5.13 g)
M2 is for their M1 × 65.4

1

$$\%\text{ purity of Zn} = \frac{5.13}{5.68} \times 100$$

M3 is M2 × 100 / 5.68 provided M2 is < 5.68

1

= 90.2% ***OR*** 90.3%
Allow alternative methods.
M1 = Moles $ZnCl_2$ = 10.7 (= 0.0784)
136.4
M2 = Theoretical moles Zn = 5.68 (= 0.0869)
65.4
M3 = M1 × 100 / M2 = (0.0784 × 100 / 0.0869)
*M4 = 90.2% **OR** 90.3%*

1

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(d) Ionic

If not ionic CE = 0/3

1

Strong (electrostatic) attraction (between ions)

1

between oppositely charged ions / + and − ions / F^- and Zn^{2+} ions

If IMF, molecules, metallic bonding implied CE = 0/3

1

[14]

Q7.

(a) Hydrogen/H bonds

Not just hydrogen

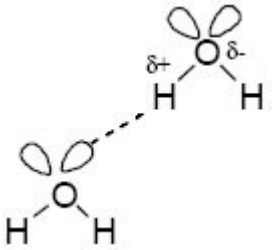
1

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

Not just dipole

1

(b)



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

3

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

OR

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

OR

H bonding is the strongest IMF

Ignore energy references
Comparison must be stated or implied

1

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

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surface area

Not heavier/greater Mr

1

therefore increased Van der Waals/IMF forces

Ignore references to dipole-dipole forces

1

(e) Dative (covalent)/coordinate

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

1

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

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

1

(f) ionic

1

if not ionic CE = 0

oppositely charged ions/+ and – ions or particles

atoms or molecules loses M2 and M3

1

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

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

1

[13]

Q8.

(a) (i) Average/mean mass of 1 atom (of an element);

Average mass of 1 atom × 12.

1

Mass 1/12 atom of ^{12}C;

Mass 1 atom of ^{12}C.
QWC.

1

(ii) Other isotope = 46.0%;

1

$$107.9 = \frac{(54 \times 107.1) + (46 \times ?)}{100};$$

M2 whole expression.

1

108.8;

Answer 108.8 (3 marks).

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Answer min 1 d.p..

1

Same electronic configuration/ same number of electrons (in outer shell)/ both have 47 electrons;

Ignore protons and neutrons unless incorrect.
Not just electrons determine chemical properties.

1

(b) Ionisation;

1

high energy electrons fired at sample;

Allow electron gun /blasted with electrons.

1

Acceleration;

1

With electric field/accelerating potential/potential difference;

Allow by negative plate.

1

Deflection;

1

With electromagnet/ magnet/ magnetic field;

M2 dependent on M1.
M4 dependent on M3.
M6 dependent on M5.

1

(c) (Silver) metallic (bonding);

Vdw/molecules CE=0.

1

Regular arrangement of same sized particles;

1

+ charge in each ion;

Ignore multiple positive charges.
Candidates do not need to show delocalised electrons.

1

(d) Ionic (bonds);

1

Minimum 4 ions shown in 2D square arrangement placed Correctly;

Do not allow multiple charges on ions.

1

Further 3 ions shown correctly in a cubic lattice;

1

Strong (electrostatic) forces/bonds;

If vdw/molecules/covalent mentioned CE = 0 for M4 and M5.

1

Between <u>+ and – ions</u>;

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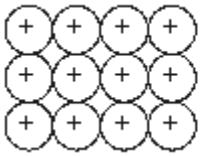
Accept between <u>oppositely charged ions</u>.

1

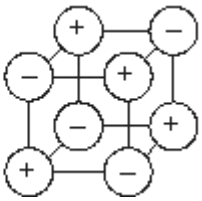
[20]

Q9.

(a)



(1)



(1)

[Diagrams must be complete and accurate]

2

(b) (i) <u>Attraction</u> /electrostatic forces/bonds/attractions between (positive) ions/lattice and <u>delocalised/free</u> electrons/sea of electrons.

[Not metallic bonding]

[Not just 'forces']

1

(ii) Electrostatic attractions/forces between ions or attractions between (oppositely charged) ions/ Na^+ & Cl^-

[Not ionic bonding]

1

(iii) (Here) the ionic bonding in NaCl is stronger/requires more energy to break than the metallic bonding in Na

QoL Accept 'bonding/forces of attraction in NaCl is strong<u>er</u> than in Na'

[If IMF/molecules/van der Waals'/dipole–dipole mentioned in parts(i) or (ii), then CE = 0 for parts (i) and/or(ii) and CE = 0 for part(iii)]

1

(c) Comparison:
Sodium conducts **and** sodium chloride does NOT conduct

Allow 'only Na conducts'

Accept 'Na conducts, NaCl only conducts when molten'

[Do not accept sodium conducts better than sodium chloride etc.]

1

Explanation:
(Delocalised) electrons flow though the metal

1

Allow e^- move/carry current/are charge carriers/transfer charge.

[Not 'electrons carry electricity']

[Not 'NaCl has no free charged particles']

<u>Ions</u> can't move in solid salt

1

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(d) Layers can slide over each other – idea that ions/atoms/particles move

[Not molecules]

[Not layers separate]

1

(e) (i)

Na	Cl	O
$\frac{21.6}{23}$	$\frac{33.3}{35.5}$	$\frac{45.1}{16}$

1

0.9(39)	0.9(38)	2.8(2)
Hence: 1	1	3

Accept backwards calculation, i.e. from formula to % composition, and also accept route via M_r to 23; 35.5; 48, and then to 1:1:3

[If % values incorrectly copied, allow M1 only]

[If any wrong A_r values/atomic numbers used = CE = 0]

1

(ii) $3Cl_2 + 6NaOH \rightarrow 5NaCl + NaClO_3 + 3H_2O$

1

[12]

Q10.

(a)

Particle	Relative charge	Relative mass	
Proton	+1 **or** 1+	1	**(1)**
Neutron	0 **or** no charge/neutral/zero	1 (not – 1)	**(1)**
Electron	–1 or 1–	1/1800 to 1/2000	**(1)**

or negligible
or zero
or 5.0×10^{-4} to 5.6×10^{-4}

if 'g' in mass column - wrong
penalise once

3

(b) $^{38}_{18}Ar$ **(1)(1)**

Allow numbers before or after Ar

2

(c) *S*: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$ **(1)**

Allow upper case letters

S^{2-}: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ **(1)**

If use subscript penalise once

2

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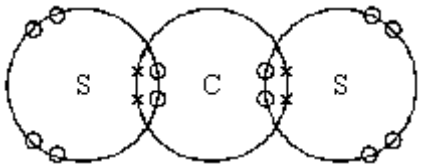
(d) *Block*: p **(1)**
Explanation: Highest energy or outer orbital is (3) p
OR outer electron, valency electron in (3) p
NOT 2p etc.

2

(e) (i) *Bonding in Na_2S*: ionic **(1)**
Bonding in CS_2: covalent **(1)**
ignore other words such as dative / polar / co-ordinate

(ii) Clear indication of electron transfer from Na to S **(1)**
1 e^- from each (of 2) Na atoms or 2 e^- from 2 Na atoms **(1)**
QoL correct English

(iii)



Correct covalent bonds **(1)**
All correct including lone pairs **(1)**
Allow all •s or all ×s
M2 tied to M1
NOT separate e^-s in S•- 2 l p

(iv) $CS_2 + 2H_2O \rightarrow CO_2 + 2H_2S$ **(1)**
Ignore state symbols even if wrong

7

[16]

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Q1.

(a) Most students understood that electrons are now arranged in energy levels, although many didn't make reference to sub-atomic particles in their answer. Students did not always make a comparison and it was not always clear which model they were referring to in their responses.

(b) Almost all students (91.3%) were able to write the correct electron configuration in terms of shells and sub-shells, although a few students made no reference to sub-shells.

(c) Many students were able to identify that the two elements were nitrogen and beryllium but many were then unable to write the correct formula of the compound formed between them.

Q2.

(a) This levels-of-response question discriminated very well, with approximately one third of students scoring marks in each of the three levels. Some excellent answers were seen. Some students, however, answered very well initially but then used wrong terminology, for example wrong bonding and/or intermolecular forces in all/some of the substances, and showed contradictions in their answers.

(b) Unfortunately, the equation was often seen with sodium oxide as the product rather than sodium hydroxide. In the calculation, many students did not use the 2:1 ratio from the equation, leading to an answer of 267 cm^3. However, this part of the question also discriminated well, with over 25% of students gaining full marks; most students scored some marks and less than 3% scored zero.

(c) Just under half of the students (48.5%) gave a correct answer; the commonest error was to multiply the amount, in moles, by volume rather than dividing by volume.

(d) This part discriminated well, though only a few students (7%) scored full marks. The structure often had the wrong number of lone pairs and/or the wrong bond angle. That lone pair-lone pair repulsion is greater than bond pair-bond pair repulsion was known by the majority of students.

Q5.

The correct answer to the calculation in part (a) was seen regularly, but there were some students who made an attempt at it, gained two or three marks, and then could not complete the calculation. The most common errors were either to ignore the factor of 2 from the equation or multiply by 78 rather than 39. The calculation in part (b) was attempted by almost all students resulting in the full range of marks. The first three marks were regularly seen in students' answers but often this was followed by a failure to multiply by the correct factor from the equation. It was disappointing to note that there were still some students who could not rearrange the ideal gas equation correctly. In part (c)(i) many students did not score full marks since they could not convert volume into dm3 and therefore could not give the concentration in mol dm^{-3} as asked for in the question. Many students could not balance the equation in part (c)(ii). Part (d) was well answered although there were some students who thought the azide ion was N^{3-} rather than N^{3-}. The arrow in part (e)(i) was rarely in the right place and it was disappointing to note how many did not use an arrowhead on one of the bonds shown as specified in the question. Part (e)(ii) was not well answered with many students suggesting species that were not

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molecules; Ti was a common incorrect answer. The whole range of answers was seen in part (e)(iii) but many students were able to identify the correct formula.

Q6.

Some students found no difficulty with the three numerical parts of this question. However, this question proved challenging for many students who often gave a jumble of figures with little explanation of where they came from.

Part (a) was the most well answered of the calculations although a small number could not score the first mark. In part (b), most students scored the mark for the number of moles of HCl. However, many students then used 0.083 in their answer and did not realise that the HCl was the limiting reagent. Many added the moles of HCl to the moles of pure zinc oxide whilst others multiplied the moles of HCl by 2 rather than dividing.

Answers to part (c) used various methods with many scoring the first two marks of the alternative method shown in the mark scheme. It should be noted that if an answer requires 3 significant figures, then the calculation should use at least 3 significant figures throughout. If less than this is used and then the answer is given as 3 ‘significant’ figures, this will have introduced error and the final answer will not be within the margin of tolerance allowed. The bonding in part (d) was answered well by the majority of students.

Q7.

Candidates answered part (a) well with only a few losing marks for simply referring to ‘hydrogen’ or ‘dipole bonds’. Part (b) was done well by many candidates. Weaker candidates did not show hydrogen bonds from the lone pair. There were a number of recurring errors including water as HO_2, partial charges missing or the wrong way round. Part (c) was generally answered well with candidates relating their answers to comparisons between IMF’s. Candidates found part (d) more challenging and there were several answers in terms of the greater attraction between the outer electrons and the protons in the nucleus or electronegativity differences. Part (e) was generally well answered with candidates knowing the type of bonding and making an attempt at the explanation. Marks were lost for general descriptions of dative covalent bonding rather than referring specifically to the species given in the question. The type of bonding in part (f) proved a good discriminator. Although many candidates gave the correct type of bond, weaker ones suggested covalent or metallic bonds. The explanation also proved more difficult. Many lost marks for breaking IMF’s as well as, or instead of, ionic bonds. Candidates who knew about strong electrostatic attractions often failed to say that this was between oppositely charged ions.

Q8.

Many candidates produced good answers here but it must be stressed that the definition of relative atomic mass must be absolutely correct for the award of both marks. Many candidates left out ‘average’ mass or the factor of 12.

Having to find the RAM of one of the isotopes challenged many of those who were unable to manipulate the equation but candidates regularly scored the first two marks and only lost the third calculation mark due to lack of dexterity with rearranging and algebra. The idea of isotopes having the same electron arrangement was generally well known although lots of answers included references to protons and/or neutrons.

Part (b) was well answered with the most common error being the confusion of electric and magnetic field. The processes were very well known. In part (c) there was confusion over metallic and ionic bonding. In part (d) most candidates had the idea of a 3D lattice but errors arose from multiple charges or negative charges on the Ag or like charges next

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to each other at some point in the lattice. Most candidates realised that ionic bonding was present, but some then contradicted their answers by mentioning intermolecular forces.

Q9.

In a surprisingly large proportion of instances, the diagrams were either left blank or were incomplete. Of those candidates who did attempt part (a), most coped well but it was not unusual for the diagram of sodium metal to contain negative charges, or for the sodium chloride diagram to show the same change on adjacent ions. Many of the explanations in part (b) were poorly done. Frequently, the answers to parts (b)(i) and (b)(ii) lacked any reference to the attraction between the relevant species. The most common answer to part (b)(iii) was to state that *ionic bonding is stronger than metallic bonding,* as if this were a universal truth, rather than deducing that this comparison was true in this case. In part (c), candidates frequently referred to sodium being a better conductor that sodium chloride; although some did then go on to clarify matters by explaining that sodium chloride would only conduct when molten. It was very common to see references to *covalent bonds, van der Waals', dipole-dipole* and *intermolecular forces* in this question. In part (c), some good explanations were seen but, all too often, they were vague and incomplete. Many candidates were aware of the importance of delocalised electrons to the conductivity of sodium; however, relatively few described them flowing though the metal. The lack of conductivity of sodium chloride was often ascribed to there being no *free electrons* in the salt. Also, a significant minority of candidates simply referred to the presence or absence of *charge carriers,* without identifying them. Very few candidates explained the lack of conductivity of solid sodium chloride in terms of its immobile ions. Parts (d) and (e) were comparatively well answered, although the malleability of sodium being was sometimes attributed to the presence of *weak intermolecular forces.* The empirical formula calculation was usually accurately calculated and the equation correctly balanced.

Q10.

Many candidates answered this question quite well but full marks were not that common. Most candidates correctly completed the table in part (a) but it was not unusual for either the signs or the values of the relative charges to be omitted. In a few instances, the values of the electron and the neutron were transposed. Success in part (b) was far from universal. Errors such as 39.9 and 36 for the mass number were quite common, as was the use of Z to represent the element. Part (c) was, in the main, successfully completed but the odd d level was seen, as were configurations for the S^{2-} ion showing $3p^2$ rather than $3p^6$ electrons, or even a $2p^8$ arrangement. While part (d) was also generally well done, some candidates were found to be unfamiliar with this part of the specification and the suggestion that the element was found in block 6, because it contained 6 outer electrons, was not uncommon. Some candidates incorrectly referred to the p-block or p-shell, rather than using the correct terms sub-level or sub-shell. In part (e), a surprising number of candidates identified incorrectly the bonding in Na_2S as being covalent or metallic, and the bonding in CS_2 as being ionic, molecular or dative. For those candidates who did recognise the ionic nature of the bonding in Na_2S, their descriptions were often vague and they did not express clearly the transfer of electrons which takes place, and the numbers of electrons involved. Many answers could have equally well fitted the description for the formation of a covalent bond. The diagram of the bonding in CS_2 was frequently flawed, with spare electrons being placed around carbon and extra lone pairs on the sulphur atoms. Some candidates showed a single bond between the sulphur and carbon atoms, whilst others only included a single sulphur atom. The equation was almost invariably correct; although, in a few cases, the equation was not balanced.

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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*.

_____

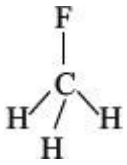
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_____

_____

(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.

_____

_____

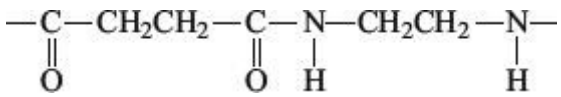
(3)

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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, $HOCH_2COOH$

_____

_____

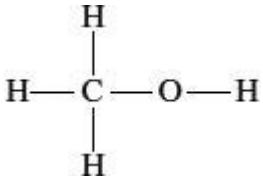
_____

(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 $CH_3COOH(l)$

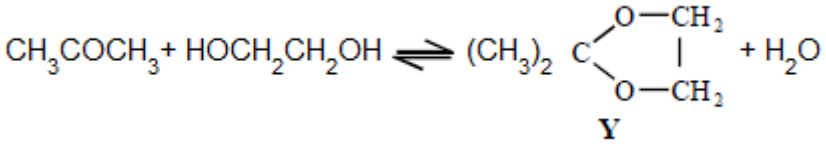
D $CH_3OH(l)$

(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.

(a) Outer electrons are in p orbitals

1

(b) decreases

1

Number of protons increases

1

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

1

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

1

Therefore van der Waals' forces between molecules are stronger

1

Therefore more energy needed to loosen forces between molecules

1

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

1

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

1

[9]

Q2.

(a) tendency / strength / ability / power of an <u>atom</u> / <u>element</u> / <u>nucleus</u> to attract / pull / withdraw electron<u>s</u> / e - density / bonding pair / shared pair

1

in a <u>covalent</u> bond

1

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

1

CH_3F dipole-dipole
(not just 'dipole')

1

HF = hydrogen bonding
(not just 'H' / 'hydrogen')

1

(ii) large difference in electronegativity between H and F / F most/very/much more electronegative / values '4' & '2.1' quoted
(not just 'high<u>er</u>')

1

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

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

1

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

(M2 / M3 may be scored from a diagram)

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

1

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

(ignore references to dipole-dipole)

1

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

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

(mark M1 and M2 separately)

1

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

(accept hydrogen bonding is very strong / strongest)

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

(not just 'HF has H-bonding')

1

[11]

Q3.

(a) polyamide or nylon (2,4)

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

1

condensation

1

(b) $H_3\overset{+}{N}-CH_2-C\overset{-}{O}O$

1

(c) ionic bonding in aminoethanoic acid

(can only score if includes that aminoethanoic is ionic)

1

stronger attractions than Hydrogen bonding in hydroxyethanoic acid

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

(mention of electrostatic forces between molecules scores 0)

1

[5]

Q4.

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

1

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

1

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

1

Hydrogen bonding between methanol molecules;

1

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

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

(if ionic/covalent etc. max 1)

(mention of bond break = CE = 0)

1

[5]

Q5.

A

[1]

Q6.

(a) <u>Hydrogen</u> bonding *(full name)*

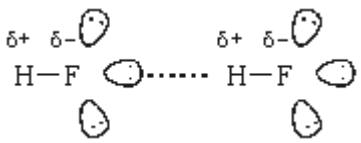
1

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

(If full charges shown, M2 = 0)

1

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



(If atoms not identified, zero for diag)

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

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

1

Dipole results from electronegativity <u>difference</u> **or** values quoted

('difference' may be inferred)

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

1

QoL Fluorine more/very electronegative **or** iodine less electronegative

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or electronegativity difference too small in HI
Comparison required, may be implied.

1

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

1

(b) NaCl is ionic (lattice)

(Treat atoms/molecules as a contradiction)

(Accept 'cubic lattice')

1

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

(NOT molecular or tetrahedral)

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

1

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

(NOT just 'weakened' etc.)

('Covalent' may be inferred from diagram)

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

2

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

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

1

[11]

Q7.

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

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

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

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

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

Note: if the explanation is clearly intramolecular = CE

4

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

Do not accept 'donation of electrons'

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

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

Ignore missing charge

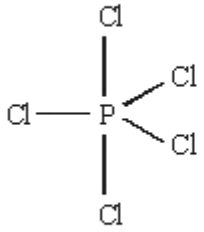
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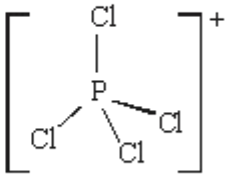
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(c)

4

PCl_5 PCl_4^+





(1) **(1)**

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

Bond Angle(s) 90° and 120° **(1)**

PCl_4^+ shown as tetrahedral [Look for: NO solid linear Cl-P-Cl bonds]

Bond angle(s) 109 or 109.5° **(1)**

[10]

Q8.

A

[1]

Q9.

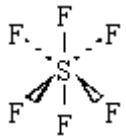
C

[1]

Q10.

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

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

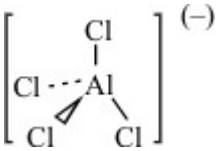


Wrong symbols - no diagram mark

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

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

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



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

QoL may be awarded here also
Mark all points independently

8

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

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

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

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

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

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

4

[12]

Q11.

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

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

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

OR London, Dispersion, temporary dipole

3

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

OR within molecule

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

(ii) molecular **(1)**

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

OR V.dW forces
OR intermolecular forces
Mention of ions CE=0

4

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

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

OR V.dW

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

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

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

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

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

QL mark (Look for unambiguous statements using correct terminology)

5

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

Strong forces between ions **(1)**

OR lots of energy required to break bonds

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

mention of molecules etc CE=0

3

(e) macromolecular **(1)**

OR giant molecule / lattice or correct diagram

Strong covalent bonds **(1)**

OR lots of energy required to break bonds

2

[17]

Q12.

B

[1]

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Q2.

Overall, this question produced the most inaccurate answers on the paper. While a higher proportion of candidates offered acceptable answers in part (a) than has been the case in the recent past, many attempts were incomplete and so failed to earn credit. A significant number of candidates failed to specify that the electrons being attracted were those in the covalent bond, while others identified these electrons as being lone pair electrons. Imprecise statements, such as "*An atoms ability to attract electrons to itself when covalently bonded*", were quite common. In some cases, definitions referred to electrons being *removed* from a covalent bond and so earned no credit.

While an encouraging number of candidates correctly deduced the types of intermolecular forces present in the part (b)(i), errors were common. It was not unusual for *van der Waals'*, *dipole-dipole* and *hydrogen bonding* all to be quoted but to be applied to the wrong substances. Similarly, duplication of one of these intermolecular forces was quite often seen. In a few instances, *ionic bonding* and *metallic bonding* were seen, and some candidates simply referred to *dipole* rather than to *dipole-dipole* attractions. Part (b)(ii) was poorly done. On previous papers, similar questions required candidates to draw a diagram to illustrate hydrogen bonding between molecules; such questions tend to be quite well done. In this question, candidates are required to explain how hydrogen bonding occurs and many explanations were found lacking. The presence of a dipole between the atoms in a molecule of HF was well known but quite frequently not well described. Many candidates omitted to link the partial charges to specific atoms, while others referred to hydrogen atoms being *positive* and/or fluorine atoms being *negative*, inferring that these charges were full rather than partial charges. Others specifically referred to the presence of '+' and '–' charges. An explanation of the origin of the dipole was required but this was often missing or vague. Many candidates simply referred to the hydrogen atom being *deshielded*, or referred to a *deshielded proton* but made no reference to the electronegativity of fluorine being much higher than that of hydrogen. The final mark for this question was for describing the attraction of the $^{\delta+}$H on one molecule to a lone pair of electrons on a fluorine atom of another molecule; such descriptions were infrequently seen.

Part (c) was difficult for a significant number of candidates. Many tried to explain the increasing boiling point in terms of increased dipole-dipole attractions, despite the decreasing trend in electronegativity difference evident from the data provided in the table. Of those candidates who identified the presence of van der Waals' forces, relatively few linked the increase in these forces to the increasing size of the halogen atoms. Some candidates based their explanation on the breaking of *bonds*, or even of *covalent bonds*. In part (c)(ii), candidates tended to simply refer to the presence of hydrogen bonding in HF, rather than comparing this with the weaker van der Waals' attractions present in the other hydrogen halides.

Q3.

Part (a) was answered well by many candidates. In part (b), only the better candidates drew the structure as a zwitterion. Part (c) was poorly answered: very few stated that amino acids have ionic bonding and even fewer compared it correctly the strength of these electrostatic interactions with the hydrogen bonding present between molecules of hydroxyethanoic acid. There was frequent use of the term molecule in relation to the ionic form of glycine.

Q4.

Many candidates coped well with this question and full marks were quite common. In part (a), some candidates referred simply to a difference in electronegativity between hydrogen and oxygen, rather than identifying oxygen as having the greater electronegativity value, while a few got it completely the wrong way round. The formation of the dipole across the O-H bond was often poorly explained, as many candidates simply referred to electrons being more strongly attracted towards oxygen, rather than identifying those electrons as being the bonding electrons. Many candidates earned this second mark by showing the appropriate partial charges on the oxygen and hydrogen atoms. In part (b), many good answers were seen, with candidates basing their answers on the different intermolecular forces present in the two substances. It was quite common, however, for dipole-dipole attractions to be offered for either substance, for van der Waals' forces to be specified for both substances or for the higher boiling point of methanol to be attributed to the breaking of its covalent bonds.

Q6.

Many very good answers were seen to this question and high marks were quite common. Many clear and accurate diagrams were seen; however, diagrams showing just one HF molecule, or showing less than three lone pairs on the fluorine were reasonably common. Dipoles were not always correctly shown and hydrogen bonds were not always drawn between a lone pair on a fluorine atom and the hydrogen atom. Occasionally, lone pairs were shown on hydrogen atoms. The explanation of the absence of hydrogen bonding in HI was reasonably well known but some answers were rather vague. As the question dealt with the variation in the intermolecular forces present in the hydrogen halides, an understanding that these forces are determined by the magnitude of the difference in electronegativity present in the molecule was expected. Thus, a comparison of the electronegativity differences present in the two compounds was required if full marks were to be awarded. Such a comparison was quite frequently lacking. In part (b), contradictions abounded. Many candidates lost marks through careless use of language, where *ionic/covalent/ molecular/macromolecular* were used indiscriminately. Intermolecular attractions were stated to exist in ionic sodium chloride, while van der Waals' forces often appeared in discussions of the diamond structure. Rather than referring to the large amount of energy required to *break* the covalent bonds in diamond, words such as *disturb* or *weaken* were frequently used and earned no credit.

Q7.

This question produced many good answers. In part (a)(i), electronegativity was frequently quoted as the required property of the atoms. A reference to the 'high electronegativity of fluorine and chlorine' was accepted here but vague references to 'high electronegativity of the atoms' was not. Errors included simple references to 'unequal sharing', which did not address the question, and arguments based on the number of protons present in the nuclei. Many candidates provided acceptable explanations in part (a)(ii) but many confused attempts were also seen. Most candidates attributed the difference in boiling points to differences in the strength of intermolecular attractions but the types of attraction present in the two systems were quite frequently confused. It was not always clear that the forces described were intermolecular in nature. In part (b), the origin of a co-ordinate bond was well known, however, some candidates confused the direction of electron pair donation. The quality of drawing seen in part (c) varied considerably. Most diagrams proved to be acceptable but some were very poor. In some cases, the use of dotted lines and wedges to show the direction of the bonds was more of a hindrance than a help. It is recommended that candidates who intend to use these devices practice them beforehand. Some diagrams, especially that of $AlCl_4^-$ showed a lone pair, while other diagrams clearly indicated a planar structure. Most candidates were able to deduce the appropriate bond angles, but errors were not uncommon.

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Q10.

The quality of answers offered by candidates in part (a) varied considerably. There were some very good and clear diagrams of the species but there were many poor ones also. A considerable number of the diagrams for the $AlCl_4^-$ ion showed a lone pair of electrons and some candidates described the dative bond as being a lone pair. The suggestion of a bond angle of 107° in the $AlCl_4^-$ ion was quite common. A few diagrams of the structure of SF_6 also contained lone pairs, nd in some cases bond angles of 60° or 120° were quoted. References to repulsion between fluorine or chlorine atoms are unacceptable but were still rather common. A considerable number of candidates performed a calculation to determine the number of electron pairs present in the species. Often, there was no indication of whether pairs were bonding or non-bonding pairs and in some instances candidates quoted such figures without reference to electrons at all. In many cases, explanations were rambling and lacking in precision. Few candidates attributed the regular shapes of the species to equal repulsion between specified numbers of bonding pairs, and so the marks allocated for the explanation of the shapes were frequently not earned. Some interesting answers to part (b) were seen. Many candidates experienced some difficulty in applying their understanding of 'changes of *state*' and '*behaviour of gases*' (specification section 10.3.4) in this somewhat novel context. While many correctly deduced that the energy required to vaporise the solvent was taken from the skin and so induced cooling, few candidates attempted to explain the meaning of the term *volatile solvent*. The spreading of the fragrant molecules by *diffusion* was frequently reported but few candidates attempted to explain why the fragrance would be detected *after a while*, rather than instantaneously.

Q11.

This question discriminated very effectively between good and weak candidates. Answers given by the latter were often imprecise, contradictory and incomplete. In part (a) ionic and covalent bonding were surprisingly frequent incorrect answers. Many answers to part (b)(i) did not display a clear understanding of the distinction between the covalent intramolecular bonds and the van der Waals' intermolecular bonding in iodine. In part (b)(ii) the iodine crystal was often described as ionic even when ionic bonding was not mentioned in the previous part. In part (b)(iii) candidates frequently suggested incorrectly that covalent bonds between iodine atoms must be broken. In part (c)(i) most candidates gained one mark for mentioning hydrogen bonds but few drew a comparison between those bonds and the weaker intermolecular forces in hydrogen chloride. In part (c)(ii) many candidates did not answer the question. They referred to iodine and chlorine rather than to hydrogen iodide and hydrogen chloride. Marks were lost frequently in part (d) because sodium chloride molecules were mentioned, particularly in part (d)(ii). In part (e), despite reference in the question to structure and bonding many candidates did not mention the macromolecular structure of graphite.

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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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_____

_____

_____

_____

_____

_____

_____

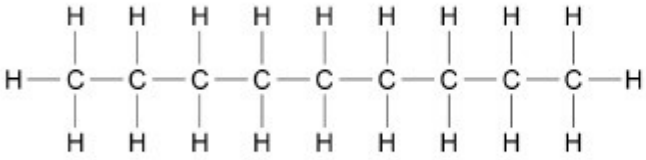
(3)

(Total 8 marks)

Q2.

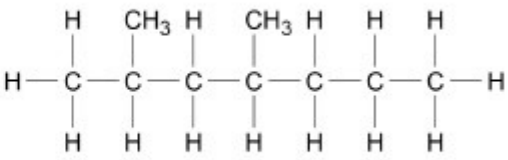
The alkanes nonane and 2,4-dimethylheptane are structural isomers with the molecular formula C_9H_{20}
They are found in crude oil and can be separated by fractional distillation.
Both can be used in fuels or cracked to form other products.

