Q1.

This question is about Period 3 elements and their compounds.

(a) Which is **not** a correct statement about magnesium hydroxide?

Tick (✓) **one** box.

It is used to neutralise stomach acid	☐
It forms a solution with pH = 14 at 25 °C	☐
It has the empirical formula H_2MgO_2	☐

(1)

(b) Give an equation for the reaction of aluminium oxide with sulfuric acid.

_____

(1)

(c) Identify a reagent or test that could be used to distinguish between aqueous solutions of sulfur dioxide and sulfur trioxide with the same concentrations.

State the observation in each case.

Reagent or test _____

Observation with sulfur dioxide solution _____

_____

Observation with sulfur trioxide solution _____

_____

(3)

(d) The mass spectrum of the element phosphorus has a peak at $\frac{m}{z} = 124$

Give the formula of the species responsible for this peak.

_____

(2)

(e) Give an equation for the reaction of phosphorus(V) oxide with sodium hydroxide solution.

_____

(1)

(f) Draw the displayed formula of the molecule formed when phosphorus(V) oxide reacts with water.

(1)

(g) The table below shows the melting points of three substances.

Substance	Melting point / K
sodium chloride	1074
chlorine	172
hydrogen chloride	158

Explain why the melting points of these substances are different.

You should refer to the structure of and bonding in each substance.

(6)

(Total 15 marks)

Q2.

This question is about magnesium and its compounds.

(a) State **one** observation when magnesium reacts with steam.

Give an equation, including state symbols, for this reaction.

Observation _____

_____

Equation

_____

(2)

(b) Describe the bonding in magnesium.

_____

_____

_____

_____

(2)

(c) Explain, in terms of structure and bonding, why magnesium chloride has a high melting point.

_____

_____

_____

_____

_____

_____

(3)

(d) Give **one** medical use for magnesium hydroxide.

_____

_____

(1)

(Total 8 marks)

Q3.

Which substance contains delocalised electrons?

A cyclohexane ⬭

B graphite ⬭

C iodine ⬭

D sodium chloride ⬭

(Total 1 mark)

Q4.

Which has a bond angle of 109.5°?

A C (diamond) ⬭

B C (graphite) ⬭

C NH_2^- ⬭

D NH_3 ⬭

(Total 1 mark)

Q5.

This question is about compounds that contain fluorine.

(a) Sodium fluoride contains sodium ions (Na^+) and fluoride ions (F^-).
Na^+ and F^- have the same electron configuration.

Explain why a fluoride ion is larger than a sodium ion.

_____

_____

_____

_____

_____

_____

(2)

(b) Explain, in terms of structure and bonding, why the melting point of sodium fluoride is high.

(2)

(c) The ion H_2F^+ is formed when hydrogen fluoride gains a proton as shown in the equation

$$HF + H^+ \rightarrow H_2F^+$$

Name the type of bond formed when HF reacts with H^+
Explain how this bond is formed.

Type of bond _____

Explanation _____

(2)

(d) Fluoroantimonic acid contains two ions, SbF_6^- and H_2F^+

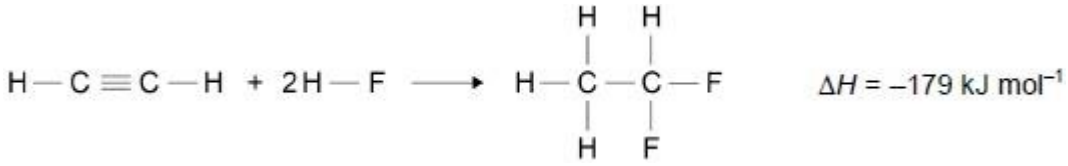
Draw the shape of the SbF_6^- ion and the shape of the H_2F^+ ion. Include any lone pairs that influence the shape.

Name the shape of each ion.

	SbF_6^-	H_2F^+
Shape		
Name of shape		

(4)

(e) Hydrogen fluoride reacts with ethyne (C_2H_2) as shown in the equation. All compounds are in the gaseous state.



The table shows some mean bond enthalpy data.

Bond	C–H	C≡C	H–F	C–C
Mean bond enthalpy / kJ mol^{-1}	412	837	562	348

Use the data in the table above to calculate a value for the bond enthalpy of a C–F bond in the product.

C–F bond enthalpy _____ kJ mol^{-1}

(3)

(Total 13 marks)

Q6.

Which substance has delocalised electrons?

A graphite ⬭

B iodine ⬭

C sodium chloride ⬭

D tetrachloromethane ⬭

(Total 1 mark)

Q7.

Which change occurs when water is vaporised?