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 _____

_____

_____

_____

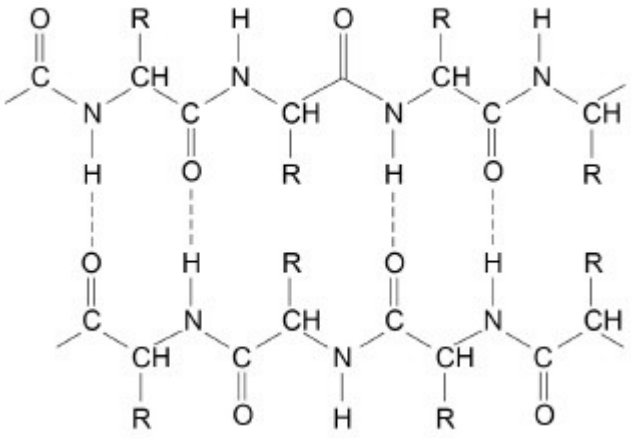
(2)

(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)

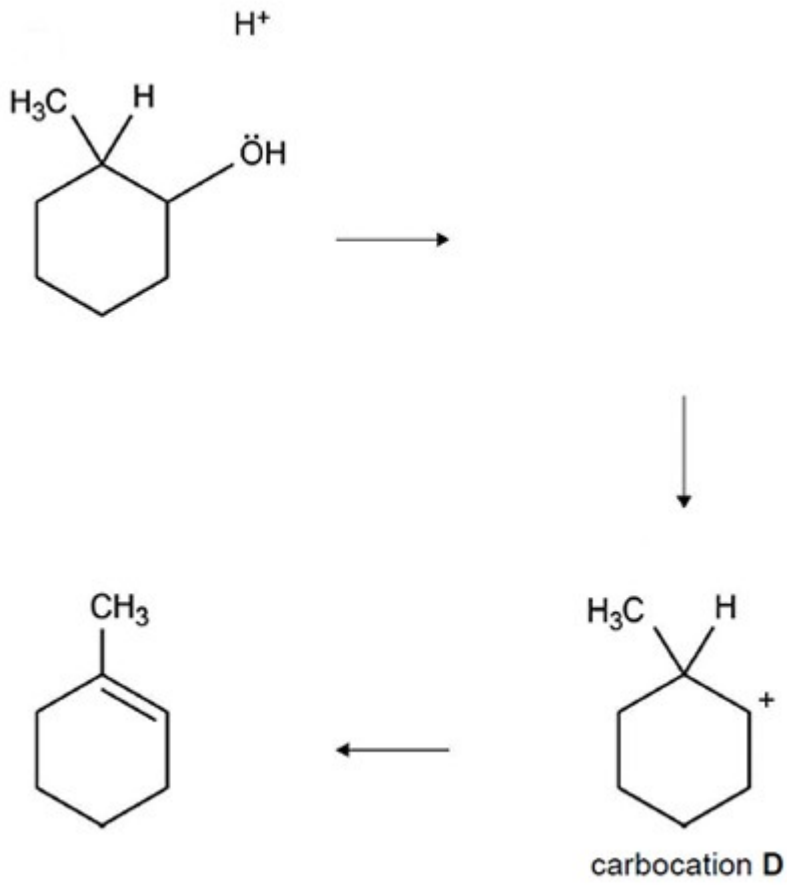
Q7.

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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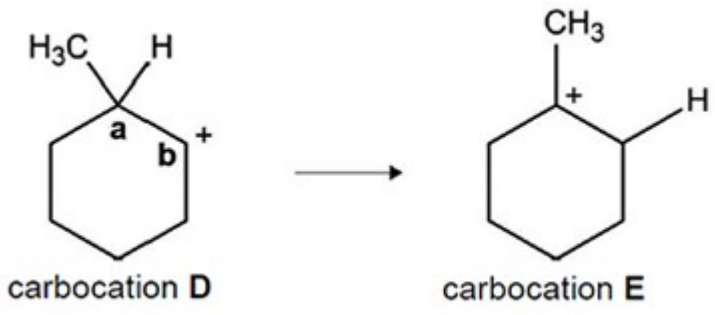


(4)

(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.

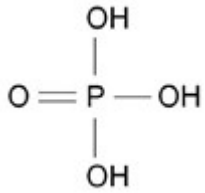
(2)

(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)

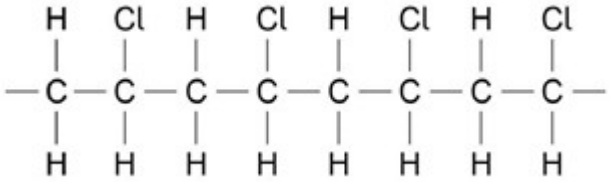
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(Total 14 marks)

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.

_____

_____

_____

_____

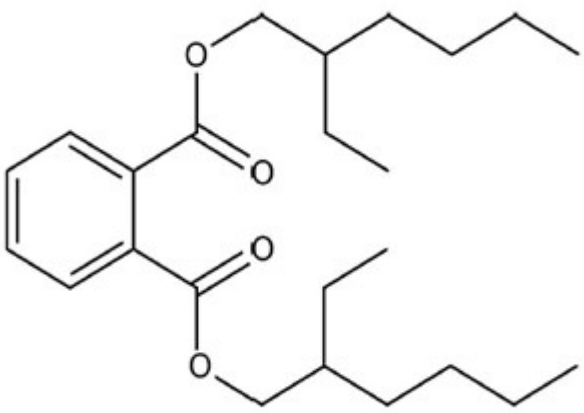
_____

_____

_____

(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.

_____

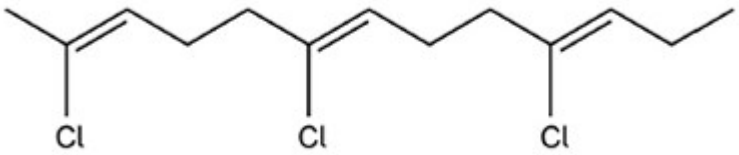
_____

_____

_____

(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 ⬭

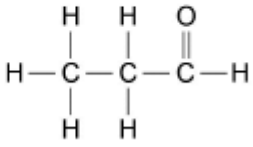
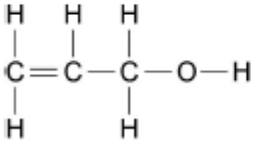
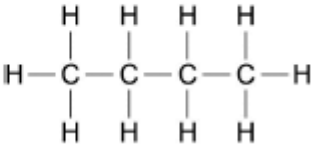
D CH_3F ⬭

(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.

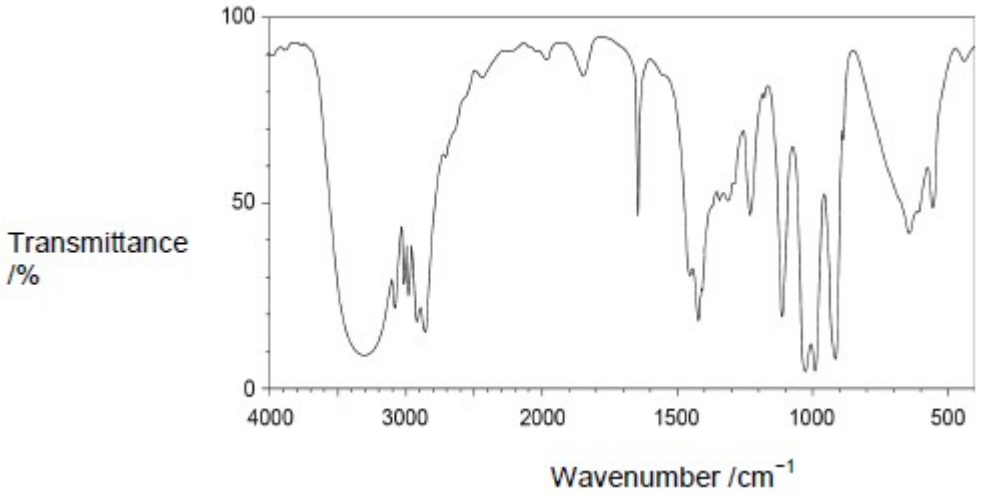
_____

_____

_____

(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.

_____

_____

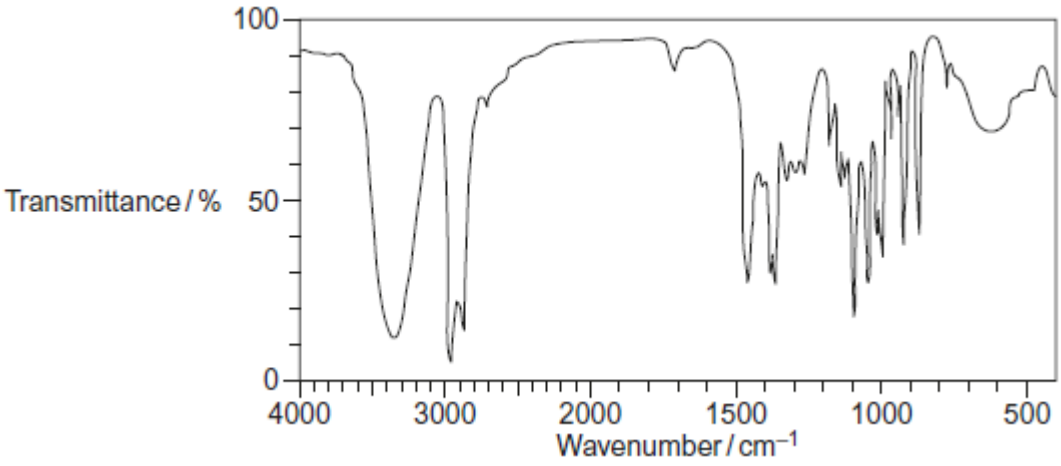
_____

_____

_____

(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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_____

_____

_____

_____

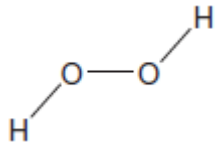
_____

(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.

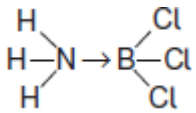
_____

(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.

_____

_____

_____

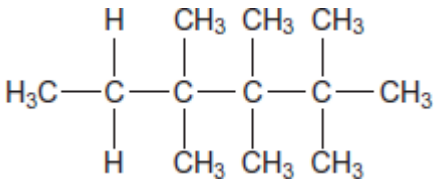
_____

_____

(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.

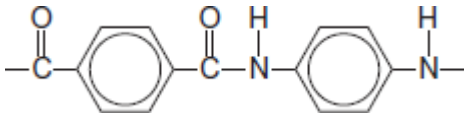
_____

(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.

_____

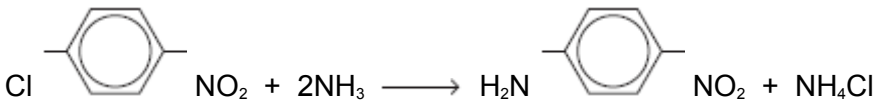
(1)

(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**.

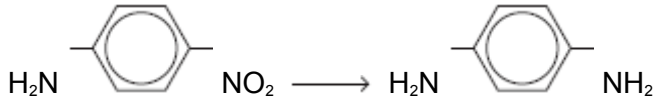
Stage **1**



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 _____

_____

_____

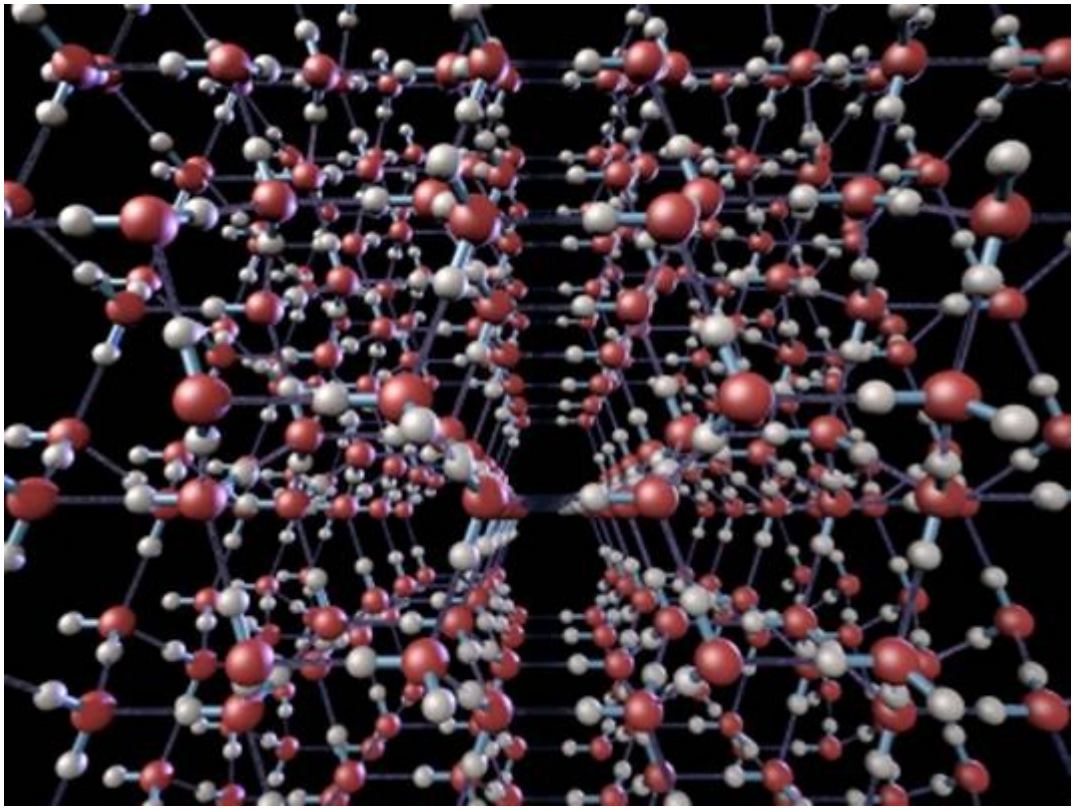
(2)

(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 _____

_____

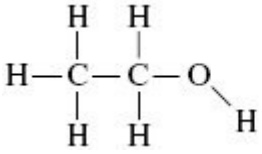
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(3)

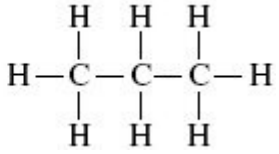
(Total 13 marks)

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)

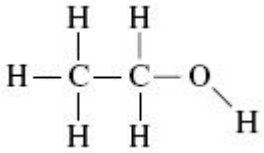
(ii) State the strongest type of intermolecular force present in each compound.

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.

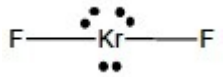
..... $AsCl_3$ + ... $NaBH_4$ → ..... AsH_3 + ... NaCl + ... BCl_3

(1)

(Total 14 marks)

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Q1.

(a) 

Allow diagram with 2 bonds <u>and</u> 3 lone pairs

1

<u>Linear</u>

1

<u>180°</u>

1

(b) Lone pairs repel more than bond pairs

1

Allow idea of reducing bond angle

bond angle will be lower (than regular tetrahedral angle) / bond angle of 103-106°

1

(c) Van der Waals forces

Allow London forces, dispersion forces, induced dipole-dipole

Apply List for M1.

Allow M2 if vdW mentioned in M1, otherwise CE=0

1

(Uneven distribution of electrons in) one molecule <u>induces</u> dipole in neighbouring/another/nearby <u>molecule</u>

1

symmetrical molecule / dipoles cancel

OR

no hydrogens bonded to F (N or O), therefore no hydrogen bonding

1

[8]

Q2.

(a) **M1** C_nH_{2n+2}

1

M2 14.0*n* + 2.0 or 14n + 2

or 2(7.0n + 1.0) or 2.0(7n + 1) or 2(7n + 1)

1

(b) **M1** nonane has stronger / greater / more <u>van der Waals' forces between molecules</u>

or converse arguments for 2,4-dimethylbutane having lower boiling point

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question refers to nonane if not expressly stated by candidate

intermolecular forces = forces between molecules

***M1** ignore abbreviations vdW and/or imf*

1

M2 nonane molecules pack closer together / more (surface) contact

***M2** ignore reference to surface area alone*

CE=0 reference to breaking (covalent) bonds / breaking chain

1

(c) $C_9H_{20} + 14O_2 \rightarrow 9CO_2 + 10H_2O$

allow multiples; ignore any state symbols; correct structures rather than formulae are fine

1

(d) **M1** nitrogen and oxygen from air react

***M1** must be at least one reference to air and no reference to nitrogen/oxygen coming from the fuel*

1

M2 at high temperature

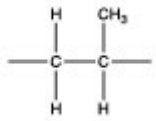
ignore reference to pressure, heat, hot, incomplete combustion

if temperature is stated, must be over 1000°C

1

(e) thermal (cracking)

1

(f) 

allow any correct structural representation

ignore any n or brackets

1

[9]

Q3.

B

[1]

Q4.

(a) Aldehyde/propanal has <u>dipole-dipole</u> forces (between molecules)

If any 'covalent bonds broken' CE=0 for clip.

Ignore Van der Waal forces

M1

Alcohol/propan-1-ol AND Carboxylic acid/ propanoic acid have hydrogen bonding (between molecules).

Ignore reference to energy

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M2

The forces between the molecules in aldehyde are weaker (than those in alcohol and acid so it will evaporate first.)

M3 only awarded following correct M1 OR M2

Allow converse for M3

M3

(b) Keep the temperature of the reaction mixture below the boiling point of propan-1-ol/below 97 °C

Allow temperature in range 49-96 inclusive

Allow description of cooling the vessel

M1

Cool the distillate / collecting vessel

Ignore reference to oxidising agents

Penalise lid / sealed container

M2

(c) Add named carbonate/hydrogencarbonate OR magnesium to a sample of the distillate.

Incorrect chemical CE=0

Allow formula (mark on for incorrect formula)

Allow blue litmus or correct named indicator

M1

Effervescence/fizz/bubbles would confirm presence of acid or converse

Blue litmus turns red confirms acid present or converse

Allow gas/CO_2 produced which turns lime water cloudy OR gas/H_2 produced which burns with a squeaky pop

M2

(d) (Temperature difference = 15.1 °C)

If ΔT wrong – AE mark on otherwise can only award M2

If use 457 in M1, can only score M2

q = 150 × 4.18 × 15.1 or 9467.7 J or 9.4677kJ

M1

amount ethanol burned = 0.457/46.0 = 9.93×10^{-3} mol

If use 457 in M2 can score 2 for - 0.953 kJ mol-1

M2

Heat change per mole = (M1/1000)/M2 = 952.99 kJ mol-1

ΔH = – 953 kJ mol^{-1} must be 3sfs and must be negative

(allow range -953 to -954)

BEWARE if they miss conversion to kJ and also miss conversion to g, they get answer = - 953 which scores 1

+953 can score M1 and M2

Allow -950 or -960 for rounding to 2sf

M3

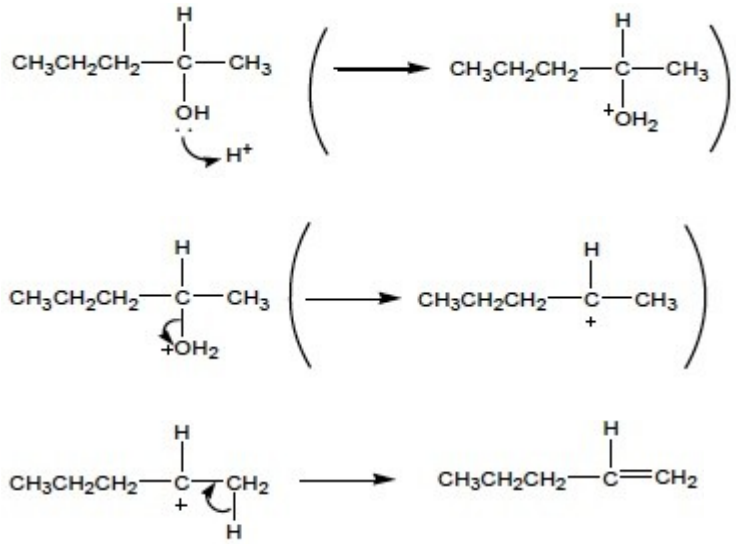
(e) Elimination

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Penalise base elimination

M1

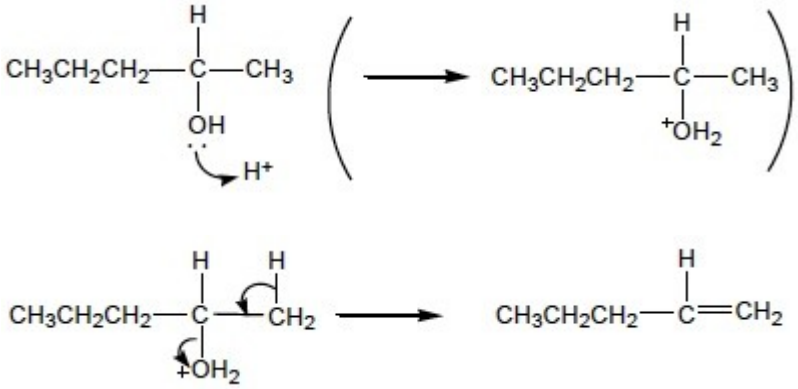
Mechanism : Either (E1)



M2 for protonation of alcohol, i.e. lp plus arrow to H^+ or to H of H–O– in H_2SO_4 and from H-O bond to O
M3 for protonated alcohol plus arrow showing loss of water
M4 for arrow showing loss of H^+
From correct carbocation (E1)
wrong alcohol used / alkene formed loses M4

3

OR (E2)



M2 for protonation of alcohol, i.e. lp plus arrow to H^+ or to H of H–O– in H_2SO_4 and from H-O bond to O
M3 for protonated alcohol plus arrow showing loss of water
M4 for arrow showing simultaneous loss of H^+
wrong alcohol used / alkene formed loses M4

3

(f) *E*-pent-2-ene

Allow trans

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M1

C=C bond cannot <u>rotate</u> **and**

Each carbon in the double bond has (2) different groups attached.

Allow (two) different groups on each/either side of the double bond.

M2

[16]

Q5.

(a) electron deficient H

Allow H delta plus / slightly positive

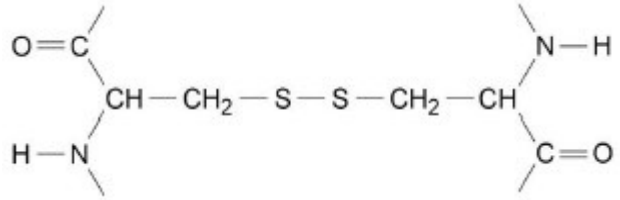
M1

(Which attracts) lone pair/electron pair on O

Penalise lone pair/electron pair donation

M2

(b)



Penalise dashed/dotted S—S

Ignore extra additions to structures

1

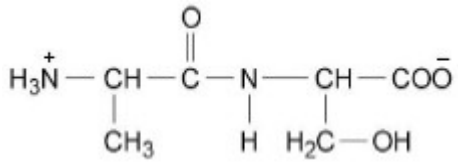
(c) Tertiary or Quaternary

Allow 3° or 4°

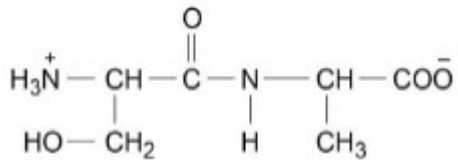
do not penalise minor error in spelling e.g. Quarternary

1

(d)



OR



Incorrect peptide bond CE=0

M1 for correct dipeptide

M2 for correct charges

Ignore additional dipeptide in working

Allow –CONH— or –COHN—

1

1

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[6]

Q6.

(a) Power of an atom to attract a pair of electrons in a covalent bond.

Allow power of an atom to attract a bonding/shared pair of electrons

Allow power of an atom to withdraw electron density from a covalent bond

Not lone pair Not Element

1

(b) Difference in electronegativity leads to bond polarity

If chloride (ions) mentioned then CE = 0

1

(dipoles don't cancel therefore the molecule has an overall permanent dipole) and there is an attraction between $\partial+$ on one molecule and $\partial-$ on another

partial charges should be correct if shown and can score M2 from diagram

1

(c)

SiH_4	**Tetrahedral**		1 shape & no tick
PH_3	**Pyramidal (trigonal) Allow tetrahedral**	✓	1 shape & tick
$BeCl_2$	**Linear**		1 shape & no tick
CH_3Cl	**(Distorted)Tetrahedral**	✓	1 shape & tick

If shapes are drawn rather than named then penalise first mark gained

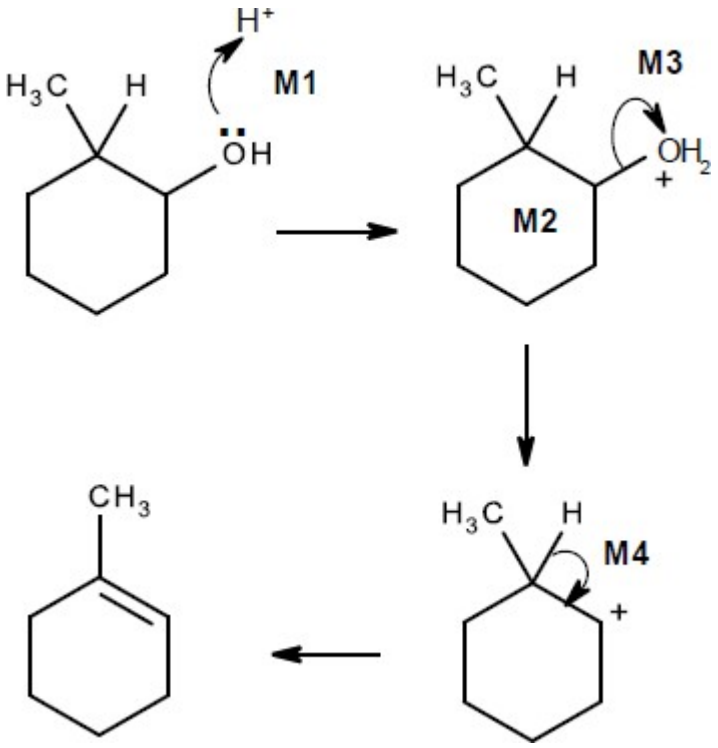
4

[7]

Q7.

(a)

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M1 curly arrow from lone pair on O to H^+

1

M2 correct structure of intermediate with + on O

1

M3 curly arrow from C-O bond to O

1

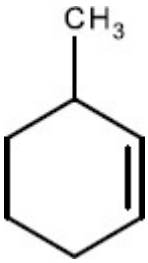
M4 curly arrow from correct C-H bond towards correct C-C bond

1

*Ignore other species that are drawn, but penalise any curly arrows to/from other species for **M1/3/4** as relevant (but allow attack by an anion of phosphoric acid on the H that is lost in **M4** in addition to the arrow specified)*

*for **M2**, the O of the $^+OH_2$ group must be bonded to the ring*

(b)



Any correct structural representation

1

(c) **M1** more stable (carbocation formed)

*For **M1** penalise more stable product*

1

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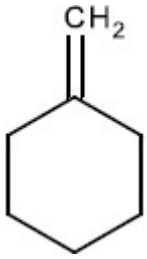
M2 changes from secondary to tertiary (carbocation)

*For **M2** allow explanation via inductive effect with more alkyl / C groups attached or inductive effect from methyl group as alternatives*

Allow 2° or 2^{y} for secondary and 3° or 3^{y} for tertiary

1

(d)



Any correct structural representation

1

(e) **M1** cyclohexene : van der Waals' <u>forces</u> (between molecules)

1

M2 cyclohexanol : hydrogen bonds (between molecules)

1

M3 phosphoric acid: hydrogen bonds (between molecules)

1

M4 idea that cyclohexene has weakest forces

1

M5 separated by (simple / fractional) <u>distillation</u>

1

M6 cyclohexene has lowest boiling point / boils off first

Extended response

Maximum of 5 marks for answers which do not refer to the van der Waals forces or hydrogen bonds being between molecules in some way

***M1** penalise reference to presence of other intermolecular forces*

***M1** allow vdW forces (on this occasion)*

***M1/2/3** penalise reference to breaking covalent bonds*

***M2 & M3** ignore reference to van der Waals and/or (permanent) dipole-dipole forces*

***M2** allow use of term H bonds (on this occasion)*

***M4** allow converse argument*

***M4 & M6** – allow correct comparison of cyclohexene forces and boiling point to one of the other two compounds if only one of cyclohexanol or phosphoric acid discussed*

[14]

Q8.

(a) **M1** it / PVC is bigger/longer molecule / has more electrons / has bigger surface area / greater M_r

1

M2 it / PVC has stronger (van der Waals' / dipole-dipole) forces <u>between molecules</u> / <u>intermolecular</u> forces

1

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***M1** and **M2** independent of each other*

CE = 0 if reference to hydrogen bonds or breaking of covalent bonds when substances are melted

*Comparison must be implied in **M1** or **M2** to score 2 marks*

If there is no comparison at all, then 1 mark could score either for explaining that PVC has strong <u>intermolecular</u> forces due to being a big/long molecule / having many electrons / large surface area / large M_r, or, for explaining that chloroethene has weak <u>intermolecular</u> forces due to being a small/short molecule / having few electrons / low surface area / low M_r,

(b) 38

ignore additional words

1

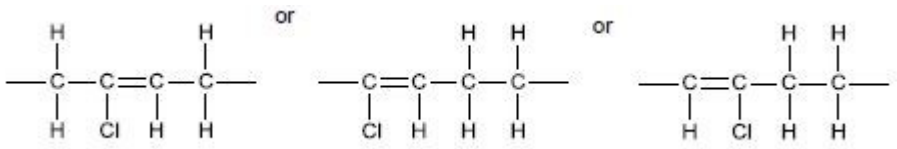
(c) Need both ideas that

- it is present AND
- because PVC needs to be flexible / bendy

penalise incorrect properties

1

(d) Displayed structure required



ignore any bracket or n

1

[5]

Q9.

A

[1]

Q10.

(a) $SrCl_2$> ICl > Br>

If wrong can award 1 for one in the correct 'position'

2

$SrCl_2$ <u>strong ionic</u> bonds / (<u>strong</u> electrostatic attraction between opposite ions)

1

Lattice so <u>many</u> strong bonds to overcome

1

ICl has <u>dipole-dipole</u> between molecules – weaker than ionic bonds

1

Br_2 has van der Waals forces between molecules – much weaker

Accept London / dispersion / induced dipole forces

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1

(b) $Cl_2 + H_2O \rightleftharpoons HCl + HClO$

OR *$2Cl_2 + 2H_2O \rightleftharpoons O_2 + 4HCl$*

OR $Cl_2 + H_2O \rightleftharpoons 2H^+ + Cl^- + ClO^-$

1

Kills bacteria

1

Wasteful as most potable water not used for drinking - used in washing clothes etc

OR Some people suffer eye irritation / Some people find the taste unpleasant

OR can react with organic compounds to produce harmful substances

Allow 'it is potentially toxic as it can be if over concentrated'

1

(c) $6Br_2 + P_4 \longrightarrow 4PBr_3$

Accept 4P for P_4

1

Pyramidal shown in a diagram (but the name of the shape isn't needed)

1

100–108°

Actual value is 101° (hence larger range of values allowed)

1

(d) Tetrahedral shown in a diagram (but the name of the shape isn't needed)

1

109.5°

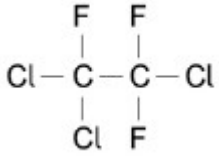
Accept 109° or 109°28'

1

[14]

Q11.

(a)



1

(b) Initiation: $CCl_2FCF_2Cl \longrightarrow Cl\bullet + CCl_2FCF_2\bullet$.

Allow initiation equations where more than one Cl• is formed

1

$Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$

1

$ClO\bullet + O_3 \longrightarrow 2O_2 + Cl\bullet$

1

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(c) Acts as a catalyst

1

(d) B

1

(e) 1,1,1,2-tetrafluoroethane

1

(f) Iodine is bigger than fluorine so the van der Waals forces between CH_3I molecules
are stronger than those between CH_3F molecules

1

The dipole-dipole forces between CH_3F molecules are stronger than those between CH_3I molecules

Or vice versa

1

The van der Waals forces are stronger than the dipole-dipole forces so these dominate

1

[10]

Q12.

(a) [Kr] $5s^2$ $4d^{10}5p^5$

1

(b) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3
All stages are covered and the explanation of each stage is correct and complete.

Answer communicates the whole explanation coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

5-6 marks

Level 2
All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies **OR** two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression through the stages. Some steps in each stage may be out of order and incomplete.

3-4 marks

Level 1
Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, **OR** only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

Level 0
Insufficient correct chemistry to warrant a mark.

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0 marks

Indicative Chemistry content

Stage 1

I_2 is molecular.

HI is molecular.

Stage 2

IMF hold the molecules together.

There are weak IMF forces hence the melting point is low in both substances.

I_2 bigger molecule than HI so I_2 has more electrons.

Stage 3

Therefore stronger van der Waals between molecules in I_2 that need more energy to break causing the melting point to be higher.

HI also shows permanent dipole-dipole attraction between molecules but these forces are less than the vdW forces in iodine.

6

(c) No delocalised electrons or ions

1

(d) $\frac{1}{2}H_2 + \frac{1}{2}I_2 \longrightarrow HI$

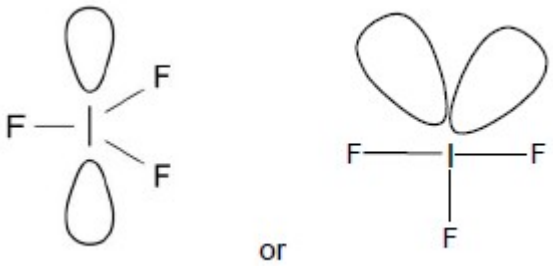
Allow multiples

1

(e) NH_4I_3

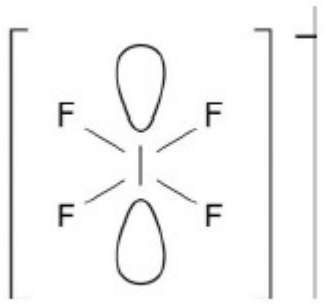
1

(f)



Allow any shape with 3 bond pairs and 2 lone pairs

1



Allow any shape with 4 bond pairs and 2 lone pairs (e.g. lone pairs in equatorial positions)

1

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(g) +5

1

+7

1

[14]

Q13.

B

[1]

Q14.

A

[1]

Q15.

D

[1]

Q16.

C

[1]

Q17.

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

1

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

1

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

1

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

Units essential

1

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

1

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

Mark consequentially to ΔS in part (a)

1

(c) Diagram marks

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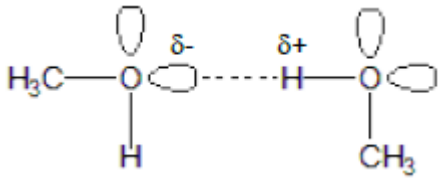


Diagram of a molecule showing O–H bond and two lone pairs on each oxygen

1

Labels on diagram showing δ+ and δ- charges

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

1

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

1

Explanation mark

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

1

[10]

Q18.

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

1

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

1

Any ethanal and ethanol that initially evaporates can then be oxidised

1

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

1

(c) Mixture heated in a suitable flask / container

A labelled sketch illustrating these points scores the marks

1

With still head containing a thermometer

1

Water cooled condenser connected to the still head and suitable <u>cooled</u> collecting vessel

1

Collect sample at the boiling point of ethanal

1

Cooled collection vessel necessary to reduce evaporation of ethanal

1

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

1

Intermolecular forces / dipole-dipole are weaker than hydrogen bonding

1

(e) Reagent to confirm the presence of ethanal:

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

OR

Add Fehling's solution

1

Warm

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

1

Result with Tollen's reagent:

Silver mirror / black precipitate

OR

Result with Fehling's solution:

Red precipitate / orange-red precipitate

1

Reagent to confirm the absence of ethanoic acid

Add sodium hydrogencarbonate or sodium carbonate

1

Result; no effervescence observed; hence no acid present

1

M5 can only be awarded if M4 is given correctly

OR

Reagent; add ethanol and concentrated sulfuric acid and warm

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

hence no acid present

[16]

Q19.

C

[1]

Q20.

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

Not just the same atoms;

1

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

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

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

Ignore reference to number of decimal places

1

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

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

1

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

Marked independently from M1

Could score from bond labelled on correct signal on spectrum

Allow any value within these ranges

If additional incorrect signals given penalise M2

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

1

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

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

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

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

Level 3

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

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all **three** compounds

5-6 marks

Level 2
- **Relative** boiling points of **two** compounds correctly compared
- Strongest intermolecular force for these **two** compounds correctly identified
- Answer explains this coherently and logically and uses correct terminology for **these two** compounds

3-4 marks

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

1-2 marks

Level 0
None of the indicative chemistry content given.

0 marks

Indicative chemistry content:

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

• Prop-2-en-1-ol has hydrogen bonds

• Propanal has (permanent) dipole-dipole forces

• Butane has van der Waals' forces

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

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

[10]

Q21.

(a) Electron movement in first molecule / temporary dipole

Allow description

1

Induces a dipole in another molecule

Allow description

1

(Induced-temporary) attraction or δ+ attracts δ- in different/adjacent molecules

M3 dependent on M1 and M2

Allow electrostatic attraction

M3 could be scored in diagram

If other type of force / metallic / ionic / polar bonds / permanent dipoles / difference in electronegativity mentioned CE = 0

1

(b) (i) (Methanol) H-bonds / hydrogen bonding

1

(Methanethiol) dipole-dipole forces or van der Waals

1

H-bonds are a stronger / are the strongest IMF

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Allow H-bonds require more energy to overcome

If M1 and M2 not scored, allow 1 for methanol has stronger IMFs

If breaking covalent bonds then CE=0

1

(ii) (Fractional) distillation

Allow description

Do not allow heating unqualified

1

(c) (Methaneselenol is a) bigger molecule / larger Mr / larger no of electrons / Se bigger atom

1

With <u>stronger/more</u> <u>vdw</u> forces <u>between molecules</u>

If breaking covalent bonds then CE=0

1

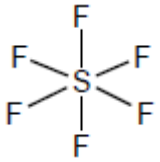
(d) (i) 

Diagram showing 6 bond pairs

1

(Bond angle) 90° for SF_6

Ignore 180°

1

Octahedral

1

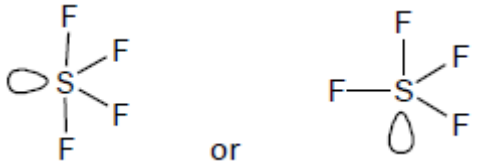


Diagram showing 4 bond pairs <u>and 1 lone pair</u>

1

(Bond angles) for SF_4

If shape of SF_4 is not based on 4 bond pairs <u>and 1 lone pair</u> cannot score M4 or M5

Any **two** from:

Allow 85 – 89°

Do not allow 90°

Allow 100 – 119°

Do not allow 120°

Allow 170 – 179°

Do not allow 180°

2

(ii) NaCl (as product in any equation)

1

$3\ SCl_2 + 4\ NaF \rightarrow SF_4 + S_2Cl_2 + 4\ NaCl$

Allow multiples

Ignore states

1

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[17]

Q22.

(a) OH AND alcohol

IGNORE hydroxy(l)

1

(b) **A** = butan-2-ol / $CH_3CH(OH)CH_2CH_3$

If formulae given then must be unambiguous

If both formula and name given then formula must match name for mark to be awarded

1

B = butan-1-ol / $CH_3CH_2CH_2CH_2OH$

1

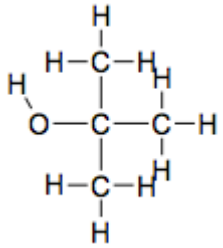
Product from **A / P** is a ketone
AND
Product from **B / Q** is an aldehyde

Penalise reference to incorrect class of alcohol

1

(c) Type of Bond: C=C

1



*Must show all bonds in Isomer **C** including O–H bond*

1

Reagent: conc. H_2SO_4 / conc. H_3PO_4

If incorrect attempt at correct reagent, mark on

Apply list principle for reagents and conditions marks

Conc required - may appear on conditions line

NOT (aq) For M3 even if seen on conditions line

ALLOW

Reagent = Al_2O_3

Condition = 'passing vapour over hot solid' owtte

1

Conditions: 180 °C / High temp / Hot / Reflux /

ALLOW stated temp in range 100-300 °C/373-573 K

IGNORE 'heat'

M4 dependent on correct reagent in M3

1

(d) (i) S = aldehyde/CHO **AND** T = carboxylic/COOH/CO_2H

1

T forms hydrogen bonds

1

(Which are) stronger than / need more energy to break than forces between molecules/IMFs in S ora (or reverse argument)

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If implication of breaking covalent bonds max M1 only

1

(ii) (No oxidation has occurred as..)

(Still) contains peak at 3230−3550 cm-1 due to O−H/alcohol

Does not contain peak at 2500−3000 cm-1 due to O−H/carboxylic acid

Does not contain peak at 1680−1750 cm-1 due to C=O

Must have wavenumber range (or value within range) and bond or functional group to score each mark.

Any 2

[13]

Q23.

(a) 94−105.5°

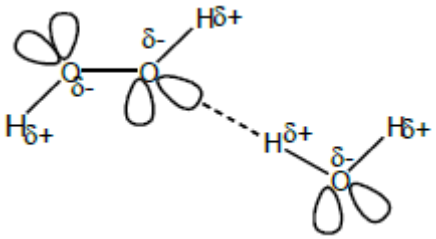
1

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

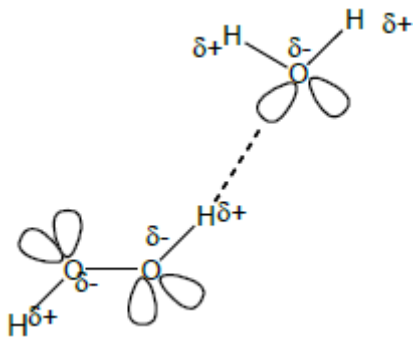
Not just hydrogen

1

(ii)



OR



1 mark for all lone pairs

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

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

3

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

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Mark independently

1

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

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

If breaking covalent bonds CE = 0

1

[7]

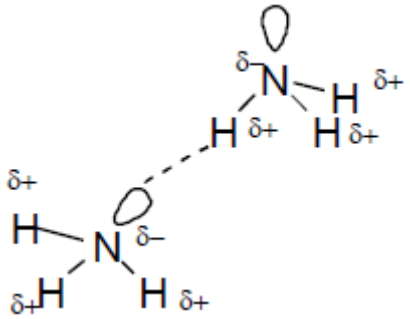
Q24.

(a) (i) Hydrogen bonds / H bonds

Not just hydrogen.

1

(ii)



M1 – lone pair on each N.

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

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

If not ammonia molecules, CE = 0 / 3.

3

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

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

1

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

1

in a <u>covalent</u> bond

1

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

Allow Li_2O_2, allow correct lithium carbide formula.

1

(iii) BH_3 / H_3B

Allow B_2H_6 / H_6B_2

Do not allow lower case letters.

1

[9]

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Q25.

(a) Crude oil **OR** petroleum

Not petrol.

1

Fractional distillation / fractionation

Not distillation alone.

1

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

Allow balanced equations that produce CO_2 in addition to CO.

Accept multiples.

1

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

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

1

M2 at high temperatures

Allow temperatures above 1000 °C or spark.

Not just heat or hot.

M2 dependent on M1.

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

1

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

Allow multiples.

1

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

Allow multiples.

1

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

Allow C_xH_{2x+2}

CnH2n+2

Allow CxH2x+2

1

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

Only.

1

C_3H_7

Only.

1

Zeolite / aluminosilicate(s)

Ignore aluminium oxide.

1

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

1

More / stronger <u>van der Waals' forces between molecules</u>

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

If breaking bonds, CE = 0 / 2.

1

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

Only.

Ignore punctuation.

1

Chain

Ignore branch(ed).

1

(f) Cl_2

Only.

Cl–Cl

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

Ignore Chlorine.

1

[16]

Q26.

(a) Hydrogen <u>bond</u>(ing)

Allow H bonding.

Penalise mention of any other type of bond.

1

(b) (i) Ammonia is a nucleophile

Allow ammonia has a lone pair.

1

Benzene repels nucleophiles

Allow (benzene) attracts / reacts with electrophiles.

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

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

1

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

Ignore dil / conc of HCl.

Ignore the term 'catalyst'.

Allow H_2SO_4 with Sn and Fe but not conc.

Ignore NaOH following correct answer.

Not $NaBH_4$ nor $LiAlH_4$.

1

(iii) <u>conc HNO_3</u>

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conc H_2SO_4

1

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

1

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

OR using two equations

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

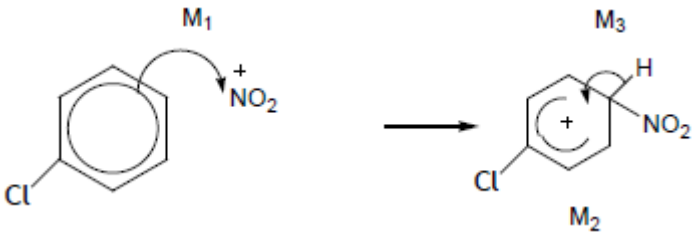
$H_2NO_3^+ \longrightarrow H_2O + NO_2^+$

Allow 1:1 equation.
$HNO_3 + H_2SO_4 \longrightarrow NO_2^+ + H_2O + HSO_4^-$.

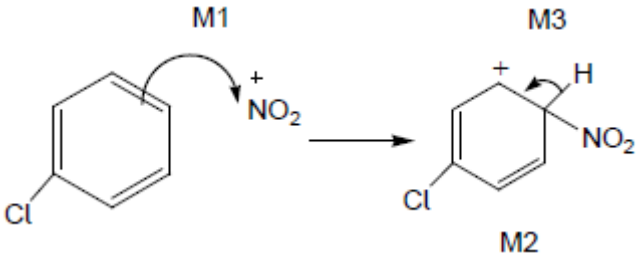
1

(iv) Electrophilic substitution

1



OR



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

3

[11]

Q27.

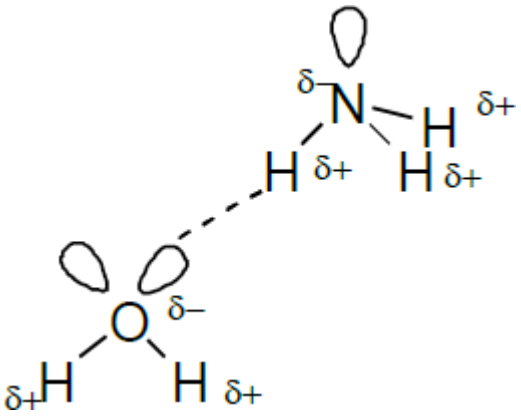
(a) Hydrogen bonding / hydrogen bonds / H-bonding / H-Bonds

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Not just hydrogen.

1

(b)

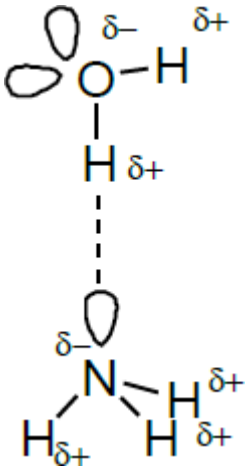


One mark for minimum of 4 correct partial charges shown on the N-H and O-H

One mark for the 3 lone pairs.

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

OR



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

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

3

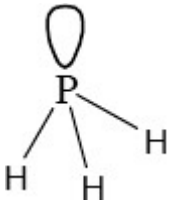
(c) (Phosphine) does not form hydrogen bonds (with water)

1

[5]

Q28.

(a)



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

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1

(b) Coordinate / dative

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

1

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

Do not allow a generic description of a coordinate bond.

1

(c) 109.5° / 109½ / 109° 28☐

Allow answers in range between 109° to 109.5°

1

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

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

Do not allow phosphine is not very electronegative.

1

[5]

Q29.

(a) Covalent

If not covalent CE = 0/2

If dative covalent CE = 0/2

If blank mark on

Ignore polar

If number of pairs of electrons specified, must be 3

1

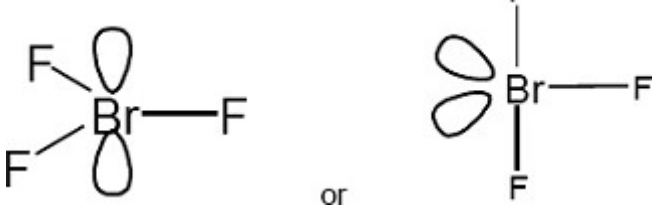
Shared <u>pair</u>(s) of electrons / one electron from Br and one electron from F

Not 2 electrons from 1 atom

Not shared pair between ions/molecules

1

(b) (i)



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

Penalise Fl

1

BrF_3 if trigonal planar shown = 120°

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

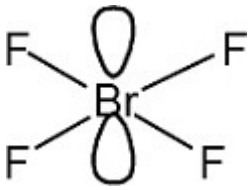
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or if T shape shown 84 – 90°

Irrespective of shape drawn

1

(ii)



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

Allow Fl

1

BrF_4^- 90°

Only

Ignore 180°

1

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

If molecules, IMF, metallic, CE =0

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

Ignore atoms

1

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

1

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

If ions mentioned they must be correct

Strong bonds between + and – ions =3/3

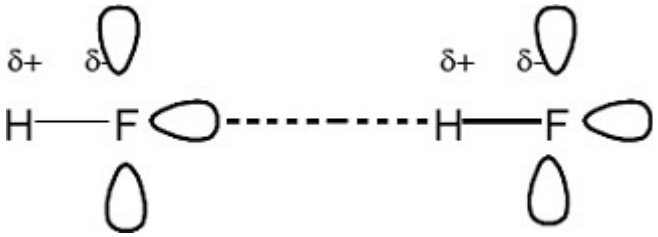
1

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

Not just hydrogen

1

(ii)



One mark for 4 partial charges

One mark for 6 lone pairs

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

Allow Fl

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If more than 2 molecules are shown they must all be correct. Treat any errors as contradictions within each marking point.
CE = 0/3 if incorrect molecules shown.

3

(e) vdw / van der Waals forces between molecules

QoL
Not vdw between HF molecules, CE = 0/2
vdw between atoms, CE = 0/2
If covalent, ionic, metallic, CE=0/2

1

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

1

[15]

Q30.

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

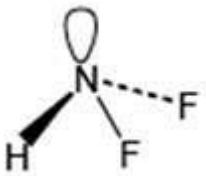
1

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

1

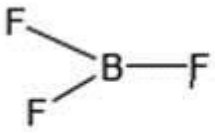
Stronger VdW intermolecular forces = M2
If stated VdW between atoms lose M2

(b) (i)



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

1



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

1

NHF_2 shape - pyramidal / trigonal pyramid

Accept tetrahedral / triangular pyramid

1

BF_3 shape - trigonal planar

Not triangular or triangular planar

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1

(ii) 107°

Allow 106-108°

1

(c) Hydrogen bonds

Allow H-Bonds

Not just Hydrogen

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

1

(d) Coordinate / dative covalent / dative

If covalent mark on

If ionic / metallic CE = 0

1

Lone pair / both electrons/ 2 electrons on $N(HF_2)$ donated (to BF_3)

Direction of donation needed here

1

[10]

Q31.

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

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

CE if holes filled with air, O_2 etc

CE if macromolecule

CE if atoms further apart (since ambiguous)

Ignore spaces filled with H_2O

Ignore reference to H bonds

Allow better tessellation in liquid water

1

(b) (i) Hydrogen bonding

Allow H bonds

Do not allow 'hydrogen' only but mark on

1

(ii) Van der Waals'/VdW

Allow London forces, dispersion forces, temporary induced dipole forces

1

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

Not H Bonds are strong (needs comparison)

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

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

1

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

1

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

do not insist on the + sign
Allow triangular pyramid
Not square pyramid
Ignore bond angles in structure
M2 independent of M1

1

(ii) 107°

Allow range 106 – 108°
Ignore °(C)

1

(iii) NH_3/ammonia

Contradictions (eg NH_4 ammonia) CE = 0

1

(d) 3

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

1

[9]

Q32.

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

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

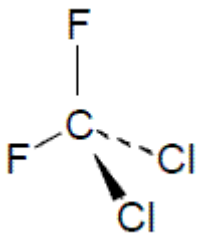
1

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

1

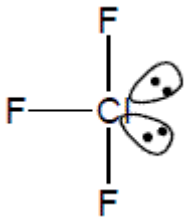
Only
Ignore state symbols even if wrong

(b)

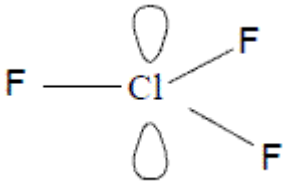


1

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OR

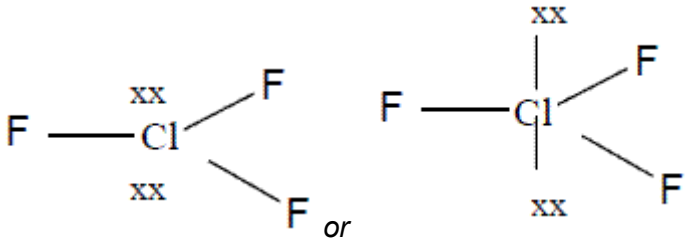


Allow any structure with 4 bp

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

Ignore wrong bond angles

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



Or a structure with 3 bp and 2 lp

1

(c) Dipole – dipole

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

1

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

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

1

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

CE if lone pair is from B

1

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

Must have the – sign on the F ie F^-
Ignore Fl^-
M3 dependent on M2

1

(ii) 109° to 109.5°

1

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

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

1

= 54.3%

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

1

[11]

Q33.

(a) Hydrogen/H bonds

Not just hydrogen

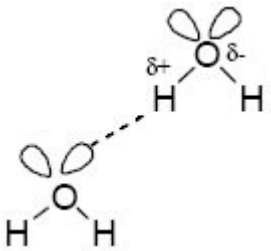
1

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

Not just dipole

1

(b)



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

3

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

OR

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

OR

H bonding is the strongest IMF

Ignore energy references
Comparison must be stated or implied

1

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

Not heavier/greater Mr

1

therefore increased Van der Waals/IMF forces

Ignore references to dipole-dipole forces

1

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(e) Dative (covalent)/coordinate

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

1

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

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

1

(f) ionic

1

if not ionic CE = 0

oppositely charged ions/+ and – ions or particles

atoms or molecules loses M2 and M3

1

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

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

1

[13]

Q34.

(a) (i) Covalent;

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

1

Shared pair of electrons (one from each atom);

Not shared electrons.

1

(ii) Hydrogen bonds / H bonds;

Not just hydrogen.

1

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

1

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

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

1

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

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

1

Showing the Hydrogen bond from the lone pair on O of one

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molecule to the delta + on the H of the other molecule;

1

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

Accept multiples.
Allow C_2H_6O.

1

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

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

1

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

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

1

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

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

1

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

Accept incomplete reaction.

1

(ii) Occupies a (much) smaller volume;

Not easier to store or transport.

1

[13]

Q35.

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

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

1

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

Not distort
Not remove electrons

1

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

1

Hydrogen bonds/H bonds;

Not just hydrogen

1

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

Insufficient to say N= 3.1 and H = 2.1

1

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

Not N becomes (fully) negative or vice versa

1

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

QWC
Can score M2 and 3 from a diagram

1

(d) Co-ordinate/dative;

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

1

Both electrons/ lone pair (on P/PH_3)

Not lone pair on hydrogen

1

Shares/donated from P(H_3)/ to H(δ+);

1

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

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

1

Pyramidal/tetrahedral/ trigonal pyramidal;

Not bipyramidal/triangular

1

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

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

1

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

Accept multiples

1

[14]

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Q1.

(a) A good number of students realised that the KrF_2 molecule has three lone pairs around the krypton but few were able to appreciate that this is a linear molecule. Some students did not show any lone pairs on their diagrams.

(b) Most students understood that lone pairs reduce the bond angle in a molecule so this was answered well.

(c) A good number of students realised that the intermolecular forces were van der Waals' but were unable to describe accurately how these forces arise or why other intermolecular forces are not present between SiF_4 molecules. Only 4.9% of students gained full marks.

Q2.

(a) Most students knew the general formula of alkanes and many could also deduce the M_r in terms of n, where n is the number of C atoms.

(b) A lot of students believed that covalent bonds break when alkanes are boiled. Other students lost a mark for poor use of terminology by not referring to forces between molecules. 62.2% of students failed to score on this question.

(c) Nearly all students (82.8%) could write the balanced equation for the complete combustion of nonane.

(d) A good number of students knew how NO is formed in an engine, but many did not appreciate that the nitrogen comes from the air and that high temperatures are required for the formation of NO.

(e) Most students (75.7%) knew that thermal cracking is used to form alkenes.

(f) Few students (30.9%) could draw the repeating unit of poly(propene) correctly.

Q3.

Students found it hard to predict which compound had the highest boiling point. Many thought the fluoroalkane had the highest boiling point, possibly as they incorrectly believed it might contain hydrogen bonds between molecules.

Q4.

(a) This question discriminated well: 28.3% of students correctly identified the types of intermolecular forces and noted that hydrogen bonding in the alcohol and the acid was stronger than dipole-dipole attractions between propanal molecules. Despite the request in the question to consider intermolecular forces, a few students still discussed the breaking of bonds in the molecules and so gained no marks, although fewer did this than is often the case in this type of question.

(b) Very few students (4%) scored both marks in this question and only 39.2% scored at least one mark, despite the question being based on one of the required practical activities.

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(c) This part was answered well by nearly two-thirds of the students. The main error was to test for the aldehyde rather than the acid.

(d) This question discriminated well and there was a good spread of marks. Sadly, some students did not quote their answers to three significant figures and/or remember the negative sign for their exothermic enthalpy change of combustion.

(e) The major errors in the answers to this acid-catalysed elimination of water were where students confused this mechanism with the elimination of HX from a halogenoalkane using a base. However, just under a third of students scored full marks in a correct mechanism, either via the formation of a carbocation or by showing the simultaneous loss of water and H+ from a protonated alcohol.

(f) This part was challenging and a surprising proportion of students (8%) made no attempt. A large number scored no marks as they discussed the formation of different alkenes, rather than why pent-2-ene shows E-Z isomerism. Sadly, some of those who did gain the first mark failed to gain the second as this required two statements, not only that the C=C bond cannot rotate, but also that each carbon in the double bond has two different groups attached to it.

Q5.

(a) There were many good answers to this question. Most students scored the first mark for correctly identifying that the hydrogen on the nitrogen is electron deficient. The second mark proved to be more difficult and many failed to identify that the attraction was between the lone pair on the oxygen and the electron deficient hydrogen.

(b) This question was not well answered and 12.6% of the students made no attempt at all. Of those who did, very few seemed to be aware of disulphide bridges. Others did not show the bridge as a covalent bond, omitted the two CH2 groups, or had an additional hydrogen attached to each sulfur.

(c) This part was well known; 73.5% of students gained the mark.

(d) Over half of the students drew a correct zwitterion. The most common errors were using a wrong amino acid or including an oxygen atom between the C and N of the peptide link. Other students were penalised due to careless drawing of the structures (by including too many or too few H atoms) or if they showed loss of a proton from the alcohol group in serine.

Q6.

(a) This was a straightforward definition that was reasonably well known, with 51.8% of students successful.

(b) The second mark was rarely scored, perhaps showing that students had not read the question carefully enough. The best answers often included a good diagram to shown the interaction between molecules.

(c) The shapes were quite well known, but the link with overall polarity less so. This question was a good discriminator, with almost even proportions of students scoring 0, 1, 2, 3 and 4 marks.

Q7.

(a) The first use of a mechanism with skeletal structures proved to be challenging for many students, even with the framework provided.

(b) While this was challenging, many students could work out the structure of the alternative product.

(c) Many students realised that this question referred to the relative stability of carbocations, with the best students referring to the extra stability of tertiary carbocation **E** relative to secondary carbocation **D**. Students' explanations were often confused and it was not always clear to which carbocation they were referring.

(d) This was a very challenging question and only the best students could deduce the structure.

(e) This question showed students' confusion between covalent bonds within molecules and the forces between molecules, and their poor understanding that covalent bonds do not break when molecular substances change state. Other students failed to refer to hydrogen bonds and van der Waals' forces acting between molecules. Some students focused on the practical procedure to separate the cyclohexene rather than on how the strength of the intermolecular forces affected the boiling points – it is important to answer the specific question that is asked.

Q8.

(a) Many students believed incorrectly that covalent bonds break when PVC melts and failed to score on this question.

(b) This question required students to know how many hydrogen atoms were on each carbon atom in a skeletal structure, but many struggled to count them correctly.

(c) Very few students appeared to know why plasticisers are added to some polymers. This is new content for this specification.

(d) This question required students to draw the displayed structure of a repeating unit and proved to be challenging.

Q20.

Organic molecules with the same M_r

Many students could know in (a) that the three molecules had the same molecular formula or were isomers, but few stated that they had identical relative formula masses. Most students in (b) could identify the prop-2-en-1-ol using the IR spectrum stating the use of the O-H or C=C absorption to do so. (c) question proved challenging and discriminated well. The best students could identify the correct order of boiling points, identify the correct intermolecular forces and use good language to communicate this in a structured way. Many students could identify van der Waals' forces in butane and hydrogen bonds in prop-2-en-1-ol, but few could identify permanent dipole-dipole forces in propanal. Indeed, many students mistakenly thought that propanal had hydrogen bonding. In addition, many students referred incorrectly to the breaking of covalent bonds and referred to the strength of the covalent bonds, rather than concentrating on intermolecular forces.

Q21.

Students struggled to explain how van der Waals' forces arise between molecules. Most scored a mark by referring to 'electron movement' but did not go on to explain that a dipole is induced in an adjacent molecule. Many answers were based on the difference in

electronegativity. Most students correctly explained the difference in boiling points between methanol and methanethiol and between methaneselenol and methanethiol. On occasions the quality of students' language was poor either stating that boiling results in all bonds breaking or indicating that the O-H bond in methanol was broken. For this reason a statement that the relevant forces act 'between molecules' is necessary to gain credit. Nearly all students answered part (b)(ii) correctly. The shape and bond angles of SF_6 proved a good discriminator. Some students were not able to deduce the correct number of lone pairs around SF_4 and others did not appreciate the effect of the single lone pair on the bond angles. In part (d)(ii) most students were able to deduce NaCl as the missing product but not all were able to balance the equation. Multiples were accepted.

Q22.

In part (b) students needed to read the question carefully and organise their thinking clearly to avoid confusing **A** with **P** and **B** with **Q** in their answers. A significant minority of students got the identities of **A** and **B** wrong way round or thought that they were carbonyls – despite having got part (a) correct in most cases.

In part (c) most students correctly identified **C** but many lost the mark for the displayed formula through not showing the O–H bond. Many students seemed to confuse the dehydration of an alcohol with the elimination reaction of a halogenoalkane and incorrectly chose ethanolic KOH as the reagent needed for the conversion of **C** into **R**.

In questions on IR spectra it is important for students to be aware that any reference to a wavenumber of an absorption must be linked to the bond responsible for that absorption.

Q23.

There were several different angles given in part (a) but the majority of students gave the correct one. The type of intermolecular force in part (b)(i) was very well answered. There were many students who scored full marks on the diagram in part (b)(ii) showing the lone pairs as lobes, two crosses or two dots. It should be stressed that students who choose to use dots should ensure that they are bold and clear. Some students however failed to score full marks since they did not have the correct number of lone pairs on each of the oxygen atoms. Partial charges, if seen, were generally correct. Several students did not read the question and used two water molecules instead of what was required. Answers to part (c) were generally quite poor and showed that students did not really understand the concept of electronegativity; many tried to compare the electronegativity of molecules rather than atoms. The students who correctly stated that the electronegativity of sulphur was lower than oxygen could often not explain the relevance of electronegativity difference to hydrogen bonding being absent between the molecules.

Q24.

Hydrogen bonding was well known in part (a)(i) and the diagram to show the interaction in part (a)(ii) was also generally well done; the main error was failing to show the hydrogen bond from the lone pair to the $H\delta^+$. Part (b) was generally well known but some students thought that the electron pair came from the boron atom.

The definition in part (c)(i) was well known by most students but there were still some who referred to single electrons or referred to an element / substance rather than an atom / nucleus or forgot to mention the type of bond. Responses to parts (c)(ii) and (c)(iii) often showed a lack of understanding; many students could not select the correct elements to write a formula and for those who could select the correct elements the ratio in the formula was often incorrect.

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Q25.

Part (a) was very well answered but many students could not give a correct balanced equation in part (b); some gave carbon as a gaseous product. Answers to part (c) were mixed. Some were excellent and gave the correct answer and condition but far too many thought that the nitrogen was from a nitrogen-containing impurity in the paraffin. Equations given in part (c)(ii) were generally good but many students found writing the equation in part (c)(iii) more difficult.

The general formula of the alkanes was well known in part (d)(i). Answers to part (d)(ii) suggested that many students did not read the question carefully and so did not write equations giving two molecules with equal numbers of carbon atoms. Due to this error, the empirical formula was often incorrect. A range of catalysts was seen but many did know the correct one. In part (d)(iii), far too many students thought that covalent bonds were broken during melting. When students realise that the van der Waals forces are broken they must state that these forces are between the molecules. In a few answers, students referred to van der Waals bonds breaking and this is unclear. The IUPAC name in part (e) proved difficult for many students, especially the numbers of the substituent groups. The type of isomerism in part (e) was well known by most students; the most common incorrect answer was positional isomerism.

Q26.

In part (b)(i), only the highest-scoring students gave the simplest correct answer in terms of the benzene repelling the nucleophile ammonia but alternative answers were allowed, including a comparison of the strength or polarity of the C–Cl bond in chlorobenzene with that in a haloalkane.

There was also some confusion between identifying regions of high electron density such as lone pairs and delocalised electrons, and referring to benzene and ammonia as being negatively charged. Some students also wrongly discussed further substitution. Part (b)(ii) was well answered. However, reagents were needed in full, so Sn with HCl was required not just H^+. Parts (b)(iii) and (iv) were also well answered. In part (b)(iii), ‘concentrated’ was needed with both acids to gain two marks, and M3 was often lost for the charge missing on $H_2NO_3^+$. The electrophilic substitution mechanism was generally well done although the positioning of the horseshoe representing delocalised electrons caused some problems in this example where the substitution did not occur at the carbon at the “top” of the benzene ring.

Q27.

Most students could state the correct intermolecular force in part (a). In part (b), although many students scored all three marks there were many diagrams that were difficult to read since they were too small or very faint. Marks were lost by not giving the correct number of lone pairs or omitting the partial charges. In part (c), many students did not relate solubility to interaction between phosphine and water. It also appeared that a few students think that there is hydrogen bonding between P and H in the phosphine molecule.

Q28.

The structure in part (a) was well answered. Part (b) was also answered well although a few students gave generic answers about co–ordinate bonds rather than specific answers to this question. Various bond angles were seen for part (c). In part (d), the idea of an electronegativity difference was often seen but then students often gave responses that were not specific to the molecule in the question. Many students lost marks by referring to the electronegativity of the phosphine molecule.

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Q29.

Part (a) was generally answered well although many students did not refer to a shared pair of electrons in the covalent bond. The required number of bond pairs and lone pairs in parts (b)(i) and (ii) were reasonably well known although many students did not appreciate that the lone pairs would repel each other and the bond pairs as far apart as possible and hence lost the marks for the bond angles. Some students incorrectly gave B as the symbol for bromine. The answers to part (c) differentiated well. Weaker students generally scored zero due to chemical errors. Where students identified ionic bonding, marks were lost by not stating oppositely charged ions or by referring to incorrect ions eg K^+ and F^-. The type of intermolecular force in part (d)(i) was well known. Weaker students did not know the formula HF in part (d)(ii) and many students lost marks due to careless omissions of the partial charges or the lone pairs. Students generally realised that van der Waals' forces were present in fluorine and hence the boiling point was low. However many answers did not refer to van der Waals' forces acting between molecules and some answers referred incorrectly to the breaking of weak covalent bonds.

Q30.

Many candidates answered part (a) well but there were a significant number who did not make it clear that the van der Waals forces were between the molecules. Part (b)(i) differentiated well. There were many examples of the wrong number of lone pairs in both molecules and a frequent occurrence of bi-pyramids in candidates' answers. The angle in part (b)(ii) generated a range of values although the answer to part (c) was given correctly by a majority of candidates. Part (d) was generally well done although several candidates gave the wrong direction for the donation of the lone pair.

Q31.

Part (a) proved a difficult question with many candidates failing to refer to molecules. Of those that did many thought that the space between the molecules was filled with air or oxygen. Many considered hydrogen bonds but not the effect on the spacing between the molecules. Intermolecular forces in part (b) were generally well known although a few thought incorrectly that there are dipole-dipole forces between methane molecules. In part (b)(iii), many candidates stated that hydrogen bonds were strong but then failed to make the comparison between the intermolecular forces in the two molecules. The shape in part (c)(i) was generally well attempted but less able candidates included two or no lone pairs of electrons. Many candidates thought that the ion was planar, but of those who correctly stated the shape as tetrahedral many followed with a bond angle of 109° in part (c)(ii) showing that they had not taken account of the lone pair of electrons in the molecule. The identification of the molecule in part (c)(iii) proved difficult and many candidates suggested ions rather than a molecule. Part (d) was not well answered.

Q32.

In part (a)(i) many candidates omitted the word 'pair' from their answer and hence did not score the mark. The equation in part (a)(ii) was not answered well since many candidates failed to read the question, which asked for an equation to produce one mole of product. Other errors included not giving the correct formulae for chlorine or fluorine molecules. Candidates found the first structure in part (b) relatively easy, but answers for the structure of ClF_3 often included the wrong number of lone pairs of electrons. Part (c) was answered well. The idea of co-ordinate bonding was generally well known but the explanation in part (d)(i) was not. Many candidates thought that the lone pair originated from the B rather than the F^-. A large range of answers was seen in part (d)(ii) with 107.5 being the most popular incorrect answer. If candidates understood the concept of atom economy then they generally scored 2 marks in part (e).

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Q33.

Candidates answered part (a) well with only a few losing marks for simply referring to 'hydrogen' or 'dipole bonds'. Part (b) was done well by many candidates. Weaker candidates did not show hydrogen bonds from the lone pair. There were a number of recurring errors including water as HO_2, partial charges missing or the wrong way round. Part (c) was generally answered well with candidates relating their answers to comparisons between IMF's. Candidates found part (d) more challenging and there were several answers in terms of the greater attraction between the outer electrons and the protons in the nucleus or electronegativity differences. Part (e) was generally well answered with candidates knowing the type of bonding and making an attempt at the explanation. Marks were lost for general descriptions of dative covalent bonding rather than referring specifically to the species given in the question. The type of bonding in part (f) proved a good discriminator. Although many candidates gave the correct type of bond, weaker ones suggested covalent or metallic bonds. The explanation also proved more difficult. Many lost marks for breaking IMF's as well as, or instead of, ionic bonds. Candidates who knew about strong electrostatic attractions often failed to say that this was between oppositely charged ions.

Q34.

This question was not as well done as others on the paper. The answer to (a)(i) often did not refer to a covalent bond being the sharing of a pair of electrons. Part (a)(ii) was done quite well although dipole-dipole forces was often incorrectly given as an answer. The diagrams in part (b) were often unclear and had many errors including partial charges on the wrong atoms, incorrect number of lone pairs and multiple hydrogen bonds to the same atom. The equation in part (c)(i) showed that many candidates could not balance this correctly since they did not notice the O in ethanol. There were several vague answers given in part (c)(ii) and many candidates talked about carbon dioxide being a green house gas rather than the products of incomplete combustion and their associated problems. The economic requirement in part (c)(iii) was poorly answered with many vague answers e.g., less efficient which did not fully answer the question. In part (d)(i) many candidates did not know how the sulfur dioxide is removed with many incorrectly giving water as the answer. Answers to part (d)(ii) produced several interesting but incorrect answers.

Q35.

The definition required in part (a) was generally well known. Common errors included reference to a single electron or omitting covalent bond. Part (b) was quite a good discriminator with many candidates merely giving 'dipole-dipole interaction' or just 'hydrogen'. Part (c) also discriminated well. Many candidates relied upon attraction between the partial charges on the hydrogen and nitrogen neglecting the importance of the lone pair on the nitrogen atom. Most candidates knew about co-ordinate bonding and scored the first mark in part (d). The idea of sharing a pair of electrons was well known although the direction of donation was often wrong or unclear. Many scored both marks in part (e) and some good 3-D diagrams were seen. Candidates lost marks by omitting the H atoms, replacing the As with N or P and stating the shape as bipyramidal or planar. Part (f) proved difficult for weaker candidates. There were a few who failed to realise the significance of the negative signs and thought that AsH_3 had the higher boiling point and some referred to breaking covalent bonds rather than intermolecular forces. The equation in part (g) was usually correctly balanced.

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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.

_____

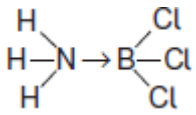
(1)

(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.

_____

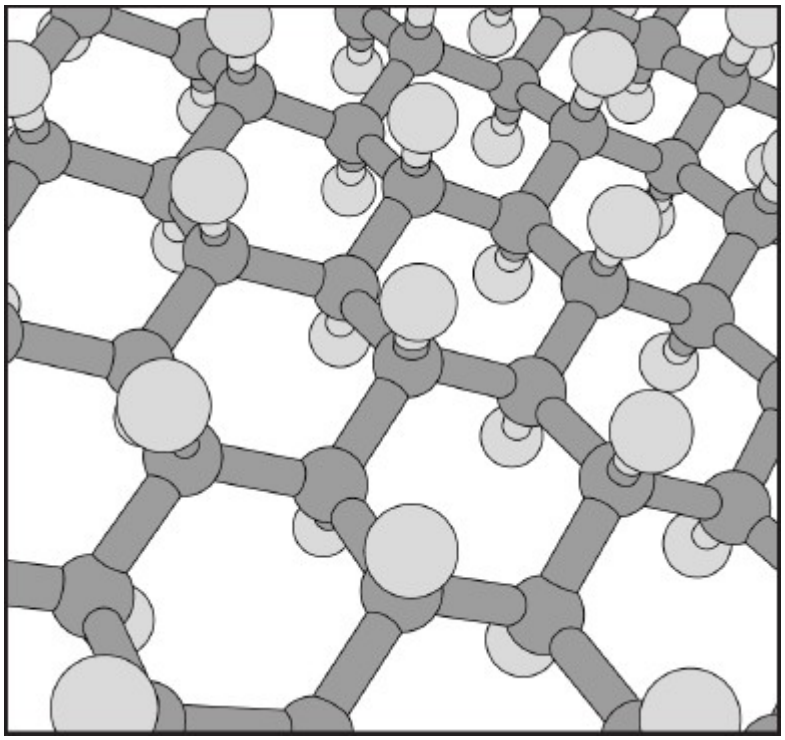
(1)

(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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_____

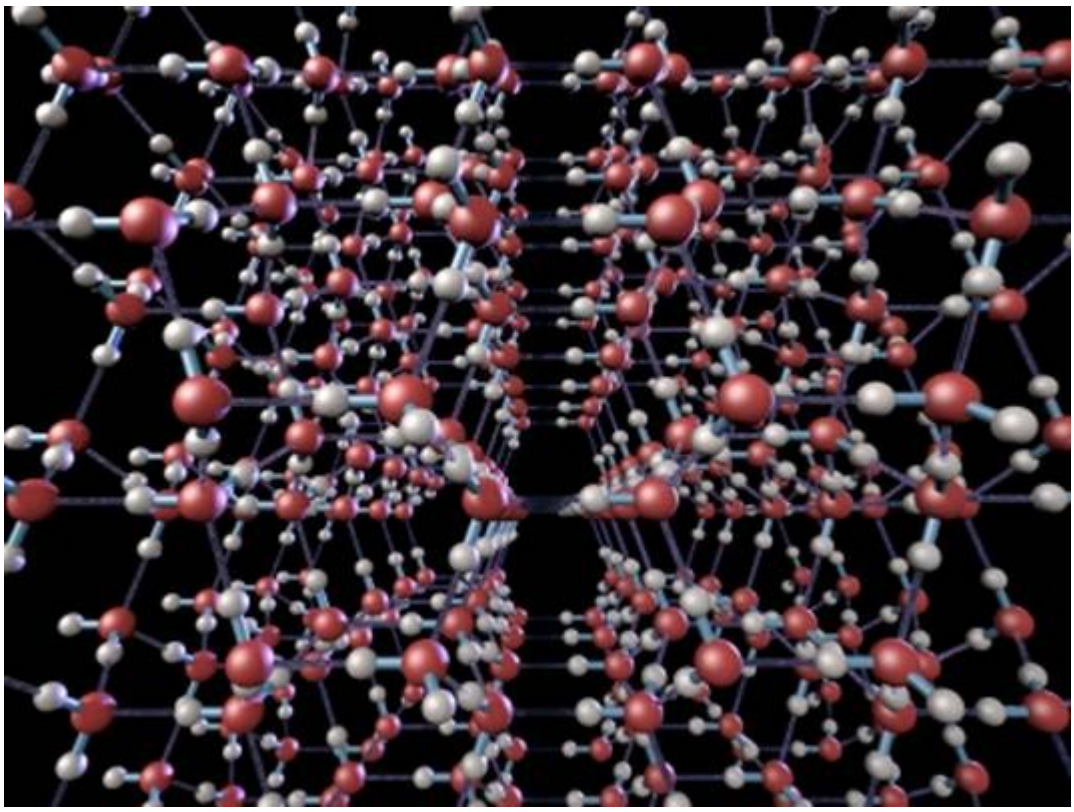
(2)

(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 _____

_____

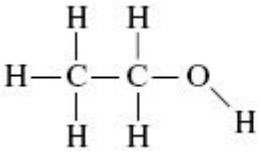
_____

(3)

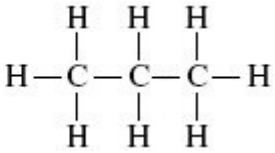
(Total 13 marks)

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 _____

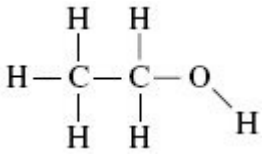
Liquid propane _____

(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.

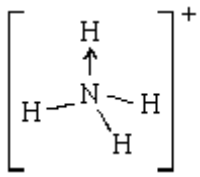
_____

(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.

(a) Covalent

Do not allow dative covalent or coordinate (covalent)

1

(b) $Cl^{(-)}$ not donating lone pair (to $Cu^{(2+)}$)

$Cl^{(-)}$ does not form a coordinate/dative bond (to $Cu^{(2+)}$)

Allow without charges but penalise incorrect charges

Cl^-/it is bonded ionically (to Cu^{2+})

1

(c) $[Cu(H_2O)_6]^{2+} + 4NH_3 \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$

1

Deep blue / Royal blue / Dark blue (solution)

1

Allow combination of:

$[Cu(H_2O)_6]^{2+} + 2NH_3 \longrightarrow [Cu(H_2O)_4(OH)_2] + 2NH_4^+$

$[Cu(H_2O)_4(OH)_2] + 4NH_3 \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2O + 2OH^-$

Do not penalise missing square brackets

Ignore initial colour of Cu^{2+} (aq)

(d) $CuCO_3$ or copper carbonate

Penalise incorrect oxidation state

Allow correct formula for basic copper carbonate

1

(e) HCl/ hydrochloric acid

Ignore concentration

Allow soluble chloride salt

Also allow any reagent which leads to a change in colour of solution due to a change in ligands (e.g. $NH_2CH_2CH_2NH_2$) or change in oxidation state (e.g. SO_2) and associated correct equations.

1

$[Cu(H_2O)_6]^{2+} + 4Cl^- \longrightarrow [CuCl_4]^{2-} + 6H_2O$

$[Cu(H_2O)_6]^{2+} + 4HCl \longrightarrow [CuCl_4]^{2-} + 6H_2O + 4H^+$

Mark independently

1

(f) $(3)d^{10}$ or has full (3)d (sub) shell/orbital

Penalise incorrect principal quantum number

1

It is colourless/cannot absorb (frequencies of) visible light

Ignore clear

1

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[9]

Q2.

B

[1]

Q3.

C

[1]

Q4.

(a) Correct diagram of NH_3 including LP on N

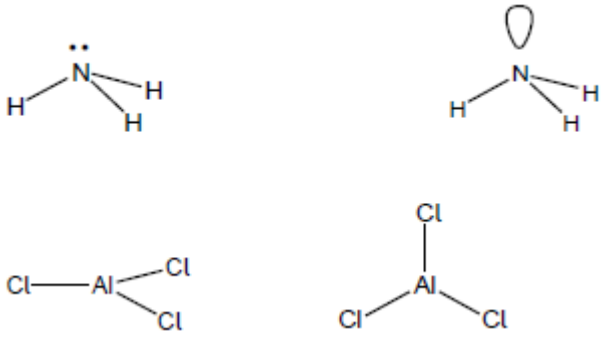
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Correct diagram of $AlCl_3$

1

Bond angles in range 106-108° and bond angle of 120°

1



Ignore shape names

(b) Dative (covalent) /co-ordinate bond

Wrong bond CE=0 but mark on if covalent quoted

1

Shared pair of / both electrons come from the $N(H_3)$

1

(c) Aluminium is now surrounded by 4 electron pairs/bonds or is tetrahedral

Independent

1

Therefore Cl-Al-Cl bond angle decreases / changes
(from 120° in $AlCl_3$) to allow range 107-111° in H_3NAlCl_3

1

[7]

Q5.

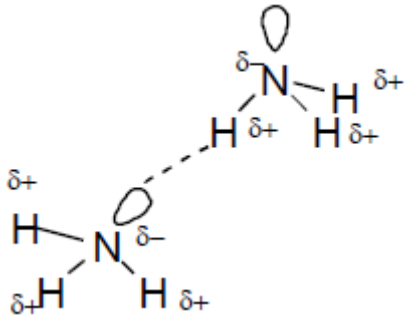
(a) (i) Hydrogen bonds / H bonds

Not just hydrogen.

1

(ii)

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M1 – lone pair on each N.

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

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

If not ammonia molecules, CE = 0 / 3.

3

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

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

1

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

1

in a covalent bond

1

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

Allow Li_2O_2, allow correct lithium carbide formula.

1

(iii) BH_3 / H_3B

Allow B_2H_6 / H_6B_2

Do not allow lower case letters.

1

[9]

Q6.

(a) Giant covalent / giant molecular / macromolecular

Not giant alone.

Not covalent alone.

1

(b) Shared pair of electrons / one electron from each C atom

1

(c) No delocalised / free / mobile electrons

Allow all (outer) electrons involved in (covalent) bonds.

Ignore ions.

1

(d) CH

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Allow HC
C and H must be capital letters.

1

[4]

Q7.

(a) $Al + 1.5Cl_2 \rightarrow AlCl_3$

Accept multiples.
Also $2Al + 3Cl_2 \rightarrow Al_2Cl_6$
Ignore state symbols.

1

(b) Coordinate / dative (covalent)

If wrong CE=0/2 if covalent mark on.

1

Electron pair on Cl^- donated to $Al(Cl_3)$

QoL
Lone pair from Cl^- not just Cl
Penalise wrong species.

1

(c) Al_2Cl_6 or $AlBr_3$

Allow Br_3Al or Cl_6Al_2
Upper and lower case letters must be as shown.
Not $2AlCl_3$

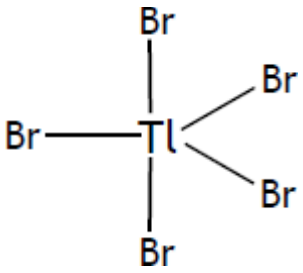
1

(d) $SiCl_4$ / silicon tetrachloride

Accept silicon(4) chloride or silicon(IV) chloride.
Upper and lower case letters must be as shown.
Not silicon chloride.

1

(e)



Accept shape containing 5 bonds and no lone pairs from Tl to each of 5 Br atoms.
Ignore charge.

1

Trigonal bipyramid(al)

1

(f) (i) Cl — Tl — Cl

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Accept this linear structure only with no lone pair on Tl

1

(ii) (Two) bonds (pairs of electrons) repel equally / (electrons in) the bonds repel to be as far apart as possible

Dependent on linear structure in (f)(i).

Do not allow electrons / electron pairs repel alone.

1

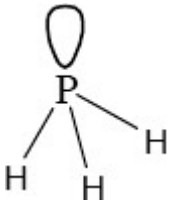
(g) Second

1

[10]

Q8.

(a)



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

1

(b) Coordinate / dative

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

1

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

Do not allow a generic description of a coordinate bond.

1

(c) 109.5° / 109½ / 109° 28☐

Allow answers in range between 109° to 109.5°

1

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

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

Do not allow phosphine is not very electronegative.

1

[5]

Q9.

(a) Covalent

If not covalent CE = 0/2

If dative covalent CE = 0/2

If blank mark on

Ignore polar

If number of pairs of electrons specified, must be 3

1

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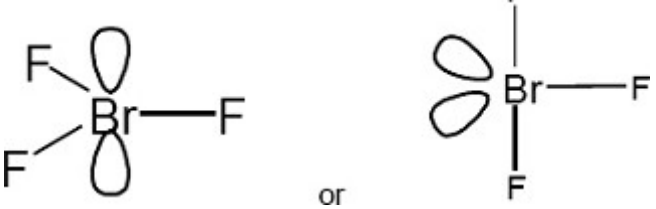
Shared pair(s) of electrons / one electron from Br and one electron from F

Not 2 electrons from 1 atom

Not shared pair between ions/molecules

1

(b) (i)



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

Penalise Fl

1

BrF_3 if trigonal planar shown = 120°

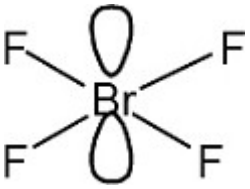
Allow 84 – 90° or 120° and ignore 180°

or if T shape shown 84 – 90°

Irrespective of shape drawn

1

(ii)



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

Allow Fl

1

BrF_4^- 90°

Only

Ignore 180°

1

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

If molecules, IMF, metallic, CE =0

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

Ignore atoms

1

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

1

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

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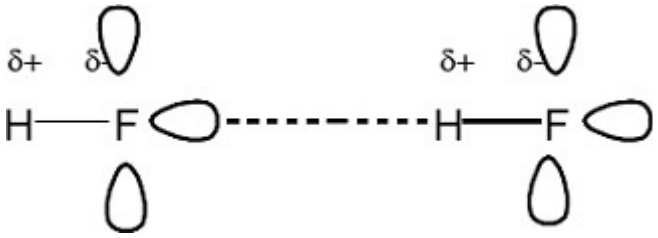
If ions mentioned they must be correct
Strong bonds between + and – ions =3/3

1

(d) (i) Hydrogen <u>bonds</u>/hydrogen <u>bonding</u>/H <u>bonds</u>/H <u>bonding</u>
Not just hydrogen

1

(ii)



One mark for 4 partial charges
One mark for 6 lone pairs
One mark for H bond from the <u>lone pair to the Hδ+</u>
Allow Fl
If more than 2 molecules are shown they must all be correct. Treat any errors as contradictions within each marking point.
CE = 0/3 if incorrect molecules shown.

3

(e) vdw / van der Waals forces between molecules
QoL
Not vdw between HF molecules, CE = 0/2
vdw between atoms, CE = 0/2
If covalent, ionic, metallic, CE=0/2

1

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

1

[15]

Q10.

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

1

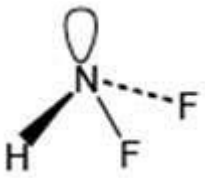
<u>Stronger</u> / <u>more</u> van der Waals forces / vdw / London / temporarily induced dipole / dispersion forces <u>between molecules</u>

1

Stronger VdW intermolecular forces = M2
If stated VdW between atoms lose M2

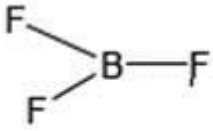
(b) (i)

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

1



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

1

NHF_2 shape - pyramidal / trigonal pyramid

Accept tetrahedral / triangular pyramid

1

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

Not triangular or triangular planar

1

(ii) 107°

Allow 106-108°

1

(c) Hydrogen bonds

Allow H-Bonds

Not just Hydrogen

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

1

(d) Coordinate / dative covalent / dative

If covalent mark on

If ionic / metallic CE = 0

1

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

Direction of donation needed here

1

[10]

Q11.

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

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

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CE if holes filled with air, O_2 etc

CE if macromolecule

CE if <u>atoms</u> further apart (since ambiguous)

Ignore spaces filled with H_2O

Ignore reference to H bonds

Allow better tessellation in liquid water

1

(b) (i) Hydrogen bonding

Allow H bonds

Do not allow 'hydrogen' only but mark on

1

(ii) Van der Waals'/VdW

Allow London forces, dispersion forces, temporary induced dipole forces

1

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

Not H Bonds are strong (needs comparison)

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

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

1

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

1

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

do not insist on the + sign

Allow triangular pyramid

Not square pyramid

Ignore bond angles in structure

M2 independent of M1

1

(ii) 107°

Allow range 106 – 108°

Ignore °(C)

1

(iii) NH_3/ammonia

Contradictions (eg NH_4 ammonia) CE = 0

1

(d) 3

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

1

[9]

Q12.

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

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

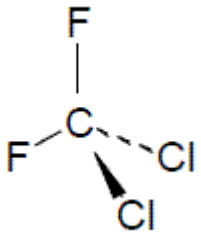
1

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

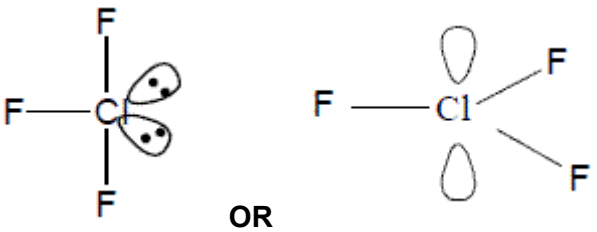
1

Only
Ignore state symbols even if wrong

(b)

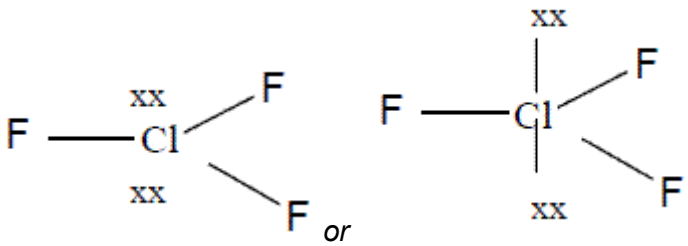


1



OR

Allow any structure with 4 bp
In $CClF_2$, watch for Cl in centre- it must be C
Ignore wrong bond angles
Representations of lone pairs allowed are the two examples shown with or without the electrons in the lobe.
Also they can show the lone pair for either structure by two crosses/dots or a line with two crosses/dots on it e.g.



Or a structure with 3 bp and 2 lp

1

(c) Dipole – dipole

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

1

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

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

1

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

CE if lone pair is from B

1

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

Must have the – sign on the F ie F^-
Ignore Fl^-
M3 dependent on M2

1

(ii) 109° to 109.5°

1

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

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

1

= 54.3%

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

1

[11]

Q13.

(a) Hydrogen/H bonds

Not just hydrogen

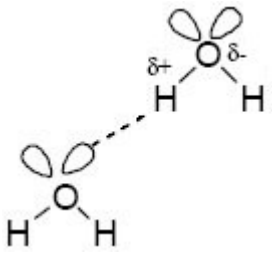
1

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

Not just dipole

1

(b)



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

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CE = 0

3

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

OR

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

OR

H bonding is the strongest IMF

Ignore energy references
Comparison must be stated or implied

1

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

Not heavier/greater Mr

1

therefore increased Van der Waals/IMF forces

Ignore references to dipole-dipole forces

1

(e) Dative (covalent)/coordinate

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

1

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

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

1

(f) ionic

1

if not ionic CE = 0

oppositely charged ions/+ and – ions or particles

atoms or molecules loses M2 and M3

1

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

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

1

[13]

Q14.

(a) (i) Covalent;

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

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1

Shared pair of electrons (one from each atom);

Not shared electrons.

1

(ii) Hydrogen bonds / H bonds;

Not just hydrogen.

1

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

1

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

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

1

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

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

1

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

1

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

Accept multiples.
Allow C_2H_6O.

1

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

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

1

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

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

1

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

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

1

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

Accept incomplete reaction.

1

(ii) Occupies a (much) smaller volume;

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Not easier to store or transport.

1

[13]

Q15.

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

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

1

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

Not distort
Not remove electrons

1

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

1

Hydrogen bonds/H bonds;

Not just hydrogen

1

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

Insufficient to say N= 3.1 and H = 2.1

1

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

Not N becomes (fully) negative or vice versa

1

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

QWC
Can score M2 and 3 from a diagram

1

(d) Co-ordinate/dative;

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

1

Both electrons/ lone pair (on P/PH_3)

Not lone pair on hydrogen

1

Shares/donated from P(H_3)/ to H(δ+);

1

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

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

1

Pyramidal/tetrahedral/ trigonal pyramidal;

Not bipyramidal/triangular

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1

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

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

1

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

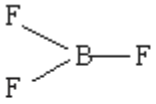
Accept multiples

1

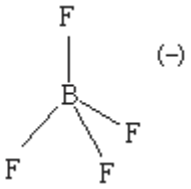
[14]

Q16.

(i)



(1)



(1)

[Do not allow shapes which show a lone pair]

2

BF_3 Trigonal planar/planar triangular

[Not plane triangle]

1

BF_4^- Tetrahedral

[Not distorted tetrahedral]

1

Equal repulsion between (4) bonding pairs/bonds/bonding electrons

1

109(½)°

1

(ii) Lone pair donated / both electrons supplied by one atom

1

from F^- (to B)

[ignore missing charge or fluorine or 'atom']

1

dative/dative covalent/coordinate bonding

1

[9]

Q17.

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(a) dative / coordinate (covalent) bond;

1

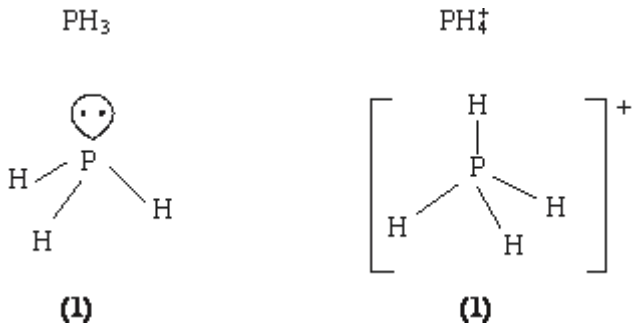
Lone/non-bonding pair / both electrons;

1

(donated) <u>from P</u> to H^+;

1

(b)



(1) (1)

pyramidal *OR* trigonal pyramid 109($^{1/2}$)°;
(accept tetrahedral)

4

[7]

Q18.

(a) **4**LiH + $AlCl_3$ → $LiAlH_4$ + **3**LiCl

1

(b) H^- = $1s^2$ **or** $1s_2$

1

(c) Tetrahedral or diagram
(Not distorted tetrahedral)

1

(Equal) <u>repulsion</u>

1

between four <u>bonding</u> pairs / <u>bonds</u>
(Not repulsion between H atoms loses M2 and M3)
(Not 'separate as far as possible')
('4' may be inferred from a correct diagram)

1

(d) Dative (covalent) or coordinate

1

Lone pair **or** non-bonding pair of electron **or** both e^-

1

QoL Donated from H^- to Al **or** shared between H and Al
(tied to M2)
(Not 'from H atom') (Not 'to Al ion') (Not 'e^-s transferred')

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1

[8]

Q19.

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

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

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

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

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

Note: if the explanation is clearly intramolecular = CE

4

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

Do not accept 'donation of electrons'

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

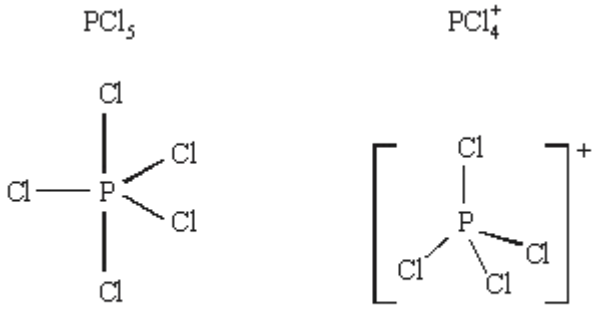
M1 can be earned by a general explanation of coordinate bonding, even if the electron pair is said to come from Al.
The second mark, M2, is for this specific bond

Ignore missing charge

2

(c)

4



(1) (1)

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

Bond Angle(s) 90° and 120° **(1)**

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

Bond angle(s) 109 or 109.5° **(1)**

[10]

Q20.

(a)

Particle	Relative charge	Relative mass	

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Proton	+1 **or** 1+	1	**(1)**
Neutron	0 **or** no charge/neutral/zero	1 (<u>not</u> – 1)	**(1)**
Electron	–1 or 1–	1/1800 to 1/2000	**(1)**

or negligible
or zero
or 5.0×10^{-4} to 5.6×10^{-4}

if 'g' in mass column - wrong
penalise once

3

(b) $^{38}_{18}Ar$ **(1)(1)**

Allow numbers before or after Ar

2

(c) *S*: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$ **(1)**

Allow upper case letters

S^{2-}*:* $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ **(1)**

If use subscript penalise once

2

(d) *Block*: p **(1)**
Explanation: Highest energy or outer orbital is (3) p

OR outer electron, valency electron in (3) p
NOT 2p etc.

2

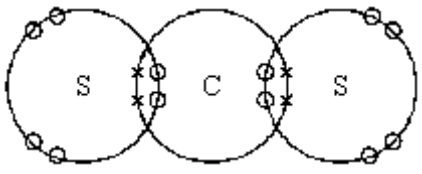
(e) (i) *Bonding in* Na_2S: ionic **(1)**
Bonding in CS_2: covalent **(1)**

ignore other words such as dative / polar / co-ordinate

(ii) Clear indication of electron transfer from Na to S **(1)**
1 e^- from each (of 2) Na atoms or 2 e^- from 2 Na atoms **(1)**

QoL correct English

(iii)



Correct covalent bonds **(1)**
<u>All correct</u> including <u>lone pairs</u> **(1)**

Allow all •s or all ×s
M2 tied to M1
NOT separate e⁻s in S•- 2 l p

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(iv) $CS_2 + 2H_2O \rightarrow CO_2 + 2H_2S$ **(1)**

Ignore state symbols even if wrong

7

[16]

Q21.

(a) (i) Covalent **(1)**

(ii) Co-ordinate **(1)** (or dative)

(iii) Both / two / pair electrons come from nitrogen **(1)**

(iv) 4 bonding / electron pairs **(1)**

repel equally **(1)**

OR are identical

as far apart as possible **(1)**

OR to position of minimum repulsion

tetrahedron **(1)**

7

(b) Power (or ability) of an element / atom to attract electron pair/electrons/ an electron/electron density **(1)**

in a covalent bond **(1)**

Allow attract from, withdraw in, do not allow remove from, withdraw from.

2

(c) (i) Electron deficient **(1)**

Or small, slight, partial positive charge

(ii) H < N **(1)**

2

[11]

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Q1.

(a) 63.7% of candidates answered this correctly.

(b) Students usually answered this correctly (71.2%); a common incorrect answer was that chloride ions did not have lone pairs.

(c) The colour of the solution formed was better known than the equation; many students could not give a correct ionic equation and $[Cu(NH_3)_6]^{2+}$ was a common incorrect product.

(d) 78.1% of candidates answered this correctly.

(e) This part was generally answered well, with 59.4% of students gaining at least one mark. Hydrochloric acid was often given as the reagent; chlorine was the most common wrong answer. Equations were often unbalanced. A common incorrect product was $CuCl_4^-$

(f) Students could often state that the electronic configuration was d^{10}, but the effect on electron transitions was less well known. Students often failed to realise the importance of visible light being absorbed. Some students scored the mark by stating the complex was colourless.

Q4.

The fairly familiar shapes here proved quite easy for many students and the rest of the question also proved to be quite accessible except for (c) where many were unable to explain the change in the Cl-Al-Cl bond angle.

Q5.

Hydrogen bonding was well known in part (a)(i) and the diagram to show the interaction in part (a)(ii) was also generally well done; the main error was failing to show the hydrogen bond from the lone pair to the $H\delta^+$. Part (b) was generally well known but some students thought that the electron pair came from the boron atom.

The definition in part (c)(i) was well known by most students but there were still some who referred to single electrons or referred to an element / substance rather than an atom / nucleus or forgot to mention the type of bond. Responses to parts (c)(ii) and (c)(iii) often showed a lack of understanding; many students could not select the correct elements to write a formula and for those who could select the correct elements the ratio in the formula was often incorrect.

Q6.

Part (a) was answered well although a few students lost the mark by simply stating ‘giant’ or ‘giant lattice’. Generally, students did well in part (b), although some forgot to mention a pair or two electrons being shared. Most students scored the mark in part (c) but could not work out the correct empirical formula in part (d).

Q7.

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The equation in part (a) was given correctly by only a few students. Far too many students could not give the correct formula for aluminium chloride. The type of bonding in part (b) was well answered but many students thought that the pair of electrons originated from the Cl atom or from the Al atom. In part (e), the majority of students gave a correct structure and formula. Incorrect answers were due to the insertion of lone pairs of electrons. The linear shape in part (f) was generally answered well but the explanation of the shape often did not refer to repulsion between the bonding electron pairs. The majority of students scored the mark in part (g), realising that the outer electrons are removed first during successive ionisations.

Q8.

The structure in part (a) was well answered. Part (b) was also answered well although a few students gave generic answers about co–ordinate bonds rather than specific answers to this question. Various bond angles were seen for part (c). In part (d), the idea of an electronegativity difference was often seen but then students often gave responses that were not specific to the molecule in the question. Many students lost marks by referring to the electronegativity of the phosphine molecule.

Q9.

Part (a) was generally answered well although many students did not refer to a shared pair of electrons in the covalent bond. The required number of bond pairs and lone pairs in parts (b)(i) and (ii) were reasonably well known although many students did not appreciate that the lone pairs would repel each other and the bond pairs as far apart as possible and hence lost the marks for the bond angles. Some students incorrectly gave B as the symbol for bromine. The answers to part (c) differentiated well. Weaker students generally scored zero due to chemical errors. Where students identified ionic bonding, marks were lost by not stating oppositely charged ions or by referring to incorrect ions eg K^+ and F^-. The type of intermolecular force in part (d)(i) was well known. Weaker students did not know the formula HF in part (d)(ii) and many students lost marks due to careless omissions of the partial charges or the lone pairs. Students generally realised that van der Waals' forces were present in fluorine and hence the boiling point was low. However many answers did not refer to van der Waals' forces acting between molecules and some answers referred incorrectly to the breaking of weak covalent bonds.

Q10.

Many candidates answered part (a) well but there were a significant number who did not make it clear that the van der Waals forces were between the molecules. Part (b)(i) differentiated well. There were many examples of the wrong number of lone pairs in both molecules and a frequent occurrence of bi-pyramids in candidates' answers. The angle in part (b)(ii) generated a range of values although the answer to part (c) was given correctly by a majority of candidates. Part (d) was generally well done although several candidates gave the wrong direction for the donation of the lone pair.

Q11.

Part (a) proved a difficult question with many candidates failing to refer to molecules. Of those that did many thought that the space between the molecules was filled with air or oxygen. Many considered hydrogen bonds but not the effect on the spacing between the molecules. Intermolecular forces in part (b) were generally well known although a few thought incorrectly that there are dipole-dipole forces between methane molecules. In part (b)(iii), many candidates stated that hydrogen bonds were strong but then failed to make the comparison between the intermolecular forces in the two molecules. The shape in part (c)(i) was generally well attempted but less able candidates included two or no lone pairs

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of electrons. Many candidates thought that the ion was planar, but of those who correctly stated the shape as tetrahedral many followed with a bond angle of 109° in part (c)(ii) showing that they had not taken account of the lone pair of electrons in the molecule. The identification of the molecule in part (c)(iii) proved difficult and many candidates suggested ions rather than a molecule. Part (d) was not well answered.

Q12.

In part (a)(i) many candidates omitted the word 'pair' from their answer and hence did not score the mark. The equation in part (a)(ii) was not answered well since many candidates failed to read the question, which asked for an equation to produce one mole of product. Other errors included not giving the correct formulae for chlorine or fluorine molecules. Candidates found the first structure in part (b) relatively easy, but answers for the structure of ClF_3 often included the wrong number of lone pairs of electrons. Part (c) was answered well. The idea of co-ordinate bonding was generally well known but the explanation in part (d)(i) was not. Many candidates thought that the lone pair originated from the B rather than the F^-. A large range of answers was seen in part (d)(ii) with 107.5 being the most popular incorrect answer. If candidates understood the concept of atom economy then they generally scored 2 marks in part (e).

Q13.

Candidates answered part (a) well with only a few losing marks for simply referring to 'hydrogen' or 'dipole bonds'. Part (b) was done well by many candidates. Weaker candidates did not show hydrogen bonds from the lone pair. There were a number of recurring errors including water as HO_2, partial charges missing or the wrong way round. Part (c) was generally answered well with candidates relating their answers to comparisons between IMF's. Candidates found part (d) more challenging and there were several answers in terms of the greater attraction between the outer electrons and the protons in the nucleus or electronegativity differences. Part (e) was generally well answered with candidates knowing the type of bonding and making an attempt at the explanation. Marks were lost for general descriptions of dative covalent bonding rather than referring specifically to the species given in the question. The type of bonding in part (f) proved a good discriminator. Although many candidates gave the correct type of bond, weaker ones suggested covalent or metallic bonds. The explanation also proved more difficult. Many lost marks for breaking IMF's as well as, or instead of, ionic bonds. Candidates who knew about strong electrostatic attractions often failed to say that this was between oppositely charged ions.

Q14.

This question was not as well done as others on the paper. The answer to (a)(i) often did not refer to a covalent bond being the sharing of a pair of electrons. Part (a)(ii) was done quite well although dipole-dipole forces was often incorrectly given as an answer. The diagrams in part (b) were often unclear and had many errors including partial charges on the wrong atoms, incorrect number of lone pairs and multiple hydrogen bonds to the same atom. The equation in part (c)(i) showed that many candidates could not balance this correctly since they did not notice the O in ethanol. There were several vague answers given in part (c)(ii) and many candidates talked about carbon dioxide being a green house gas rather than the products of incomplete combustion and their associated problems. The economic requirement in part (c)(iii) was poorly answered with many vague answers e.g., less efficient which did not fully answer the question. In part (d)(i) many candidates did not know how the sulfur dioxide is removed with many incorrectly giving water as the answer. Answers to part (d)(ii) produced several interesting but incorrect answers.

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Q15.

The definition required in part (a) was generally well known. Common errors included reference to a single electron or omitting covalent bond. Part (b) was quite a good discriminator with many candidates merely giving ‘dipole-dipole interaction’ or just ‘hydrogen’. Part (c) also discriminated well. Many candidates relied upon attraction between the partial charges on the hydrogen and nitrogen neglecting the importance of the lone pair on the nitrogen atom. Most candidates knew about co-ordinate bonding and scored the first mark in part (d). The idea of sharing a pair of electrons was well known although the direction of donation was often wrong or unclear. Many scored both marks in part (e) and some good 3-D diagrams were seen. Candidates lost marks by omitting the H atoms, replacing the As with N or P and stating the shape as bipyramidal or planar. Part (f) proved difficult for weaker candidates. There were a few who failed to realise the significance of the negative signs and thought that AsH_3 had the higher boiling point and some referred to breaking covalent bonds rather than intermolecular forces. The equation in part (g) was usually correctly balanced.

Q16.

Many of the diagrams in part (i) were poorly drawn, and many instances of one or more lone pairs of electrons being shown on the B atom were seen. Those candidates who tried to indicate the three-dimensional nature of the structures using wedges and dotted lines, frequently used them incorrectly. While many candidates correctly named the shapes of the species, it was not unusual for the shape of the BF_4 ion to be described as being *distorted tetrahedral.* In most instances, the correct bond angle was quoted for the BF_4” ion, however, bond angles of 107° or even 105° were quite frequently seen. An explanation for the shape of this ion was rarely attempted and, when it was, it was often given in terms of repulsion between Fluorine atoms rather than of bonding electron pairs. *Equal* repulsion was rarely seen. Part (ii) was quite well answered. Most candidates were able to show an understanding of dative covalent bonding, although a fair number of candidates predicted that there was a lone pair of electrons on boron which was donated to the fluoride ion when the bond was formed.

Q17.

This question was, in general, quite well answered, although very low scores were not uncommon. Most candidates correctly identified the bonding in part (a) as being dative or coordinate. In some cases, the bond was incompletely described as being *covalent* but references to *hydrogen bonding, van der Waals' forces* and *ionic bonding* also appeared quite frequently. The explanation of the origin of this bond was less well done. Some candidates, having read about ammonia in the stem, quoted a nitrogen atom as being the source of the lone pair which formed the dative bond. Others clearly had little idea of how a dative bond is formed. It is worrying that a number of candidates thought that H^+ ions each have a lone pair that they can donate to the phosphorus atom. In part (b), the shapes of both species were usually clearly and accurately drawn. The most common errors were to omit the lone pair of electrons on the PH_3 molecule, to add extra lone pairs of electrons on either species and to show phosphine as either a trigonal planar shape or as 'T' shaped. Errors in the naming of the shape of phosphine molecule were quite common, with *bipyramidal* and *planar triangular* being the most common. There were also many errors in the bond angle quoted for the phosphonium ion, with 107°, 90° and multiple angles being frequently seen. While *tetrahedral* was accepted this year for the shape of phosphine, *pyramidal* is preferred; centres are asked to encourage candidates to use this term.

Q18.

This question was, in general, also poorly answered. Of those candidates who attempted

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part (a), most were successful; however, a surprisingly large number of candidates made no attempt to balance the equation. Whilst, in part (b), most candidates gave the correct electronic arrangement for the hydride ion; $1s^0$ and $1s^12s^1$ were quite common errors. Candidates encountered many problems in deducing the shape of the $AlCl_4^-$ ion, with *trigonal planar*, *square planar* and *distorted tetrahedral* being the most common errors. Some candidates drew diagrams to illustrate their answer, many of which showed a lone pair on the Al atom. The explanation was frequently incomplete, or incorrectly referred to repulsions between *hydrogen atoms* or *hydride ions*, rather than between four bonding electron pairs. In part (d), many candidates were able to identify the bonding as dative/coordinate but then simply described, in general terms, the formation of such a bond. References to the donation of a lone pair from the hydride ion to the aluminium atom were relatively rare.

Q19.

This question produced many good answers. In part (a)(i), electronegativity was frequently quoted as the required property of the atoms. A reference to the 'high electronegativity of fluorine and chlorine' was accepted here but vague references to 'high electronegativity of the atoms' was not. Errors included simple references to 'unequal sharing', which did not address the question, and arguments based on the number of protons present in the nuclei. Many candidates provided acceptable explanations in part (a)(ii) but many confused attempts were also seen. Most candidates attributed the difference in boiling points to differences in the strength of intermolecular attractions but the types of attraction present in the two systems were quite frequently confused. It was not always clear that the forces described were intermolecular in nature. In part (b), the origin of a co-ordinate bond was well known, however, some candidates confused the direction of electron pair donation. The quality of drawing seen in part (c) varied considerably. Most diagrams proved to be acceptable but some were very poor. In some cases, the use of dotted lines and wedges to show the direction of the bonds was more of a hindrance than a help. It is recommended that candidates who intend to use these devices practice them beforehand. Some diagrams, especially that of $AlCl_4^-$ showed a lone pair, while other diagrams clearly indicated a planar structure. Most candidates were able to deduce the appropriate bond angles, but errors were not uncommon.

Q20.

Many candidates answered this question quite well but full marks were not that common. Most candidates correctly completed the table in part (a) but it was not unusual for either the signs or the values of the relative charges to be omitted. In a few instances, the values of the electron and the neutron were transposed. Success in part (b) was far from universal. Errors such as 39.9 and 36 for the mass number were quite common, as was the use of Z to represent the element. Part (c) was, in the main, successfully completed but the odd d level was seen, as were configurations for the S^{2-} ion showing $3p^2$ rather than $3p^6$ electrons, or even a $2p^8$ arrangement. While part (d) was also generally well done, some candidates were found to be unfamiliar with this part of the specification and the suggestion that the element was found in block 6, because it contained 6 outer electrons, was not uncommon. Some candidates incorrectly referred to the p-block or p-shell, rather than using the correct terms sub-level or sub-shell. In part (e), a surprising number of candidates identified incorrectly the bonding in Na_2S as being covalent or metallic, and the bonding in CS_2 as being ionic, molecular or dative. For those candidates who did recognise the ionic nature of the bonding in Na_2S, their descriptions were often vague and they did not express clearly the transfer of electrons which takes place, and the numbers of electrons involved. Many answers could have equally well fitted the description for the formation of a covalent bond. The diagram of the bonding in CS_2 was frequently flawed, with spare electrons being placed around carbon and extra lone pairs on the sulphur atoms. Some candidates showed a single bond between the sulphur and

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carbon atoms, whilst others only included a single sulphur atom. The equation was almost invariably correct; although, in a few cases, the equation was not balanced.

Q21.

Most candidates gained high marks for this question. Parts (a) (i) to (iii) were usually correct but a surprising number of the weaker candidates suggested that N → H represented a hydrogen bond. Full marks for part (a) (iv) were seldom awarded. Despite the instruction about electron pairs in the question, some candidates referred to repulsion between hydrogen atoms rather than between electron pairs. Answers to parts (b) and (c) were of good quality.

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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 _____

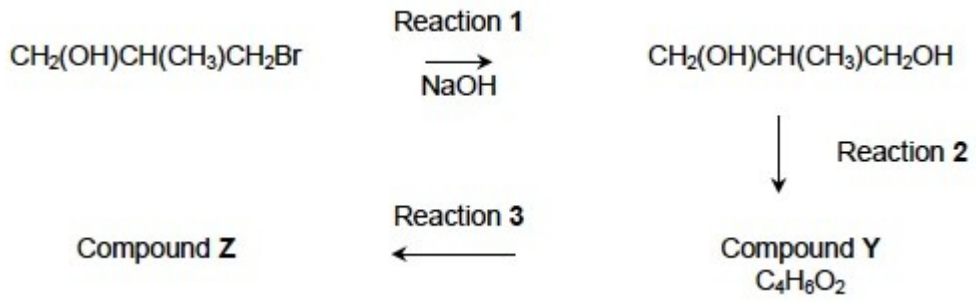
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(3)
(Total 8 marks)

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 $CHBr_3$ ⬭

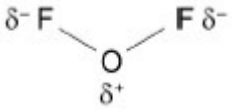
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D CBr_4 ⬭

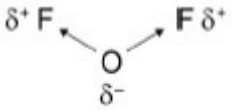
(Total 1 mark)

Q4.

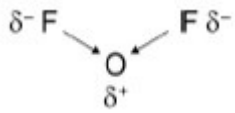
Which diagram shows the correct bonding and correct bond polarity in a molecule of oxygen difluoride?

A 

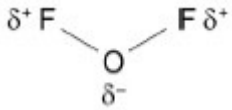
⬭

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 ⬭

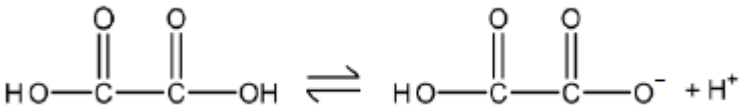
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D Ar ⬭

(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 ⬭

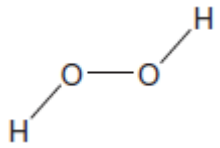
D CF_4 ⬭

(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.

_____

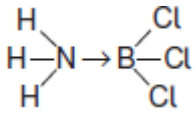
(1)

(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*.

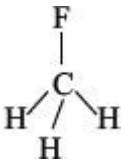
_____

_____

_____

(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.

_____

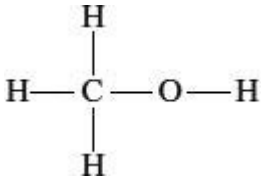
_____

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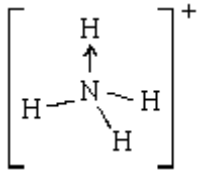
Bond angle(s) _____ *Bond angle(s)* _____

(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

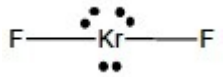
C $\overset{\delta+}{C}-\overset{\delta-}{O}$ in ethanol

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

(Total 1 mark)

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Q1.

(a) 

Allow diagram with 2 bonds <u>and</u> 3 lone pairs

1

<u>Linear</u>

1

<u>180°</u>

1

(b) Lone pairs repel more than bond pairs

1

Allow idea of reducing bond angle

bond angle will be lower (than regular tetrahedral angle) / bond angle of 103-106°

1

(c) Van der Waals forces

Allow London forces, dispersion forces, induced dipole-dipole

Apply List for M1.

Allow M2 if vdW mentioned in M1, otherwise CE=0

1

(Uneven distribution of electrons in) one molecule <u>induces</u> dipole in neighbouring/another/nearby <u>molecule</u>

1

symmetrical molecule / dipoles cancel

OR

no hydrogens bonded to F (N or O), therefore no hydrogen bonding

1

[8]

Q2.

(a) <u>3</u>-bromo-(2)-methylpropan-<u>1</u>-ol ONLY

3 and 1 are essential, 2 may be omitted, but any other number here is wrong

Ignore hyphens and commas

1

(b) Bromine is <u>more electronegative than carbon</u>

Allow difference in electronegativity if polarity of bond shown

M1

C is partially positive / electron deficient

M2 and M3 can be awarded from diagram that shows

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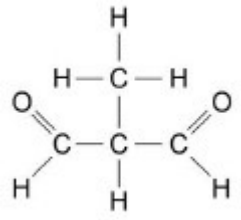
nucleophilic attack

M2

Lone/electron pair (on the nucleophile) donated to the partially positive carbon

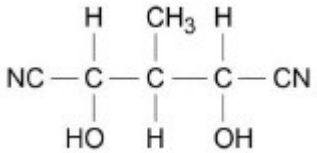
Allow lone pair attracted to / attacks the partially positive carbon

M3

(c) 

Must be displayed with all bonds shown

1

(d) 

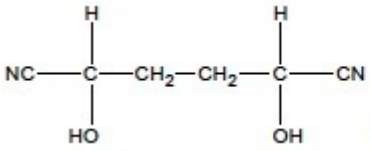
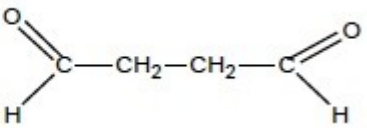
Not need be displayed

See General Marking instructions section 3.12 for penalties for incorrectly drawn bonds such as C–HO or C–NC etc.

1

KCN & (dil) acid

Allow

 from 

Allow HCN

Ignore alcoholic solvents

Penalise conc. HCl, H_2SO_4 or any HNO_3

1

[7]

Q3.

D

[1]

Q4.

A

[1]

Q5.

(a) Power of an atom to attract a pair of electrons in a covalent bond.

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Allow power of an atom to attract a bonding/shared pair of electrons

Allow power of an atom to withdraw electron density from a covalent bond

Not lone pair Not Element

1

(b) Difference in electronegativity leads to bond polarity

If chloride (ions) mentioned then CE = 0

1

(dipoles don't cancel therefore the molecule has an overall permanent dipole) and there is an attraction between $\partial+$ on one molecule and $\partial-$ on another

partial charges should be correct if shown and can score M2 from diagram

1

(c)

SiH_4	**Tetrahedral**		1 shape & no tick
PH_3	**Pyramidal (trigonal) Allow tetrahedral**	✓	1 shape & tick
$BeCl_2$	**Linear**		1 shape & no tick
CH_3Cl	**(Distorted)Tetrahedral**	✓	1 shape & tick

If shapes are drawn rather than named then penalise first mark gained

4

[7]

Q6.

C

[1]

Q7.

D

[1]

Q8.

C

[1]

Q9.

(a) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

All stages are covered and the explanation of each stage is generally correct and virtually complete.

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Answer is communicated coherently and shows a logical progression from stage 1 and stage 2 to stage 3. Steps in stage 3 must be complete, ordered and include a comparison.

Level 3
5 – 6 marks

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression from stage 1 and stage 2 to stage 3.

Level 2
3 – 4 marks

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

Level 1
1 – 2 marks

Insufficient correct Chemistry to warrant a mark.

Level 0
0 marks

Indicative Chemistry content

Stage 1: difference in structure of the two acids
- The acids are of the form RCOOH
- but in ethanoic acid R = CH_3
- whilst in ethanedioic acid R = COOH

Stage 2: the inductive effect
- The unionised COOH group contains two very electronegative oxygen atoms
- therefore has a negative inductive (electron withdrawing)effect
- The CH_3 group has a positive inductive (electron pushing) effect

Stage 3: how the polarity of OH affects acid strength
- The O–H bond in the ethanedioic acid is more polarised / H becomes more δ^+
- More dissociation into H^+ ions
- Ethanedioic acid is stronger than ethanoic acid

6

(b) Moles of NaOH = Moles of $HOOCCOO^-$ formed = 6.00×10^{-2}

Extended response

1

Moles of HOOCCOOH remaining = $1.00 \times 10^{-1} - 6.00 \times 10^{-2}$

$= 4.00 \times 10^{-2}$

1

$K_a = [H^+][A^-] / [HA]$

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$[H^+] = K_a \times [HA] / [A^-]$

1

$[H^+] = 5.89 \times 10^{-2} \times (4.00 \times 10^{-2} / V) / (6.00 \times 10^{-2} / V) = 3.927 \times 10^{-2}$

1

$pH = -\log_{10}(3.927 \times 10^{-2}) = 1.406 = 1.41$

Answer must be given to this precision

1

(c) $5H_2C_2O_4 + 6H^+ + 2MnO_4^- \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

OR $5C_2O_4^{2-} + 16H^+ + 2MnO_4^- \longrightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$

1

Moles of $KMnO_4 = 20.2 \times 2.00 \times 10^{-2} / 1000 = 4.04 \times 10^{-4}$

1

Moles of $H_2C_2O_4 = 5 / 2 \times 4.04 \times 10^{-4} = 1.01 \times 10^{-3}$

1

Concentration = moles / volume (in dm^3)

$= 1.01 \times 10^{-3} \times 1000 / 25 = 4.04 \times 10^{-2}$ (mol dm^{-3})

If 1:1 ratio or incorrect ratio used, M2 and M4 can be scored

1

[15]

Q10.

A

[1]

Q11.

(a) 94−105.5°

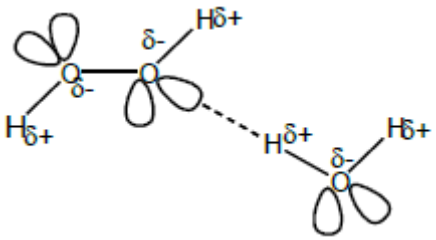
1

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

Not just hydrogen

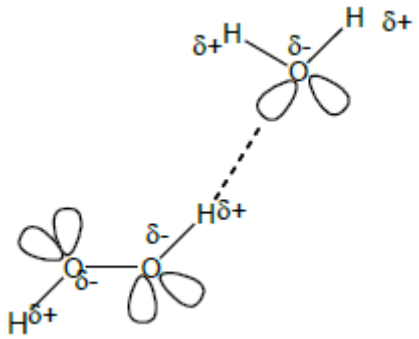
1

(ii)



OR

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1 mark for all lone pairs

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

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

3

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

Mark independently

1

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

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

If breaking covalent bonds CE = 0

1

[7]

Q12.

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

Ignore retain

1

In a <u>covalent</u> bond

1

(ii) More protons / bigger nuclear charge

1

Same or similar shielding / electrons in the same shell or principal energy level / atoms get smaller

Not same sub–shell
Ignore more electrons

1

(b) Ionic

If not ionic then CE = 0 / 3
If blank lose M1 and mark on

1

Strong or many or lots of (electrostatic) <u>attractions</u> (between ions)

If molecules / IMF / metallic / atoms lose M2 + M3, penalise

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incorrect ions by 1 mark

1

Between + and − ions / between Li^+ and F^- ions / oppositely charged ions

Allow strong (ionic) bonds for max 1 out of M2 and M3

1

(c) Small electronegativity difference / difference = 0.5

Must be comparative

Allow 2 non-metals

1

(d) (i) (simple) <u>molecular</u>

Ignore simple covalent

1

(ii) $OF_2 + H_2O \longrightarrow O_2 + 2HF$

Ignore state symbols
Allow multiples
Allow OF_2written as F_2O

1

(iii) 45.7% O

1

(O F)
(<u>45.7</u> <u>54.3</u>)
(16 19)

If students get M2 upside down lose M2 + M3
Check that students who get correct answer divide by 16 and 19 (not 8 and 9). If dividing by 8 and 9 lose M2 and M3 but could allocate M4 ie max 2

1

(2.85 2.85)
(1 1)

EF = <u>OF or FO</u>

Calculation of OF by other correct method = 3 marks
Penalise Fl by 1 mark

1

MF (= 70.0 / 35) = O_2F_2 or F_2O_2

1

[14]

Q13.

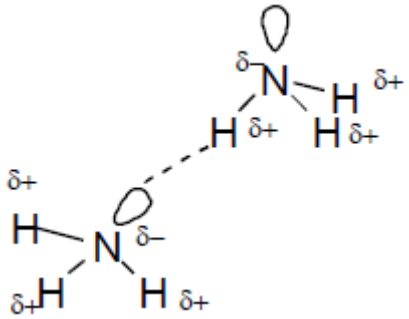
(a) (i) Hydrogen bonds / H bonds

Not just hydrogen.

1

(ii)

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M1 – lone pair on each N.

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

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

If not ammonia molecules, CE = 0 / 3.

3

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

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

1

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

1

in a <u>covalent</u> bond

1

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

Allow Li_2O_2, allow correct lithium carbide formula.

1

(iii) BH_3 / H_3B

Allow B_2H_6 / H_6B_2

Do not allow lower case letters.

1

[9]

Q14.

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

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

1

From a <u>covalent bond</u> or from a shared pair of electrons;

Not distort
Not remove electrons

1

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

1

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Hydrogen bonds/H bonds;

Not just hydrogen

1

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

Insufficient to say N= 3.1 and H = 2.1

1

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

Not N becomes (fully) negative or vice versa

1

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

QWC
Can score M2 and 3 from a diagram

1

(d) Co-ordinate/dative;

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

1

Both electrons/ lone pair (on P/PH_3)

Not lone pair on hydrogen

1

Shares/donated from P(H_3)/ to H(δ+);

1

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

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

1

Pyramidal/tetrahedral/ trigonal pyramidal;

Not bipyramidal/triangular

1

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

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

1

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

Accept multiples

1

[14]

Q15.

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

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pair / shared pair

1

in a <u>covalent</u> bond

1

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

1

CH_3F dipole-dipole

(not just 'dipole')

1

HF = hydrogen bonding

(not just 'H' / 'hydrogen')

1

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

(not just 'high<u>er</u>')

1

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

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

1

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

(M2 / M3 may be scored from a diagram)

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

1

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

(ignore references to dipole-dipole)

1

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

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

(mark M1 and M2 separately)

1

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

(accept hydrogen bonding is very strong / strongest)

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

(not just 'HF has H-bonding')

1

[11]

Q16.

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

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1

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

1

(b) van der Waals' forces between oxygen molecules;

1

Hydrogen bonding between methanol molecules;

1

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

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

(if ionic/covalent etc. max 1)

(mention of bond break = CE = 0)

1

[5]

Q17.

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

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

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

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

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

Note: if the explanation is clearly intramolecular = CE

4

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

Do not accept 'donation of electrons'

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

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

Ignore missing charge

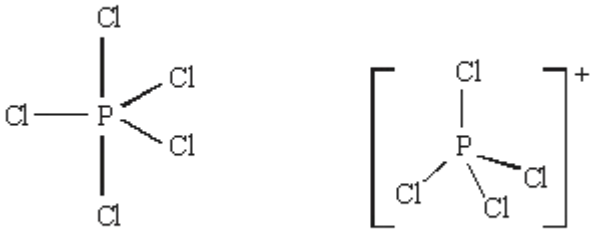
2

(c)

4

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PCl_5 PCl_4^+



(1) **(1)**

PCl_5 shown as trigonal bipyramid PCl_4^+ shown as tetrahedral
[Look for: ONE solid linear Cl-P-Cl bond] NO solid linear Cl-P-Cl bonds]

Bond Angle(s) 90° and 120° **(1)** *Bond angle(s)* 109 or 109.5° **(1)**

[10]

Q18.

(a) (i) Covalent **(1)**

(ii) Co-ordinate **(1)** (or dative)

(iii) Both / two / pair electrons come from nitrogen **(1)**

(iv) 4 bonding / electron pairs **(1)**

repel equally **(1)**
OR are identical

as far apart as possible **(1)**
OR to position of minimum repulsion

tetrahedron **(1)**

7

(b) Power (or ability) of an element / atom to attract electron pair/electrons/ an electron/electron density **(1)**

in a covalent bond **(1)**
Allow attract from, withdraw in, do not allow remove from, withdraw from.

2

(c) (i) Electron deficient **(1)**
Or small, slight, partial positive charge

(ii) H < N **(1)**

2

[11]

Q19.

A

[1]

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Q1.

(a) A good number of students realised that the KrF_2 molecule has three lone pairs around the krypton but few were able to appreciate that this is a linear molecule. Some students did not show any lone pairs on their diagrams.

(b) Most students understood that lone pairs reduce the bond angle in a molecule so this was answered well.

(c) A good number of students realised that the intermolecular forces were van der Waals' but were unable to describe accurately how these forces arise or why other intermolecular forces are not present between SiF_4 molecules. Only 4.9% of students gained full marks.

Q2.

(a) Most students correctly identified the main chain and the prefixes. However, only 40% gained the mark because of frequent errors in applying IUPAC rules in the numbering and alphabetical order of prefixes.

(b) The polarity of the bond between the bromine and the carbon, with the result that the carbon was slightly positive, was well known, although many struggled to explain this by a comparison of electronegativities. Some students failed to gain mark point 3 as they referred to nucleophiles as electron donors rather than electron pair donors, or simply stated that the nucleophile was attracted to the slightly positive carbon atom.

(c) This question was answered correctly by 39.4% of the students. Others identified the correct molecule but did not draw it as a displayed formula; $–CH_3$ was the most common error here. Some students drew an −OH group and a −C=O group in the same molecule, rather than two aldehyde groups; another common mistake was to draw butanedial.

(d) Most students identified that nitrile groups were present in this molecule, although some drew amines. There were some incorrectly drawn bonds, notably C–NC. Some who drew the incorrect butanedial in question 02.3 gained a mark here for a correct consequential structure. The reagent for Reaction **3** was not well answered. Many students missed the need for acid with KCN and some suggested the CN^- ion, which is an incomplete reagent.

Q3.

A significant majority of students (74.1%) could deduce that CBr_4 had no overall dipole.

Q4.

72.6% of students were correct. D was the commonest incorrect response, which had the correct bonding but polarity reversed.

Q5.

(a) This was a straightforward definition that was reasonably well known, with 51.8% of students successful.

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(b) The second mark was rarely scored, perhaps showing that students had not read the question carefully enough. The best answers often included a good diagram to shown the interaction between molecules.

(c) The shapes were quite well known, but the link with overall polarity less so. This question was a good discriminator, with almost even proportions of students scoring 0, 1, 2, 3 and 4 marks.

Q10.

This question proved difficult showing that the overall dipole possessed by a molecule clearly isn't a well understood concept.

Q11.

There were several different angles given in part (a) but the majority of students gave the correct one. The type of intermolecular force in part (b)(i) was very well answered. There were many students who scored full marks on the diagram in part (b)(ii) showing the lone pairs as lobes, two crosses or two dots. It should be stressed that students who choose to use dots should ensure that they are bold and clear. Some students however failed to score full marks since they did not have the correct number of lone pairs on each of the oxygen atoms. Partial charges, if seen, were generally correct. Several students did not read the question and used two water molecules instead of what was required. Answers to part (c) were generally quite poor and showed that students did not really understand the concept of electronegativity; many tried to compare the electronegativity of molecules rather than atoms. The students who correctly stated that the electronegativity of sulphur was lower than oxygen could often not explain the relevance of electronegativity difference to hydrogen bonding being absent between the molecules.

Q12.

The definition of electronegativity in part (a)(i) was poorly answered. Common errors included referring to the power of an element rather than an atom to withdraw electrons and many students did not refer to the type of bond. In part (a)(ii), many students failed to score the second mark suggesting that shielding or atomic radius increased. Quite a number of students could not identify the bonding in part (b) correctly. Many of those who could often then contradicted themselves by referring to molecules or atoms rather than ions.

Many students did not refer to the small difference in electronegativity between the two atoms in part (c). Instead, they opted for the more accessible answer of bonding between two non-metals. Part (d)(i) was not answered as well as expected. Many students did not seem aware of the difference between bonding type and crystal structure. The equation in part (d)(ii) was generally well answered although some students thought that the formula of hydrogen fluoride was H_2F_2. The calculation in part (d)(iii) was generally well answered although some students divided by 8 and 9 and a significant number of students thought that the molecular formula was 2OF.

Q13.

Hydrogen bonding was well known in part (a)(i) and the diagram to show the interaction in part (a)(ii) was also generally well done; the main error was failing to show the hydrogen bond from the lone pair to the $H\delta^+$. Part (b) was generally well known but some students thought that the electron pair came from the boron atom.

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The definition in part (c)(i) was well known by most students but there were still some who referred to single electrons or referred to an element / substance rather than an atom / nucleus or forgot to mention the type of bond. Responses to parts (c)(ii) and (c)(iii) often showed a lack of understanding; many students could not select the correct elements to write a formula and for those who could select the correct elements the ratio in the formula was often incorrect.

Q14.

The definition required in part (a) was generally well known. Common errors included reference to a single electron or omitting covalent bond. Part (b) was quite a good discriminator with many candidates merely giving 'dipole-dipole interaction' or just 'hydrogen'. Part (c) also discriminated well. Many candidates relied upon attraction between the partial charges on the hydrogen and nitrogen neglecting the importance of the lone pair on the nitrogen atom. Most candidates knew about co-ordinate bonding and scored the first mark in part (d). The idea of sharing a pair of electrons was well known although the direction of donation was often wrong or unclear. Many scored both marks in part (e) and some good 3-D diagrams were seen. Candidates lost marks by omitting the H atoms, replacing the As with N or P and stating the shape as bipyramidal or planar. Part (f) proved difficult for weaker candidates. There were a few who failed to realise the significance of the negative signs and thought that AsH_3 had the higher boiling point and some referred to breaking covalent bonds rather than intermolecular forces. The equation in part (g) was usually correctly balanced.

Q15.

Overall, this question produced the most inaccurate answers on the paper. While a higher proportion of candidates offered acceptable answers in part (a) than has been the case in the recent past, many attempts were incomplete and so failed to earn credit. A significant number of candidates failed to specify that the electrons being attracted were those in the covalent bond, while others identified these electrons as being lone pair electrons. Imprecise statements, such as "*An atoms ability to attract electrons to itself when covalently bonded*', were quite common. In some cases, definitions referred to electrons being *removed* from a covalent bond and so earned no credit.

While an encouraging number of candidates correctly deduced the types of intermolecular forces present in the part (b)(i), errors were common. It was not unusual for *van der Waals'*, *dipole-dipole* and *hydrogen bonding* all to be quoted but to be applied to the wrong substances. Similarly, duplication of one of these intermolecular forces was quite often seen. In a few instances, *ionic bonding* and *metallic bonding* were seen, and some candidates simply referred to *dipole* rather than to *dipole-dipole* attractions. Part (b)(ii) was poorly done. On previous papers, similar questions required candidates to draw a diagram to illustrate hydrogen bonding between molecules; such questions tend to be quite well done. In this question, candidates are required to explain how hydrogen bonding occurs and many explanations were found lacking. The presence of a dipole between the atoms in a molecule of HF was well known but quite frequently not well described. Many candidates omitted to link the partial charges to specific atoms, while others referred to hydrogen atoms being *positive* and/or fluorine atoms being *negative*, inferring that these charges were full rather than partial charges. Others specifically referred to the presence of '+' and '–' charges. An explanation of the origin of the dipole was required but this was often missing or vague. Many candidates simply referred to the hydrogen atom being *deshielded*, or referred to a *deshielded proton* but made no reference to the electronegativity of fluorine being much higher than that of hydrogen. The final mark for this question was for describing the attraction of the $^{\delta+}H$ on one molecule to a lone pair of electrons on a fluorine atom of another molecule; such descriptions were infrequently seen.

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Part (c) was difficult for a significant number of candidates. Many tried to explain the increasing boiling point in terms of increased dipole-dipole attractions, despite the decreasing trend in electronegativity difference evident from the data provided in the table. Of those candidates who identified the presence of van der Waals' forces, relatively few linked the increase in these forces to the increasing size of the halogen atoms. Some candidates based their explanation on the breaking of *bonds*, or even of *covalent bonds*. In part (c)(ii), candidates tended to simply refer to the presence of hydrogen bonding in HF, rather than comparing this with the weaker van der Waals' attractions present in the other hydrogen halides.

Q16.

Many candidates coped well with this question and full marks were quite common. In part (a), some candidates referred simply to a difference in electronegativity between hydrogen and oxygen, rather than identifying oxygen as having the greater electronegativity value, while a few got it completely the wrong way round. The formation of the dipole across the O-H bond was often poorly explained, as many candidates simply referred to electrons being more strongly attracted towards oxygen, rather than identifying those electrons as being the bonding electrons. Many candidates earned this second mark by showing the appropriate partial charges on the oxygen and hydrogen atoms. In part (b), many good answers were seen, with candidates basing their answers on the different intermolecular forces present in the two substances. It was quite common, however, for dipole-dipole attractions to be offered for either substance, for van der Waals' forces to be specified for both substances or for the higher boiling point of methanol to be attributed to the breaking of its covalent bonds.

Q17.

This question produced many good answers. In part (a)(i), electronegativity was frequently quoted as the required property of the atoms. A reference to the 'high electronegativity of fluorine and chlorine' was accepted here but vague references to 'high electronegativity of the atoms' was not. Errors included simple references to 'unequal sharing', which did not address the question, and arguments based on the number of protons present in the nuclei. Many candidates provided acceptable explanations in part (a)(ii) but many confused attempts were also seen. Most candidates attributed the difference in boiling points to differences in the strength of intermolecular attractions but the types of attraction present in the two systems were quite frequently confused. It was not always clear that the forces described were intermolecular in nature. In part (b), the origin of a co-ordinate bond was well known, however, some candidates confused the direction of electron pair donation. The quality of drawing seen in part (c) varied considerably. Most diagrams proved to be acceptable but some were very poor. In some cases, the use of dotted lines and wedges to show the direction of the bonds was more of a hindrance than a help. It is recommended that candidates who intend to use these devices practice them beforehand. Some diagrams, especially that of $AlCl_4^-$ showed a lone pair, while other diagrams clearly indicated a planar structure. Most candidates were able to deduce the appropriate bond angles, but errors were not uncommon.

Q18.

Most candidates gained high marks for this question. Parts (a) (i) to (iii) were usually correct but a surprising number of the weaker candidates suggested that N → H represented a hydrogen bond. Full marks for part (a) (iv) were seldom awarded. Despite the instruction about electron pairs in the question, some candidates referred to repulsion between hydrogen atoms rather than between electron pairs. Answers to parts (b) and (c) were of good quality.

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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.

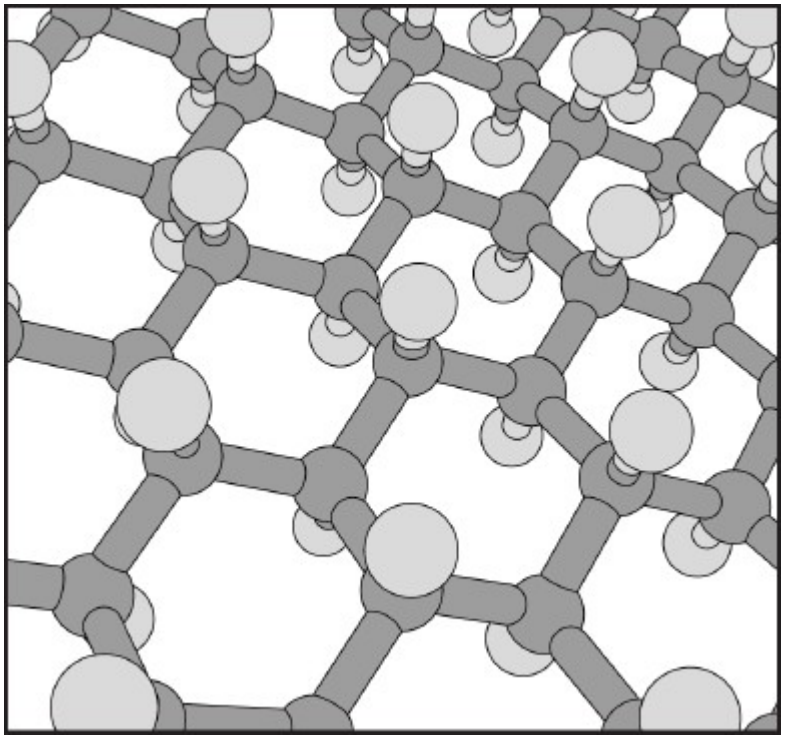
_____

(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.

_____

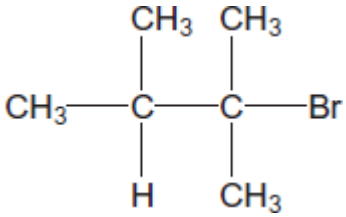
(1)

(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 _____

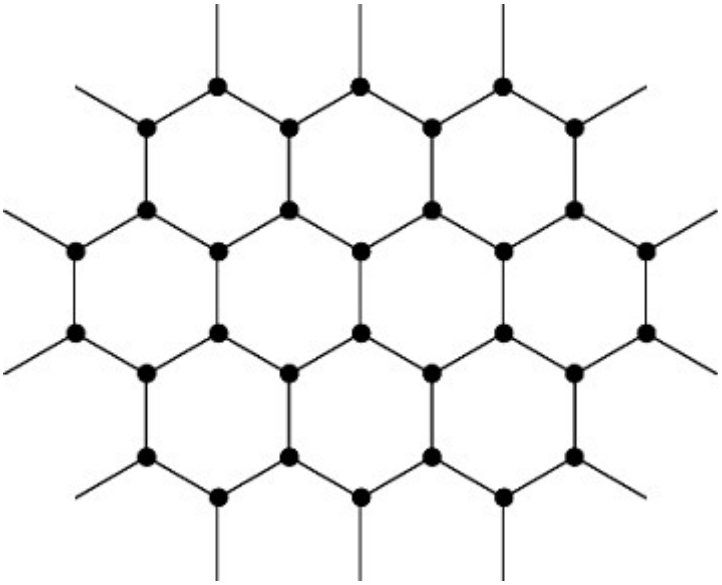
_____

(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.

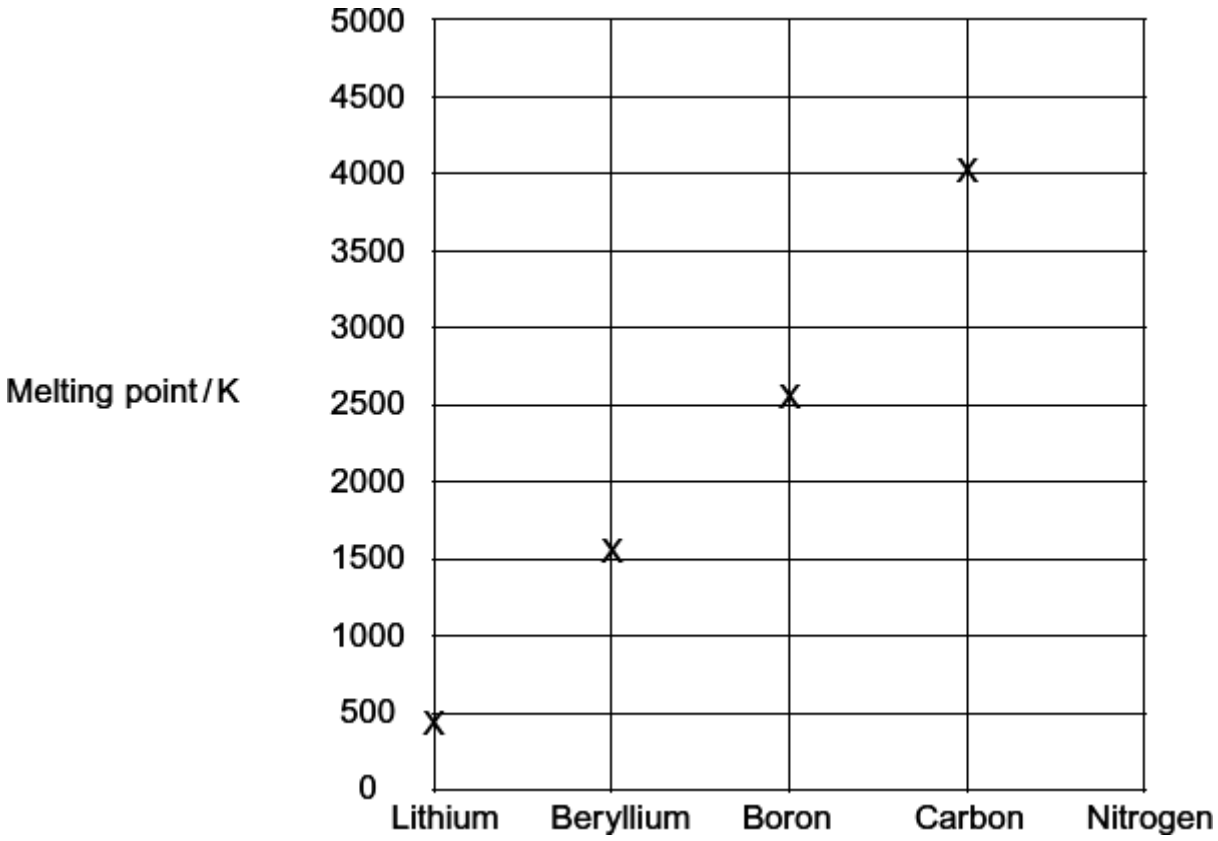
	First	Second	Third	Fourth	Fifth	Sixth
Ionisation energy / kJ mol^{-1}	1090	2350	4610	6220	37 800	47 000

_____

(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)

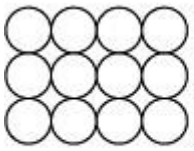
(Total 20 marks)

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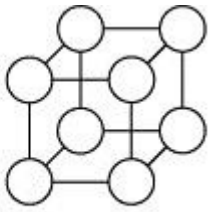
Q26.

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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_____

_____

_____

_____

_____

_____

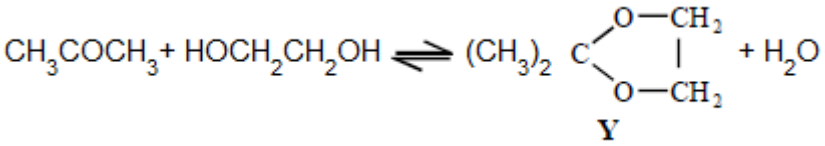
_____

_____

(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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Q1.

This question is marked using Levels of Response. Examiners should apply a 'best-fit' approach to the marking.	
Level 3 5-6 marks	All stages are covered and the explanation of each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 and then stage 3. Coherent communication requires that there is a comparison between the types of bonding and that the bonding is correct for each substance.
Level 2 3-4 marks	All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows some progression from stage 1 to stage 2 and then stage 3.
Level 1 1-2 marks	Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR only one stage is covered but the explanation is generally correct and virtually complete. Answer shows some progression between two stages
Level 0 0 marks	Insufficient correct chemistry to gain a mark.

Indicative chemistry content. Contradictions (eg molecules, IMFs, covalent bonding,) negate statements.

Stage 1 - **Na**
1a) Na has metallic bonding
1b) there is attraction/ bonding between the positive nucleus/ ion and the delocalised electrons in Na
1c) Na has a giant/lattice structure

Stage 2 – **NaBr or NaI**
2a) Ionic bonding in NaBr and/or NaI
2b) There is attraction/ bonding between the + and – ions in NaBr and/or NaI
2c) NaBr and/or NaI have a giant/lattice structure

Stage 2 – **comparison of bonding**
3a) The ionic bonds are stronger (or wtte) than the metallic bonds
3b) there is stronger attraction (or wtte) between the + and – ions in NaBr than in NaI

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3c) since the Br^- ion is smaller than the I^- ion

6

(b) **M1** $Na + H_2O \rightarrow NaOH + ½ H_2$

Allow multiples

1

M2 (Mass Na = 0.250 g so moles Na = 0.250/23.0) = 0.0109

CE: If not divided by 23, max 3/5 calculation marks – M3, M4 and M5

AE: If not divided by 1000 and final answer is 1.33×10^5 cm^3 4/5

1

M3 moles $H_2 = 5.43 \times 10^{-3}$ to 5.45×10^{-3}

M3 = M2 /2

CE: If incorrect ratio used max 3/5 calculation marks – M2, M4 and M5

1

M4 T = 298 (K) and P = 101000 (Pa)

1

M5 V = nRT/P or $(5.435 \times 10^{-3} \times 8.31 \times 298)/101000$ or 1.33×10^{-4} (m^3)

1

M6 V = 133 – 134 cm^3

Allow to 2 significant figures or more

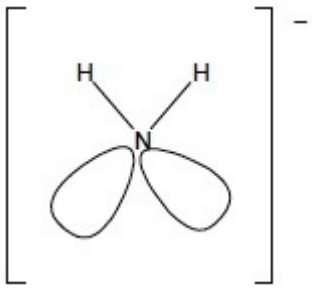
1

(c) Conc = $0.0109/ 500 \times 10^{-3} = 0.0217$-$0.022$ (mol dm^{-3})

Allow M2 from question (b)

1

(d) **M1**



Ignore charge and brackets

1

M2 104.5°

Allow 104-106

1

M3 (4) electron pairs repel to be as far apart as possible

1

M4 lp/lp repulsion> lp/bp repulsion (> bp/bp repulsion)

For M4 allow lone pairs repel more than bonding pairs

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Mark independently

1

[16]

Q2.

A

[1]

Q3.

(a) $P_4 + 5\ O_2 \longrightarrow P_4O_{10}$

allow 4 P + 5 $O_2 \longrightarrow P_4O_{10}$

allow multiples

ignore state symbols

1

(b) React with water / add water / solution (of substances in question)

If no M1 then CE = 0/3

1

Add litmus paper / universal indicator / measure pH (with pH meter)

Allow other reagents in solution, e.g. sodium carbonate solution, that give a positive result

Allow other indicators with appropriate colour changes

1

M3 is dependent on M2

Litmus: blue with sodium oxide (solution) **and** red with phosphorus oxide (solution)OR
If blue litmus added phosphorus oxide solution goes red OR
If red litmus added sodium (hydr)oxide goes blue

Universal Indicator: blue/ purple with sodium oxide (solution) **and** red with phosphorus oxide (solution)

pH meter or Universal Indicator: sodium (hydr)oxide (solution) has a higher pH (than phosphorus oxide (solution)) or vv

sodium (hydr)oxide pH (12 to 14) **and** phosphorus oxide (solution) pH (-1 to 2)

For pH meter or Universal Indicator: allow sodium (hydr)oxide (solution) has a higher pH and phosphorus oxide (solution) has lower pH.

1

(c) For silicon dioxide - giant covalent (molecule)/ macromolecular

1

For sulfur trioxide - molecular / (simple) molecule

1

Do not allow simple covalent

(d) Covalent bonds (between atoms) in SiO_2

1

Van der Waals between molecules / intermolecular forces in SO_3

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1

Covalent bonds are stronger than van der Waals forces

1

(Covalent bonds) take more energy to be <u>overcome/broken</u> or (Van der Waals) take less energy to be <u>overcome/broken</u>

1

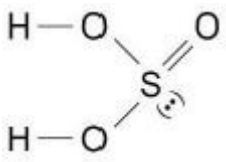
If covalent bonds between molecules of SiO_2 lose M1 only
If hydrogen bonds in SO_3 lose M2 only
If metallic or ionic max score = 1 (either M1 or M2)
If IMF in SiO_2 then max 1 (M2 only)
Allow dipole-dipole forces between molecules
For M3 and M4 comparison is required/implied

(e) $SO_3 + 2KOH \longrightarrow K_2SO_4 + H_2O$
$SO_3 + KOH \longrightarrow KHSO_4$
$SO_3 + 2OH^- \longrightarrow SO_4^{2-} + H_2O$
$SO_3 + OH^- \longrightarrow HSO_4^-$
Allow multiples
Ignore state symbols

1

(f) $3\ MgO + 2\ H_3PO_4 \longrightarrow Mg_3(PO_4)_2 + 3\ H_2O$
Allow multiples
Ignore state symbols

1

(g) 

Ignore lone pairs

1

[13]

Q4.

(a) $Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2$

1

8 − 12

1

(b) Decrease

1

(c) $BaCl_2$
Allow $Ba(NO_3)_2$ or other soluble barium salt

1

$Ba^{2+} + SO_4^{2-} \longrightarrow BaSO_4$
Allow equation if state symbols missing but penalise if state symbols are incorrect

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1

(d) Strong attraction

1

Between positive and negative ions

1

[7]

Q5.

(a) [Kr] $5s^2$ $4d^{10}5p^5$

1

(b) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3
All stages are covered and the explanation of each stage is correct and complete.

Answer communicates the whole explanation coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

5-6 marks

Level 2
All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies **OR** two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression through the stages. Some steps in each stage may be out of order and incomplete.

3-4 marks

Level 1
Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, **OR** only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

Level 0
Insufficient correct chemistry to warrant a mark.

0 marks

Indicative Chemistry content

Stage 1

I_2 is molecular.

HI is molecular.

Stage 2

IMF hold the molecules together.

There are weak IMF forces hence the melting point is low in both substances.

I_2 bigger molecule than HI so I_2 has more electrons.

Stage 3

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Therefore stronger van der Waals between molecules in I_2 that need more energy to break causing the melting point to be higher.

HI also shows permanent dipole-dipole attraction between molecules but these forces are less than the vdW forces in iodine.

6

(c) No delocalised electrons or ions

1

(d) $\frac{1}{2}H_2 + \frac{1}{2}I_2 \rightarrow HI$

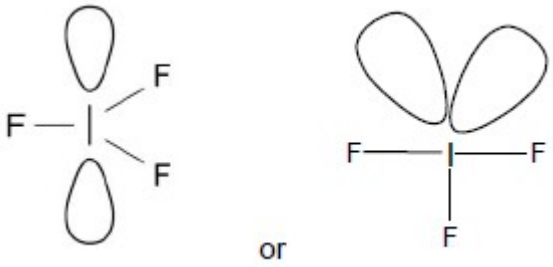
Allow multiples

1

(e) NH_4I_3

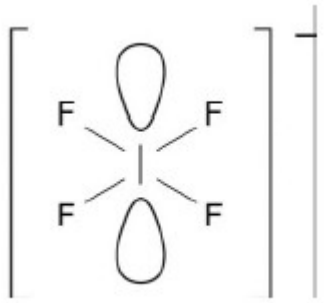
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(f)



Allow any shape with 3 bond pairs and 2 lone pairs

1



Allow any shape with 4 bond pairs and 2 lone pairs (e.g. lone pairs in equatorial positions)

1

(g) +5

1

+7

1

[14]

Q6.

Structures

M1 Bromine is (simple) molecular / simple molecules

Chemical Error penalties

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1

M2 Magnesium is metallic / consists of (positive) ions in a (sea) of delocalised electrons

If Br_2 (covalent) bonds broken lose M3 and M4

1

Strength

M3 Br_2 has weak (van der Waals) forces between the molecules / weak IMFs

If eg Mg molecules or Mg ionic bonds lose M2 and M4

1

M4 so more energy is needed to overcome the Stronger (metallic) bonds or converse. The comparison could be direct or implied.

1

Liquid range

M5 Mg has a much greater liquid range because forces of attraction in liquid / molten metal are strong(er) OR converse argument for Br_2

Must refer to liquid range to score M5

1

[5]

Q7.

B

[1]

Q8.

(a) Electron movement in first molecule / temporary dipole

Allow description

1

Induces a dipole in another molecule

Allow description

1

(Induced-temporary) attraction or δ+ attracts δ- in different/adjacent molecules

M3 dependent on M1 and M2

Allow electrostatic attraction

M3 could be scored in diagram

If other type of force / metallic / ionic / polar bonds / permanent dipoles / difference in electronegativity mentioned CE = 0

1

(b) (i) (Methanol) H-bonds / hydrogen bonding

1

(Methanethiol) dipole-dipole forces or van der Waals

1

H-bonds are a stronger / are the strongest IMF

Allow H-bonds require more energy to overcome

If M1 and M2 not scored, allow 1 for methanol has stronger IMFs

If breaking covalent bonds then CE=0

1

(ii) (Fractional) distillation

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Allow description

Do not allow heating unqualified

1

(c) (Methaneselenol is a) bigger molecule / larger Mr / larger no of electrons / Se bigger atom

1

With <u>stronger/more</u> <u>vdw</u> forces <u>between molecules</u>

If breaking covalent bonds then CE=0

1

(d) (i)

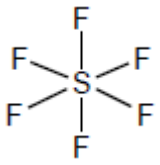


Diagram showing 6 bond pairs

1

(Bond angle) 90° for SF_6

Ignore 180°

1

Octahedral

1

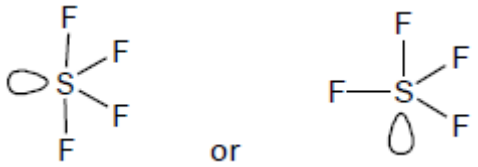


Diagram showing 4 bond pairs <u>and 1 lone pair</u>

1

(Bond angles) for SF_4

If shape of SF_4 is not based on 4 bond pairs <u>and 1 lone pair</u> cannot score M4 or M5

Any **two** from:

Allow 85 – 89°

Do not allow 90°

Allow 100 – 119°

Do not allow 120°

Allow 170 – 179°

Do not allow 180°

2

(ii) NaCl (as product in any equation)

1

$3\ SCl_2 + 4\ NaF \rightarrow SF_4 + S_2Cl_2 + 4\ NaCl$

Allow multiples

Ignore states

1

[17]

Q9.

(a) General increase

If not increase then CE

1

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Greater nuclear charge / more protons

1

Same shielding / electrons added to same shell

Allow similar

1

Stronger attraction (from nucleus) for outer electron(s)

Allow electron in outer shell

1

(b) Aluminium / Al (lower than Mg)

CE if not Al or S

1

(Outer) electron in (3)p orbital / sub-shell (level)

If 2p or 4p orbital lose M2 and M3

1

(3p) higher in energy

Allow more shielded or weaker nuclear attraction

M3 is dependent on M2

1

or
Sulfur / S (lower than P)
(Outer) electrons in (3)p orbital begin to pair
Repel

If 2p or 4p orbital lose M2 and M3

Allow 2 electrons in (3)p

M3 is dependent on M2

(c) Sulfur / S

CE if not S

1

Large jump after 6th or between 6th and 7th

Do not allow M2 if atom/ion is removed

1

(d) Silicon

CE if not Si

1

Giant covalent structure / macromolecule

1

Covalent (bonds)

Giant covalent scores M2 and M3

1

Many / strong (covalent bonds) or
(covalent bonds) need lots of energy to break

CE for M2-M4 if molecules / metallic / ionic / IMFs mentioned

1

[13]

Q10.

(a) Macromolecular / giant covalent / giant molecule

Not giant atomic

1

(b) No delocalised electrons / no free ions / no free charged particles

1

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(c) $SiO_2 + 6HF \longrightarrow H_2SiF_6 + 2H_2O$

Accept multiples

1

[3]

Q11.

(a) M1 $550 \times \frac{100}{95}$ = 579 g would be 100% mass

Allow alternative methods.

There are 4 process marks:

1

M2 So $\frac{579}{65}$ = 8.91 moles NaN_3

or

M1 $\frac{550}{65}$ = 8.46 moles NaN_3 (this is 95%)

M2 So 100% would be $8.46 \times \frac{100}{95}$ = 8.91 moles NaN_3

1: mass ÷ 65

2: mass or moles × 100 / 95 or × 1.05

3: moles NaN_3 × 2

4: moles $NaNH_2$ × 39

1

Then M3 Moles $NaNH_2$ = 8.91 × 2 = (17.8(2) moles)

1

M4 mass $NaNH_2$ = 17.8(2) × 39

1

M5 693 or 694 or 695 (g)

If 693, 694 or 695 seen to 3 sig figs award 5 marks

1

(b) M1 308 K and 150 000 Pa

1

M2 $n = \frac{PV}{RT}$ or $\frac{150\,000 \times 7.5 \times 10^{-2}}{8.31 \times 308}$

1

M3 = 4.4(0) or 4.395 moles N_2

Allow only this answer but allow to more than 3 sig figs

1

M4 Moles NaN_3 = 4.395 × $\frac{2}{3}$ (= 2.93)

M4 is for M3 × $\frac{2}{3}$

1

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M5 Mass NaN_3 = (2.93) × 65

M5 is for moles M4 × 65

1

M6 = 191 g

Allow 190 to 191 g allow answers to 2 sig figs or more

1

(c) (i) 150 / 65 = 2.31 moles NaN_3 or 2.31 moles nitrous acid

1

Conc = $2.31 \times \frac{1000}{500}$

M2 is for M1 × 1000 / 500

1

4.6(1) or 4.6(2) (mol dm^{-3})

Only this answer

1

(ii) $3HNO_2 \longrightarrow HNO_3 + 2NO + H_2O$

Can allow multiples

1

(d) Ionic

If not ionic then CE = 0 / 3

1

Oppositely charged ions / Na^+ and N_3^- ions

Penalise incorrect ions here but can allow M3

1

Strong attraction between (oppositely charged) ions / lots of energy needed to overcome (strong) attractions (between ions)

M3 dependent on M2

1

(e) (i) $N \equiv N \longrightarrow N^-$

Only

1

(ii) CO_2 / N_2O / BeF_2 / HN_3

Allow other correct molecules

1

(iii) MgN_6

Only

1

[21]

Q12.

(a) (i) d (block) **OR** D (block)

Ignore transition metals / series.

Do not allow any numbers in the answer.

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1

(ii) Contains positive (metal) ions or protons or nuclei and <u>delocalised / mobile / free / sea of</u> electrons

Ignore atoms.

1

<u>Strong attraction</u> between them or <u>strong metallic</u> bonds

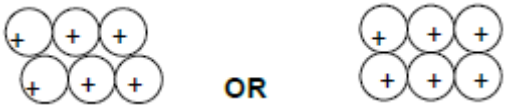
Allow 'needs a lot of energy to break / overcome' instead of 'strong'.

If strong attraction between incorrect particles, then CE = 0 / 2.

If molecules / intermolecular forces / covalent bonding / ionic bonding mentioned then CE=0.

1

(iii)



M1 is for regular arrangement of atoms / ions (min 6 metal particles).

M2 for + sign in each metal atom / ion.

Allow 2^+ sign.

2

(iv) <u>Layers / planes / sheets of atoms or ions</u> can slide over one another

QoL.

1

(b) (i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8\ (4s^0)$

Only.

1

(ii) $NiCl_2.6H_2O + \mathbf{6}\ SOCl_2 \longrightarrow NiCl_2 + \mathbf{6}\ SO_2 + \mathbf{12}\ HCl$

Allow multiples.

1

$NaOH / NH_3 / CaCO_3 / CaO$

Allow any name or formula of alkali or base.

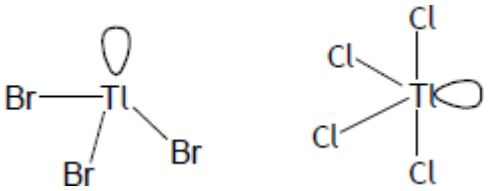
Allow water.

1

[9]

Q13.

(a)



Mark is for correct number of bonds and lone pair in each case.

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Ignore charges if shown.

2

Pyramidal / trigonal pyramid

Allow tetrahedral.

1

107°

Allow 107 to 107.5°.

1

(b) M1 Ionic

CE = 0 / 3 if not ionic.

1

M2 Oppositely charged ions / Tl^+ and Br^- ions

If molecules / intermolecular forces / metallic bonding, CE=0.

1

M3 Strong attraction between ions

M3 dependent on M2.

Allow 'needs a lot of energy to break / overcome' instead of 'strong'.

1

(c) $Tl + \frac{1}{2}Br_2 \longrightarrow TlBr$

Allow multiples.

Ignore state symbols even if incorrect.

1

[8]

Q14.

(a) Giant covalent / giant molecular / macromolecular

Not giant alone.

Not covalent alone.

1

(b) Shared pair of electrons / one electron from each C atom

1

(c) No delocalised / free / mobile electrons

Allow all (outer) electrons involved in (covalent) bonds.

Ignore ions.

1

(d) CH

Allow HC

C and H must be capital letters.

1

[4]

Q15.

(a) 2-bromo-2,3-dimethylbutane

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Ignore punctuation.

1

$C_nH_{2n+1}Br$ or $C_nH_{2n+1}X$ or $C_xH_{2x+1}Br$

Any order.

1

Stronger / more <u>vdw</u> (forces) <u>between molecules</u> (of 1-bromohexane)

QoL

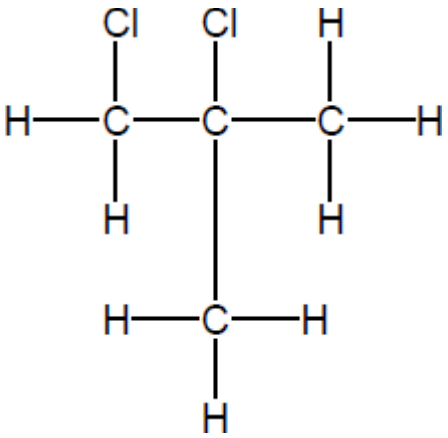
Allow converse arguments for Z

Not just more IMF.

Ignore size of molecule.

1

(b)



1

C_2H_4Cl

Any order

1

[5]

Q16.

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

Ignore retain

1

In a <u>covalent</u> bond

1

(ii) More protons / bigger nuclear charge

1

Same or similar shielding / electrons in the same shell or principal energy level / atoms get smaller

Not same sub–shell

Ignore more electrons

1

(b) Ionic

If not ionic then CE = 0 / 3

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If blank lose M1 and mark on

1

Strong or many or lots of (electrostatic) <u>attractions</u> (between ions)

If molecules / IMF / metallic / atoms lose M2 + M3, penalise incorrect ions by 1 mark

1

Between + and − ions / between Li^+ and F^- ions / oppositely charged ions

Allow strong (ionic) bonds for max 1 out of M2 and M3

1

(c) Small electronegativity difference / difference = 0.5

Must be comparative

Allow 2 non-metals

1

(d) (i) (simple) <u>molecular</u>

Ignore simple covalent

1

(ii) $OF_2 + H_2O \longrightarrow O_2 + 2HF$

Ignore state symbols
Allow multiples
Allow OF_2written as F_2O

1

(iii) 45.7% O

1

(O F)
(<u>45.7</u> <u>54.3</u>)
(16 19)

If students get M2 upside down lose M2 + M3
Check that students who get correct answer divide by 16 and 19 (not 8 and 9). If dividing by 8 and 9 lose M2 and M3 but could allocate M4 ie max 2

1

(2.85 2.85)
(1 1)

EF = <u>OF or FO</u>

Calculation of OF by other correct method = 3 marks
Penalise Fl by 1 mark

1

MF (= 70.0 / 35) = O_2F_2 or F_2O_2

1

[14]

Q17.

(a) (i) Macromolecular / giant covalent / giant molecular / giant atomic

If covalent, molecular, giant, lattice, hexagonal or blank mark on.

If metallic, ionic or IMF chemical error CE = 0 for (a)(i), (a)(ii)

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and (a)(iii).

1

(ii) Delocalised electrons / free electrons

1

Able to move / flow (through the crystal)

Allow M2 for electrons can move / flow.

Ignore electrons can carry a current / charge.

1

(iii) Covalent bonds

1

Many /strong / hard to break / need a lot of energy to break

M2 dependent on M1.

Ignore van der Waals' forces.

1

(b) (i) (Giant) metallic / metal (lattice)

If FCC or BCC or HCP or giant or lattice, mark on.

If incorrect (b)(i), chemical error CE for (b)(ii) and (c)(ii).

1

(ii) Nucleus / protons / positive ions and delocalised electrons (are attracted)

QWC Must be delocalised electrons – not just electrons.

Chemical error = 0/2 for (b)(ii) if other types of bonding or IMF mentioned.

1

Strong attraction

Allow strong metallic bonding for one mark if M1 and M2 are not awarded.

1

(c) (i) Layers of atoms/ions slide (over one another)

Do not allow just layers.

1

(ii) (Strong) (metallic) bonding re-formed / same (metallic) bonding / retains same (crystal) structure / same bond strength / same attraction between protons and delocalised electrons as before being hammered or words to that effect

If IMF, molecules, chemical error CE = 0/1 for (c)(ii).

If metallic not mentioned in (b)(i) or (b)(ii) it must be mentioned here in (c)(ii) to gain this mark.

Do not allow metallic bonds broken alone.

Ignore same shape or same strength.

1

(d) (giant) Ionic

If not ionic, chemical error CE = 0/3

1

Between + and – ions / oppositely charged ions or Mg^{2+} and O^{2-}

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If molecules mentioned in explanation lose M2 and M3

Allow one mark for a strong attraction between incorrect charges on the ions.

1

Strong attraction

1

[13]

Q18.

(a) Lithium / Li

Penalise obvious capital I (second letter).

1

(b) (i) Increase / gets bigger

Ignore exceptions to trend here even if wrong

1

(ii) Boron / B

If not Boron, CE = 0/3

1

Electron removed from (2)p orbital /sub-shell / (2)p electrons removed

If p orbital specified it must be 2p

1

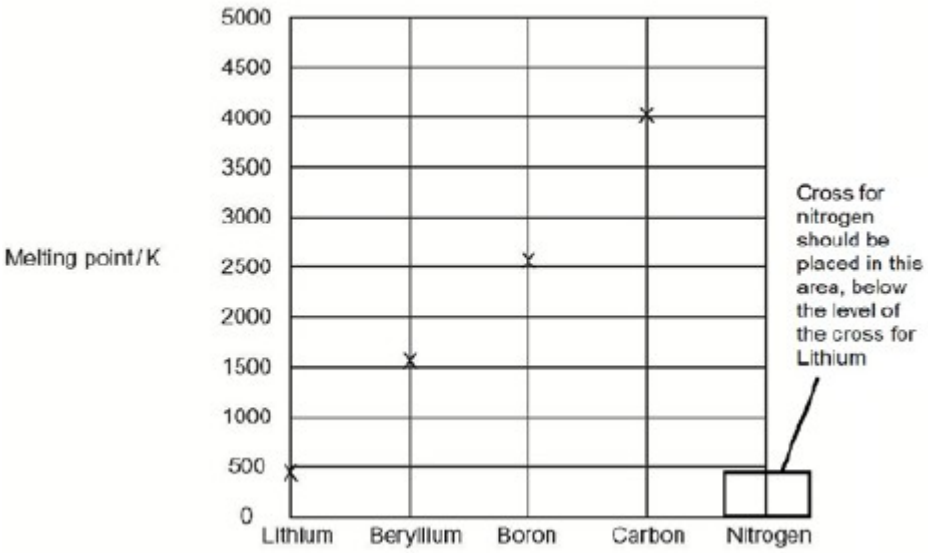
Which is higher in energy (so more easily lost) / more shielded (so more easily lost) / further from nucleus

1

(c) C / carbon

1

(d) Below Li



The cross should be placed on the diagram, on the column for nitrogen, below the level of the cross printed on the diagram for Lithium.

1

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(e) Macromolecular / giant molecular / giant atomic

Allow giant covalent (molecule) = 2

1

Covalent bonds in the structure

1

Strong (covalent) bonds must be broken or overcome / (covalent) bonds need a lot of energy to break

Ignore weakening / loosening bonds

If ionic / metallic/molecular/ dipole dipole/ H bonds/ bonds between molecules, CE = 0/3

Ignore van der Waals forces

Ignore hard to break

1

[10]

Q19.

(a) Covalent

If not covalent CE = 0/2

If dative covalent CE = 0/2

If blank mark on

Ignore polar

If number of pairs of electrons specified, must be 3

1

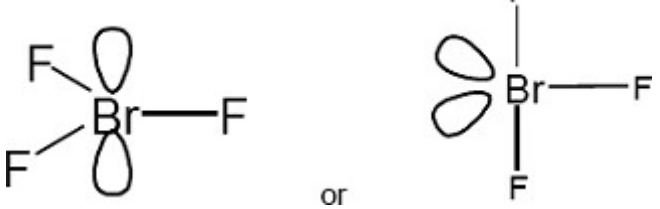
Shared pair(s) of electrons / one electron from Br and one electron from F

Not 2 electrons from 1 atom

Not shared pair between ions/molecules

1

(b) (i)



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

Penalise Fl

1

BrF_3 if trigonal planar shown = 120°

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

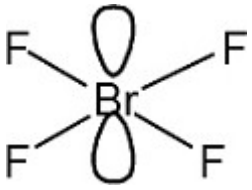
or if T shape shown 84 – 90°

Irrespective of shape drawn

1

(ii)

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

Allow Fl

1

BrF_4^- 90°

Only

Ignore 180°

1

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

If molecules, IMF, metallic, CE =0

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

Ignore atoms

1

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

1

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

If ions mentioned they must be correct

Strong bonds between + and – ions =3/3

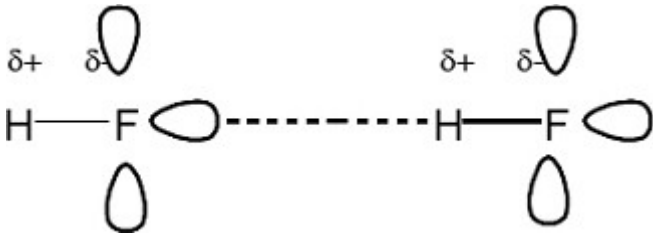
1

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

Not just hydrogen

1

(ii)



One mark for 4 partial charges

One mark for 6 lone pairs

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

Allow Fl

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

CE = 0/3 if incorrect molecules shown.

3

(e) vdw / van der Waals forces between molecules

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QoL

Not vdw between HF molecules, CE = 0/2

vdw between atoms, CE = 0/2

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

1

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

1

[15]

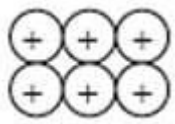
Q20.

(a) (i) Metallic

Allow body centred cubic

1

(ii)

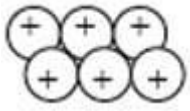


One mark for regular arrangement of particles. Can have a space between them

Do not allow hexagonal arrangement

1

OR



Na^+ Na^+ Na^+

Na^+ Na^+ Na^+

One mark for + in each

Ignore electrons

If it looks like ionic bonding then CE = 0/2

1

(b) (i) <u>Ionic</u>

CE = 0 for (b)(i) and (b)(ii) if not ionic

1

(ii) Strong (electrostatic) attraction

Any mention of IMF or molecules / metallic / covalent in (b)(ii) then CE 0/2

1

Between <u>oppositely</u> charged ions / particles

Or + and – ions

1

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(c) Iodide / I^- bigger (ion) (so less attraction to the Na+ ion)

Need comparison
Do not allow iodine is a bigger atom
Ignore I^- has one more c^- shell
CE = 0 if IMF / covalent / metallic mentioned

1

[7]

Q21.

(a) Iodine – <u>molecular</u>

Not covalent lattice

1

Graphite – macromolecular/giant covalent/giant atomic

1

(b) <u>Layers</u> of (C atoms)

1

Connected by <u>covalent bonds</u> within each layer

1

<u>Van der Waals forces</u>/<u>IMF</u> between layers/weak forces between layers

1

<u>Many/strong covalent bonds need to be broken</u>

If any other element mentioned other than C, CE = 0
Ignore the no of covalent bonds around the C if mentioned
The first 3 marks could be scored with a <u>labelled</u> diagram.
Need to label or state covalent bonds within the layers.
Covalent or ionic or metallic bonds between molecules CE = 0

1

(c) Van der Waals forces are weak or easily broken

Not vdw between atoms

1

Van der Waals <u>between molecules</u> (or implied)

Allow weak IMF = 2

1

(d) Does not have delocalised/free <u>electrons</u>

Only allow answer with respect to iodine
Not all electrons used in bonding
Ignore free ions

1

[9]

Q22.

(a) Hydrogen/H bonds

Not just hydrogen

1

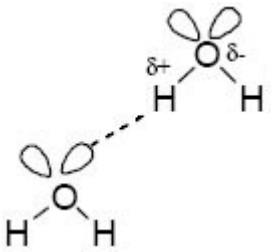
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van der Waals/vdw/dipole-dipole/London/temporarily induced dipole/dispersion forces

Not just dipole

1

(b)



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

3

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

OR

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

OR

H bonding is the strongest IMF

Ignore energy references
Comparison must be stated or implied

1

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

Not heavier/greater Mr

1

therefore increased Van der Waals/IMF forces

Ignore references to dipole-dipole forces

1

(e) Dative (covalent)/coordinate

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

1

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

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

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bond

1

(f) ionic

1

if not ionic CE = 0

oppositely charged <u>ions</u>/+ and – <u>ions or particles</u>

atoms or molecules loses M2 and M3

1

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

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

1

[13]

Q23.

(a) $2s^2\ 2p^6$;

If ignored the $1s^2$ given and written $1s^2 2s^2 2p^6$ mark as correct
Allow capitals and subscripts

1

(b) (i) $Na^+(g) \rightarrow Na^{2+}(g) + e^{(-)}$;

One mark for equation and one mark for state symbols

$Na^+(g) + e^{(-)} \rightarrow Na^{2+}(g) + 2e^{(-)}$;

M2 dependent on M1
Allow $Na^+(g) - e^{(-)} \rightarrow Na(g)$
Allow $X^+(g) \rightarrow X^{2+}(g) + e$ = 1 mark

2

(ii) $Na^{(2+)}$ requires loss of e^- from a 2(p) orbital or 2nd energy level or 2nd shell <u>and</u> $Mg^{(2+)}$ requires loss of e^- from a 3(s) orbital or 3rd energy level or 3rd shell / $Na^{(2+)}$ loses e from a lower (energy) orbital/ or vice versa;

Not from 3p

1

Less shielding (in Na);

Or vice versa for Mg

1

$e^{(-)}$ closer to nucleus/ more attraction (of electron to nucleus) (in Na);

M3 needs to be comparative

1

(iii) Aluminium /Al;

1

(c) Decreases;

If not decreases CE = 0
If blank, mark on

1

Increasing nuclear charge/ increasing number of protons;

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1

Electrons in same shell or level/ same shielding/ similar shielding;

1

(d) Answer refers to Na;

Allow converse answers relating to Mg.

Na fewer protons/smaller nuclear charge/ fewer delocalised electrons;

Allow Mg is 2+ and Na is +.
If vdw CE = 0.

1

Na is a bigger ion/ atom;

1

Smaller attraction between nucleus and delocalised electrons;

If mentioned that charge density of Mg^{2+} is greater then allow first 2 marks.
(ie charge / size / attraction).
M3 allow weaker metallic bonding.

1

(e) (Bent) shape showing 2 lone pairs + 2N−H bond pairs;

Atoms must be labelled.
Lone pairs can be with or without lobes.

1

Bent / v shape/ triangular;

Not tetrahedral.
Allow non-linear.
Bent-linear = contradiction.

1

(f) Ne has full sub-levels/ can't get any more electrons in the sub-levels/ Ne has full shells;

Not $2s^2\ 2p^6$ alone.
Not stable electron configuration.

1

[16]

Q24.

(a) (i) Average/mean mass of 1 atom (of an element);

Average mass of 1 atom × 12.

1

Mass 1/12 atom of ^{12}C;

Mass 1 atom of ^{12}C.
QWC.

1

(ii) Other isotope = 46.0%;

1

$$107.9 = \frac{(54 \times 107.1) + (46 \times ?)}{100};$$

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M2 whole expression.

1

108.8;

Answer 108.8 (3 marks).
Answer min 1 d.p..

1

Same electronic configuration/ same number of electrons (in outer shell)/ both have 47 electrons;

Ignore protons and neutrons unless incorrect.
Not just electrons determine chemical properties.

1

(b) Ionisation;

1

high energy electrons fired at sample;

Allow electron gun /blasted with electrons.

1

Acceleration;

1

With electric field/accelerating potential/potential difference;

Allow by negative plate.

1

Deflection;

1

With electromagnet/ magnet/ magnetic field;

M2 dependent on M1.
M4 dependent on M3.
M6 dependent on M5.

1

(c) (Silver) metallic (bonding);

Vdw/molecules CE=0.

1

Regular arrangement of same sized particles;

1

+ charge in each ion;

Ignore multiple positive charges.
Candidates do not need to show delocalised electrons.

1

(d) Ionic (bonds);

1

Minimum 4 ions shown in 2D square arrangement placed Correctly;

Do not allow multiple charges on ions.

1

Further 3 ions shown correctly in a cubic lattice;

1

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Strong (electrostatic) forces/bonds;

If vdw/molecules/covalent mentioned CE = 0 for M4 and M5.

1

Between + and – ions;

Accept between oppositely charged ions.

1

[20]

Q25.

(a) NaCl is ionic

1

cubic lattice

1

ions placed correctly

1

electrostatic attraction between ions

1

Covalent bonds between atoms in water

1

Hydrogen bonding between water molecules

1

Tetrahedral representation showing two covalent and two hydrogen bonds

1

2 hydrogen bonds per molecule

1

Attraction between ions in sodium chloride is very strong

1

Covalent bonds in ice are very strong

1

Hydrogen bonds between water molecules in ice are much weaker

1

Consequently, less energy is required to break the hydrogen bonds in ice to form separate water molecules than to break the ionic bonds in sodium chloride and make separate ions

1

(b)

Mark Range	The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates' QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question **Descriptor** an answer will be expected to meet most of the criteria in the level descriptor
3	– claims supported by an appropriate range of evidence – good use of information or ideas about chemistry, going beyond those given in the question – argument well structured with minimal repetition or irrelevant points

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	– accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling
2	– claims partially supported by evidence – good use of information or ideas about chemistry given in the question but limited beyond this – the argument shows some attempt at structure – the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling
0-1	– valid points but not clearly linked to an argument structure – limited use of information or ideas about chemistry – unstructured – errors in spelling, punctuation and grammar or lack of fluency

4 bonding electron pairs

1

and one lone pair

1

repel as far apart as possible QWC

1

lone pair - bond pair repulsion > bp—bp QWC

1

pushes S-F bonds closer together

1

shape is trigonal bipyramidal with lone pair either axial or equatorial QWC

1

angles <90

1

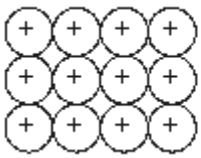
and < 120

1

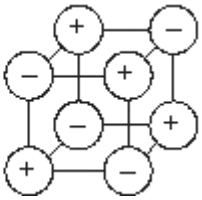
[20]

Q26.

(a)



(1)



(1)

[Diagrams must be complete and accurate]

2

(b) (i) Attraction /electrostatic forces/bonds/attractions between (positive) ions/lattice and delocalised/free electrons/sea of electrons.

[Not metallic bonding]

[Not just 'forces']

1

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(ii) Electrostatic attractions/forces between ions or attractions between (oppositely charged) ions/ Na^+ & Cl^-

[Not ionic bonding]

1

(iii) (Here) the ionic bonding in NaCl is stronger/requires more energy to break than the metallic bonding in Na

QoL Accept 'bonding/forces of attraction in NaCl is stronger than in Na'

[If IMF/molecules/van der Waals'/dipole–dipole mentioned in parts(i) or (ii), then CE = 0 for parts (i) and/or(ii) and CE = 0 for part(iii)]

1

(c) Comparison:
Sodium conducts **and** sodium chloride does NOT conduct

Allow 'only Na conducts'

Accept 'Na conducts, NaCl only conducts when molten'

[Do not accept sodium conducts better than sodium chloride etc.]

1

Explanation:
(Delocalised) electrons flow though the metal

1

Allow e^- move/carry current/are charge carriers/transfer charge.

[Not 'electrons carry electricity']

[Not 'NaCl has no free charged particles']

Ions can't move in solid salt

1

(d) Layers can slide over each other – idea that ions/atoms/particles move

[Not molecules]

[Not layers separate]

1

(e) (i)

Na	Cl	O
$\frac{21.6}{23}$	$\frac{33.3}{35.5}$	$\frac{45.1}{16}$

1

0.9(39)	0.9(38)	2.8(2)
Hence: 1	1	3

Accept backwards calculation, i.e. from formula to % composition, and also accept route via M_r to 23; 35.5; 48, and then to 1:1:3

[If % values incorrectly copied, allow M1 only]

[If any wrong A_r values/atomic numbers used = CE = 0]

1

(ii) $3Cl_2 + 6NaOH \rightarrow 5NaCl + NaClO_3 + 3H_2O$

1

[12]

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Q27.

M1 macromolecule = <u>a giant/massive/huge</u> molecule/lattice/structure with <u>covalent</u> bonding

(in words, not diagram)

(not just 'very large')

(not 'molecules bonded together'/reference to ions)

1

M2 **White**: IMF = van der Waals'

1

M3 which are weak

(tied to 'IMF' or van der Waals' in M2)

(if H-bonding or dipole-dipole, treat as CE, M2 = M3 = 0)

1

M4 **Red**: (covalent) bonds must be <u>broken/overcome</u>

(not weakened / loosened)

1

M5 (covalent) bonds are strong [tied to M4]
Or there are many (covalent) bonds
Or much energy is required to.

1

- If wrong bonding quoted, e.g. ionic bonding in white phosphorus or an IMF in red phosphorus, award no marks for that allotrope.
- In order for marks to be awarded for red phosphorus, the bonding must be stated to be covalent. One reference to covalent bonding is sufficient; the rest may be inferred as shown above. Thus, failure to refer to covalent bonding anywhere would result in the loss of M1, M4 and M5,
- Mark M1 independently. Allow the criteria for this mark to be earned elsewhere, but do not treat errors in the red allotrope description as contradictions of M1.

[5]

Q28.

Structure and hardness

M1

Q of L <u>both</u> macromolecular/giant atomic/giant covalent/giant molecular;

1

M2
C atoms in diamond joined to 4 other C atoms / diagram with min 5 C atoms i.e. shows tetrahedral shape / coordination number = 4;

1

M3
C atoms in graphite joined to 3 other C atoms diagram with clear extended hexagonal plane/pattern i.e. shows trigonal planar shape / coordination number = 3;

1

M4

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diamond hard / crystal strong;
(not diamond stronger than graphite)

1

M5
because of 3-D structure / rigid structure / not layered;

1

M6
graphite (soft) as layer can slide over each other;

1

M7
Q of L as only (weak) van der Waals' forces between layers;

1

Melting point (for either allotrope)

M8
covalent bonds must be broken / overcome;

1

M9
which are strong / many / hard to break;
(M9 tied to M8)

1

Other difference

M10
diamond is non-conductor of electricity, graphite is conductor
OR appropriate difference in appearance;

1

[9]

Q29.

QoL Bonding Both covalent
(linked statement)

1

Structure Iodine = molecular / I_2 *(stated or in diagram)*
[treat incorrect diagram as contradiction]

1

Diamond = giant molecular/macromolecular/giant covalent / giant atomic (stated only)
Reference to van der Waals' /dipole-dipole = contradiction

1

QoL Iodine dipole Weak van der Waals' forces / induced dipole-induced

1

Diamond Covalent bonds would need to be broken

1

Many / strong covalent bonds **OR** much energy needed
Tied to M5 *or near miss*
[If ionic/metallic structure suggested then CE for that substance]

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[If hydrogen bonding suggested, for I_2 lose M2 & M4; for diamond lose M3,M5&M6]

1

[6]

Q30.

C

[1]

Q31.

(a) Hydrogen bonding *(full name)*

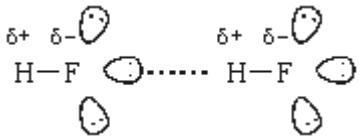
1

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

(If full charges shown, M2 = 0)

1

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



(If atoms not identified, zero for diag)

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

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

1

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

('difference' may be inferred)

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

1

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

1

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

1

(b) NaCl is ionic (lattice)

(Treat atoms/molecules as a contradiction)

(Accept 'cubic lattice')

1

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

(NOT molecular or tetrahedral)

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

1

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

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(NOT just 'weakened' etc.)

('Covalent' may be inferred from diagram)

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

2

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

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

1

[11]

Q32.

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

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

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

OR London, Dispersion, temporary dipole

3

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

OR within molecule

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

(ii) molecular **(1)**

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

OR V.dW forces

OR intermolecular forces

Mention of ions CE=0

4

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

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

OR V.dW

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

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

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

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

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

QL mark (Look for unambiguous statements using correct terminology)

5

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

Strong forces between ions **(1)**

OR lots of energy required to break bonds

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

mention of molecules etc CE=0

3

(e) macromolecular **(1)**

OR giant molecule / lattice or correct diagram

Strong covalent bonds **(1)**

OR lots of energy required to break bonds

2

[17]

Q33.

(a) (i) positive ions **(1)**
(attract) delocalised electrons **(1)** *(or sea of or free or mobile)* **(1)**

Confusion with -ve ions
or ionic lattice C.E. = 0

(ii) more protons **(1)** (or Mg^{2+} more charge than Na^{+})
attracts <u>delocalised</u> (or bonding) electrons more strongly **(1)**
Delocalised: can be brought forward from (a) (i)

OR more delocalised electrons (1)
Attacks positive ions more (1)
<u>Metallic</u> bonding is stronger scores one mark, only given if no other marks awarded

4

(b) macromolecular **(1)** *(or giant molecule etc)*
*covalent **(1)***
*<u>strong</u> covalent <u>bonds</u> **(1)***

or bonds require much energy to break

3

(c) delocalised *(OR free or sea of or mobile) electrons **(1)***

1

(d) Planes **(1)**
weak (bonds) forces between planes **(1)**

2

or v.dw forces between planes

[10]

Q34.

A

[1]

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Q1.

(a) This levels-of-response question discriminated very well, with approximately one third of students scoring marks in each of the three levels. Some excellent answers were seen. Some students, however, answered very well initially but then used wrong terminology, for example wrong bonding and/or intermolecular forces in all/some of the substances, and showed contradictions in their answers.

(b) Unfortunately, the equation was often seen with sodium oxide as the product rather than sodium hydroxide. In the calculation, many students did not use the 2:1 ratio from the equation, leading to an answer of 267 cm^3. However, this part of the question also discriminated well, with over 25% of students gaining full marks; most students scored some marks and less than 3% scored zero.

(c) Just under half of the students (48.5%) gave a correct answer; the commonest error was to multiply the amount, in moles, by volume rather than dividing by volume.

(d) This part discriminated well, though only a few students (7%) scored full marks. The structure often had the wrong number of lone pairs and/or the wrong bond angle. That lone pair-lone pair repulsion is greater than bond pair-bond pair repulsion was known by the majority of students.

Q2.

85.7% of students scored here on this straightforward question about structure and bonding.

Q3.

(a) Students generally scored the mark for the equation (78.8% correct), though some students used P_2 or gave P_2O_5 as the product and lost the mark.

(b) Many students failed to realise that water was all that was required; those students who used water mostly went on to give a correct method for testing the solution.

(c) Most students answered this well, but “simple covalent” was a common incorrect, incomplete answer for sulfur dioxide.

(d) Most students understood that covalent bonds were broken for silicon dioxide and that intermolecular forces were overcome for sulfur trioxide. Some students lost marks because they thought intermolecular forces were also overcome in silicon dioxide. There were only a few examples where students got the type of bonding completely wrong.

(e) Many students struggled with the equation here and gave the products as potassium oxide and sulfuric acid.

(f) Many students found the formula of magnesium phosphate challenging and hence could not write a correct balanced equation. Often, students failed to pick up on the information that magnesium oxide was in excess and gave magnesium hydrogenphosphate as the product.

(g) Many students found this question quite challenging; sulfuric(VI) acid was often thought to be the product. Very few students gave a correct fully displayed formula.

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Q6.

Most candidates scored some marks here but many made chemical errors such as referring to the breaking of bonds when discussing the boiling of bromine or suggesting that magnesium is ionic. Often, the simple molecular structure point was absent for both weak and strong students showing poor exam technique in terms of addressing the question.

Q7.

Usually well answered.

Q8.

Students struggled to explain how van der Waals' forces arise between molecules. Most scored a mark by referring to 'electron movement' but did not go on to explain that a dipole is induced in an adjacent molecule. Many answers were based on the difference in electronegativity. Most students correctly explained the difference in boiling points between methanol and methanethiol and between methaneselenol and methanethiol. On occasions the quality of students' language was poor either stating that boiling results in all bonds breaking or indicating that the O-H bond in methanol was broken. For this reason a statement that the relevant forces act 'between molecules' is necessary to gain credit. Nearly all students answered part (b)(ii) correctly. The shape and bond angles of SF_6 proved a good discriminator. Some students were not able to deduce the correct number of lone pairs around SF_4 and others did not appreciate the effect of the single lone pair on the bond angles. In part (d)(ii) most students were able to deduce NaCl as the missing product but not all were able to balance the equation. Multiples were accepted.

Q9.

In part (a) the trend in ionisation energy was explained well with many scoring three or four marks. Many students did not read the question carefully and explained the anomalies in the trend. Those who lost a mark usually omitted the key word 'outer' in respect of the electron being removed. In part (b) many students correctly identified and explained an element that deviated from the general trend. In part (c) most were able to recognise the large jump after the sixth ionisation energy and deduce the element as sulfur. Most students knew that silicon had the highest melting point and went on to score full marks, although aluminium was a common incorrect answer. The quality of language was not always sufficiently clear and some used chemical terms incorrectly such as covalent bonds between molecules or strong van der Waals forces between atoms.

Q10.

The type of crystal structure was well answered in part (a) and many students correctly explained, in part (b), why silicon dioxide does not conduct electricity. In part (c) many students thought the other product was oxygen and there were several students who had the right products but then failed to balance the equation.

Q11.

The correct answer to the calculation in part (a) was seen regularly, but there were some students who made an attempt at it, gained two or three marks, and then could not complete the calculation. The most common errors were either to ignore the factor of 2 from the equation or multiply by 78 rather than 39. The calculation in part (b) was attempted by almost all students resulting in the full range of marks. The first three marks were regularly seen in students' answers but often this was followed by a failure to multiply by the correct factor from the equation. It was disappointing to note that there

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were still some students who could not rearrange the ideal gas equation correctly. In part (c)(i) many students did not score full marks since they could not convert volume into dm3 and therefore could not give the concentration in mol dm^{-3} as asked for in the question. Many students could not balance the equation in part (c)(ii). Part (d) was well answered although there were some students who thought the azide ion was N^{3-} rather than N^{3-}. The arrow in part (e)(i) was rarely in the right place and it was disappointing to note how many did not use an arrowhead on one of the bonds shown as specified in the question. Part (e)(ii) was not well answered with many students suggesting species that were not molecules; Ti was a common incorrect answer. The whole range of answers was seen in part (e)(iii) but many students were able to identify the correct formula.

Q12.

This question was generally quite well answered. In part (a)(i), most students knew the correct block in the Periodic Table although some seemed to think that the name 'Transition Metals' was enough to identify the d block. In part (a)(ii), the biggest issue was the omission of 'positive' when describing ions and 'delocalised' when describing the electrons involved in the bonding. The diagrams in part (a)(iii) generally scored highly but some were untidy and failed to show a regular arrangement of ions. Surprisingly, many students did not refer to layers of atoms / ions sliding in part (a)(iv) and therefore did not score the mark. Answers to part (b)(i) were disappointing and showed that students could not write the electron configuration of ions in the d block. Balancing the equation proved difficult but a good number of students did this well and many students could suggest a suitable substance in part (b)(ii).

Q13.

Answers to part (a) showed that there are still many students who cannot work out the correct shape of an unknown molecule. The main error was drawing the incorrect number of lone pairs and this led to an incorrect name and angle in the molecules. As always, this type of question discriminated very well. In part (b), many students could not identify the correct type of bonding and, therefore, could not score any marks. Many others who could identify the correct bonding then contradicted themselves by referring to intermolecular forces in the crystalline solid.

Despite the formula TlBr being given, many students could not write a balanced equation in part (c). Many did not realise that bromine is a diatomic molecule and others showed the formation of the product from ions.

Q14.

Part (a) was answered well although a few students lost the mark by simply stating 'giant' or 'giant lattice'. Generally, students did well in part (b), although some forgot to mention a pair or two electrons being shared. Most students scored the mark in part (c) but could not work out the correct empirical formula in part (d).

Q15.

The name in part (a) was generally answered well but the general formula proved more difficult. In the explanation, it was not always clear that the van der Waals' forces were between the molecules. Part (b) was answered well by the majority of students. The main error was including CH_3 in the displayed formula and quoting the molecular formula rather than calculating the empirical formula.

Q16.

The definition of electronegativity in part (a)(i) was poorly answered. Common errors included referring to the power of an element rather than an atom to withdraw electrons and many students did not refer to the type of bond. In part (a)(ii), many students failed to score the second mark suggesting that shielding or atomic radius increased. Quite a number of students could not identify the bonding in part (b) correctly. Many of those who could often then contradicted themselves by referring to molecules or atoms rather than ions.

Many students did not refer to the small difference in electronegativity between the two atoms in part (c). Instead, they opted for the more accessible answer of bonding between two non-metals. Part (d)(i) was not answered as well as expected. Many students did not seem aware of the difference between bonding type and crystal structure. The equation in part (d)(ii) was generally well answered although some students thought that the formula of hydrogen fluoride was H_2F_2. The calculation in part (d)(iii) was generally well answered although some students divided by 8 and 9 and a significant number of students thought that the molecular formula was 2OF.

Q17.

Many students did not state the correct crystal structure of graphene in part (a)(i) and did not realise that the properties of graphite could be applied to graphene in parts (a)(ii) and (iii). Many students thought that the structure was metallic even though the reference to carbon atoms was given in the question. Many students knew about delocalised electrons in part (a)(ii) but then did not recognise that the ability to conduct electricity is because the delocalised electrons can move (or flow) along the crystal plane. Many students in part (a)(iii) thought that the high melting point was due to the breaking of van der Waals' forces. In part (b), there were a lot of students who did not realise that titanium was a metal and hence lost a few marks. The students who realised that titanium was a metal often stated in part (b)(ii) that the strong attraction was between oppositely charged particles. Part(c)(i) was not well answered with many students simply stating that titanium was malleable; this was just a restatement of the question and therefore did not score a mark. Students also found part (c)(ii) difficult to answer with many stating that bonds were not broken or restating the question ie that they have the same shape. The ionic nature of magnesium oxide in part (d) was well answered by most students.

Q18.

Answers to parts (a) and (b)(i) were generally well known. Many students recognised boron as the deviant in part (b)(ii) but some did not read the question and gave the answer oxygen which was outside the range of elements given. There were quite a number of students who thought that the deviant element was beryllium. A few students who identified boron thought that the electron was removed from the 3p orbital. Many students identified the correct element in part (c) but very few correctly showed the melting point of nitrogen in part (d). Part (e) was generally well answered. Most students knew that carbon had covalent bonding and could therefore access all the marks although a few thought that the bonding was ionic or metallic and scored zero.

Q19.

Part (a) was generally answered well although many students did not refer to a shared pair of electrons in the covalent bond. The required number of bond pairs and lone pairs in parts (b)(i) and (ii) were reasonably well known although many students did not appreciate that the lone pairs would repel each other and the bond pairs as far apart as possible and hence lost the marks for the bond angles. Some students incorrectly gave B as the symbol for bromine. The answers to part (c) differentiated well. Weaker students generally scored zero due to chemical errors. Where students identified ionic bonding, marks were lost by not stating oppositely charged ions or by referring to incorrect ions eg K^+ and F^-.

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The type of intermolecular force in part (d)(i) was well known. Weaker students did not know the formula HF in part (d)(ii) and many students lost marks due to careless omissions of the partial charges or the lone pairs. Students generally realised that van der Waals' forces were present in fluorine and hence the boiling point was low. However many answers did not refer to van der Waals' forces acting between molecules and some answers referred incorrectly to the breaking of weak covalent bonds.

Q20.

Part (a) was generally well done with the most common error being to assume ionic bonding showing circles with + and – signs in them. Very few did not show the required minimum of 6 particles. The type of bonding in sodium chloride was well known in part (b) and the explanation was answered well by a large number of candidates.

Part (c) proved more difficult and only the more able candidates were able to give a correct answer. Weaker candidates did not refer to the halide ions at all and some referred to electronegativity.

Q21.

Answers to part (a) were variable. Many candidates thought that graphite was metallic rather than macromolecular and many did not refer to iodine as being molecular. In part (b) answers were often muddled. Some candidates thought that the layers in graphite were held together by electrostatic forces between positively charged layers and delocalised electrons. Some thought graphite contained hydrogen bonding rather than van der Waals forces. This question was simply recall of knowledge and it was surprising how many candidates could not answer it correctly. The answers to part (c) often contained reference to covalent bonds being broken. Part (d) was generally answered well.

Q22.

Candidates answered part (a) well with only a few losing marks for simply referring to 'hydrogen' or 'dipole bonds'. Part (b) was done well by many candidates. Weaker candidates did not show hydrogen bonds from the lone pair. There were a number of recurring errors including water as HO_2, partial charges missing or the wrong way round. Part (c) was generally answered well with candidates relating their answers to comparisons between IMF's. Candidates found part (d) more challenging and there were several answers in terms of the greater attraction between the outer electrons and the protons in the nucleus or electronegativity differences. Part (e) was generally well answered with candidates knowing the type of bonding and making an attempt at the explanation. Marks were lost for general descriptions of dative covalent bonding rather than referring specifically to the species given in the question. The type of bonding in part (f) proved a good discriminator. Although many candidates gave the correct type of bond, weaker ones suggested covalent or metallic bonds. The explanation also proved more difficult. Many lost marks for breaking IMF's as well as, or instead of, ionic bonds. Candidates who knew about strong electrostatic attractions often failed to say that this was between oppositely charged ions.

Q23.

The electronic configuration in part (a) was generally well known. In part (b)(i) the removal of 2 electrons from the neutral atom was a common incorrect answer and in (b)(ii) many candidates missed the effect of change of shielding. Often candidates referred to s and p orbitals with no reference to the number of the principal energy level. Part (b)(iii) was disappointing and showed that many candidates find it difficult to apply concepts to different situations. Part (c) was generally well known although many candidates did not

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score the second explanation mark. In part (d) many candidates did not realise that metallic bonding, or an explanation of it, was required in the answer. Many thought that van der Waals forces were involved or mentioned losing electrons causing ionisation. In part (e) there were many unclear diagrams and many candidates had the wrong number of lone pairs of electrons. Answers to the shape of the molecule were often incorrect or contradictory e.g. bent-linear. Part (f) was well answered.

Q24.

Many candidates produced good answers here but it must be stressed that the definition of relative atomic mass must be absolutely correct for the award of both marks. Many candidates left out 'average' mass or the factor of 12.

Having to find the RAM of one of the isotopes challenged many of those who were unable to manipulate the equation but candidates regularly scored the first two marks and only lost the third calculation mark due to lack of dexterity with rearranging and algebra. The idea of isotopes having the same electron arrangement was generally well known although lots of answers included references to protons and/or neutrons.

Part (b) was well answered with the most common error being the confusion of electric and magnetic field. The processes were very well known. In part (c) there was confusion over metallic and ionic bonding. In part (d) most candidates had the idea of a 3D lattice but errors arose from multiple charges or negative charges on the Ag or like charges next to each other at some point in the lattice. Most candidates realised that ionic bonding was present, but some then contradicted their answers by mentioning intermolecular forces.

Q26.

In a surprisingly large proportion of instances, the diagrams were either left blank or were incomplete. Of those candidates who did attempt part (a), most coped well but it was not unusual for the diagram of sodium metal to contain negative charges, or for the sodium chloride diagram to show the same change on adjacent ions. Many of the explanations in part (b) were poorly done. Frequently, the answers to parts (b)(i) and (b)(ii) lacked any reference to the attraction between the relevant species. The most common answer to part (b)(iii) was to state that *ionic bonding is stronger than metallic bonding,* as if this were a universal truth, rather than deducing that this comparison was true in this case. In part (c), candidates frequently referred to sodium being a better conductor that sodium chloride; although some did then go on to clarify matters by explaining that sodium chloride would only conduct when molten. It was very common to see references to *covalent bonds, van der Waals', dipole-dipole* and *intermolecular forces* in this question. In part (c), some good explanations were seen but, all too often, they were vague and incomplete. Many candidates were aware of the importance of delocalised electrons to the conductivity of sodium; however, relatively few described them flowing though the metal. The lack of conductivity of sodium chloride was often ascribed to there being no *free electrons* in the salt. Also, a significant minority of candidates simply referred to the presence or absence of *charge carriers,* without identifying them. Very few candidates explained the lack of conductivity of solid sodium chloride in terms of its immobile ions. Parts (d) and (e) were comparatively well answered, although the malleability of sodium being was sometimes attributed to the presence of *weak intermolecular forces.* The empirical formula calculation was usually accurately calculated and the equation correctly balanced.

Q27.

This question proved to be rather testing. While many candidates coped well with it, others struggled badly. The explanations offered for the meaning of the term *macromolecular* varied widely, with many answers failing to emphasise size or to identify

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the bonding present. Some candidates simply quoted another macromolecular substance, such as diamond. Some candidates were able to apply their understanding of the high melting points of such substances as diamond and silicon to red phosphorus and so offered sound explanations. However, references to the presence of intermolecular forces in red phosphorus, or to hydrogen bonding or dipole-dipole attraction in white phosphorus were quite common. In some instances, the covalent bonds in red phosphorus were said to be strong but no clear statement of the need for these bonds to be broken was made, and so credit was not given. Some candidates made vague references to bonds being *loosened* or *weakened*, rather than broken, while others based their arguments on the need to break more covalent bonds in red phosphorus compared to white phosphorus. Many references to *molecules* being bonded together in red phosphorus were seen. Some explanations made no reference at all to phosphorus but simply dealt with the high melting points of diamond and graphite.

Q28.

Although some clear, concise and structured answers were seen, many were rambling and repetitive. In some instances a statement made towards the end of an answer contradicted a credit worthy point made earlier, and the mark was lost. Most candidates earned some marks in this question, however, very high marks were quite rare and very few candidates earned full marks. In many cases, errors were errors of omission rather than of commission, with the macromolecular nature of both allotropes, the rigidity of the diamond lattice and the presence of van der Waals' forces between the graphite layers being the points most frequently overlooked. A large minority of candidates referred to *molecules* of either or both of the allotropes. Diamond was frequently described as having intermolecular forces, and hydrogen bonding was also often seen, more often, but not exclusively, with respect to graphite. Most candidates were aware that a large amount of energy is required to break covalent bonds, but those who stated this without relating their answer to the high melting points of the materials did not earn the marks available. A large proportion of candidates drew diagrams to support their description of the structures present. The diagrams for diamond, although rarely pretty, tended to show the tetrahedral arrangement of bonds reasonably clearly. Some of the diagrams for graphite were restricted to a single ring and so not able to show the manner in which the rings are joined together. Also, the structure of graphite was frequently drawn showing a series of hexagons joining tip to tip, giving four bonds on some carbon atoms. Many candidates wasted a considerable amount of time explaining the difference in electrical conductivity of the two allotropes. The question simply asked for a one other difference to be given. No explanation was asked for, and so no marks were allocated to the explanation, no matter how convincing it might be.

Q29.

Part (a) was well answered by many candidates but it was quite common for the bonding in both substances to described as ionic, or for intermolecular forces, van der Waals' forces or even hydrogen bonding to be quoted in relation to the bonding in diamond. In some cases, marks were lost because statements such as these contradicted other correct statements made by candidates.

Q31.

Many very good answers were seen to this question and high marks were quite common. Many clear and accurate diagrams were seen; however, diagrams showing just one HF molecule, or showing less than three lone pairs on the fluorine were reasonably common. Dipoles were not always correctly shown and hydrogen bonds were not always drawn between a lone pair on a fluorine atom and the hydrogen atom. Occasionally, lone pairs were shown on hydrogen atoms. The explanation of the absence of hydrogen bonding in

HI was reasonably well known but some answers were rather vague. As the question dealt with the variation in the intermolecular forces present in the hydrogen halides, an understanding that these forces are determined by the magnitude of the difference in electronegativity present in the molecule was expected. Thus, a comparison of the electronegativity differences present in the two compounds was required if full marks were to be awarded. Such a comparison was quite frequently lacking. In part (b), contradictions abounded. Many candidates lost marks through careless use of language, where *ionic/covalent/ molecular/macromolecular* were used indiscriminately. Intermolecular attractions were stated to exist in ionic sodium chloride, while van der Waals' forces often appeared in discussions of the diamond structure. Rather than referring to the large amount of energy required to *break* the covalent bonds in diamond, words such as *disturb* or *weaken* were frequently used and earned no credit.

Q32.

This question discriminated very effectively between good and weak candidates. Answers given by the latter were often imprecise, contradictory and incomplete. In part (a) ionic and covalent bonding were surprisingly frequent incorrect answers. Many answers to part (b)(i) did not display a clear understanding of the distinction between the covalent intramolecular bonds and the van der Waals' intermolecular bonding in iodine. In part (b)(ii) the iodine crystal was often described as ionic even when ionic bonding was not mentioned in the previous part. In part (b)(iii) candidates frequently suggested incorrectly that covalent bonds between iodine atoms must be broken. In part (c)(i) most candidates gained one mark for mentioning hydrogen bonds but few drew a comparison between those bonds and the weaker intermolecular forces in hydrogen chloride. In part (c)(ii) many candidates did not answer the question. They referred to iodine and chlorine rather than to hydrogen iodide and hydrogen chloride. Marks were lost frequently in part (d) because sodium chloride molecules were mentioned, particularly in part (d)(ii). In part (e), despite reference in the question to structure and bonding many candidates did not mention the macromolecular structure of graphite.

Q33.

This question was answered well by the majority of candidates. Common errors or misconceptions were limited to parts (a)(i) and (ii). Here it was not uncommon for candidates to be confused between metallic and ionic bonding.

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