A An exothermic change occurs. ⬭

B Covalent bonds are broken. ⬭

C Intermolecular forces are overcome. ⬭

D The total energy of the molecules decreases. ⬭

(Total 1 mark)

Q8.

This question is about structure and bonding.

(a) Draw a diagram to show the strongest type of interaction between two molecules of ethanol (C_2H_5OH) in the liquid phase.

Include all lone pairs and partial charges in your diagram.

(3)

(c) Methoxymethane (CH_3OCH_3) is an isomer of ethanol.

The table shows the boiling points of ethanol and methoxymethane.

Compound	Boiling point / °C
ethanol	78
methoxymethane	−24

In terms of the intermolecular forces involved, explain the difference in boiling points.

(3)

(c) Draw the shape of the $POCl_3$ molecule and the shape of the ClF_4^- ion.
Include any lone pairs of electrons that influence the shapes.

In a $POCl_3$ molecule the oxygen atom is attached to the phosphorus atom by a double bond that uses two electrons from phosphorus.

Name each shape.

Suggest a value for the bond angle in ClF_4^-

Shape of $POCl_3$ Shape of ClF_4^-

Name of shape of $POCl_3$ _____

Name of shape of ClF_4^- _____

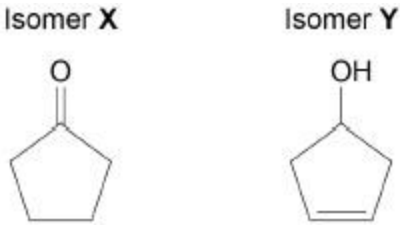
Bond angle in ClF_4^- _____

(5)

(Total 11 marks)

Q9.

Isomers **X** and **Y** have the molecular formula C_5H_8O



(a) Give the IUPAC name for isomer **X**.

_____

(1)

(b) Explain how and why isomers **X** and **Y** can be distinguished by comparing **each** of their

- boiling points
- ^{13}C NMR spectra
- infrared spectra.

Use data from Tables **A** and **C** in the Data Booklet in your answer.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(Total 7 marks)

Q10.

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.

Predict the bond angle.
Justify your prediction.

Shape

Bond angle _____

Justification _____

_____

(4)

(Total 17 marks)

Mark schemes

Q1.

(a) forms a solution with pH = 14 at 25°C

auto

1

(b) $Al_2O_3 + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2O$

allow multiples

ignore state symbols

1

(c) universal indicator

1

SO_2(aq) orange-red

1

SO_3(aq) red

1

allow correct comparison of acidic colours (red, orange, yellow)

or

pH meter
SO_2(aq) pH 2-3
SO_3(aq) pH 0-1

allow correct comparison of acidic pH ignoring values

or

any named metal carbonate (**or** formula) **or** Mg **or** Ca **or** Zn
SO_2(aq) slower effervescence
SO_3(aq) faster effervescence

if reagent is incomplete lose M1 and mark on

allow observation
allow correct comparison

allow named oxidising agent
*eg (acidified) $KMnO_4$ **or** (acidified) $K_2Cr_2O_7$*
SO_2(aq) correct colour acidified change
*SO_3(aq) no visible change **or** NVC*

allow (acidified) barium chloride solution
***or** allow (acidified) barium chloride solution*
*SO_2(aq) no visible change **or** NVC*
SO_3(aq) white precipitate

(d) $^{31}P_4^+$

Allow P_4^+ = 1 mark

Allow ^{31}P = 1 mark

2

(e) $P_4O_{10} + 12\ NaOH \rightarrow 4\ Na_3PO_4 + 6\ H_2O$

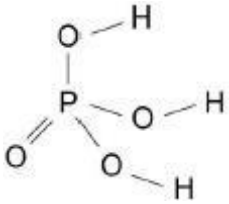
allow formation of acid salts

$P_4O_{10} + 4\ NaOH + 2\ H_2O \rightarrow 4\ NaH_2PO_4$

$P_4O_{10} + 8\ NaOH \rightarrow 4\ Na_2HPO_4 + 2\ H_2O$

1

(f)



must show all bonds

1

(g) 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 **5-6 marks**	All stages are covered and the description 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 stage 3.
Level 2 **3-4 marks**	All stages are covered but the description 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 2 and/or stage 3.
Level 1 **1-2 marks**	Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete. Answer includes isolated statements and these are presented in a logical order.
0 marks	Insufficient correct chemistry to gain a mark.

indicative chemistry content

contradictions negate statements

Stage 1 **structure**

1a NaCl ionic lattice **or** giant ionic

1b Cl_2 **and** HCl molecular (covalent)
or
Cl_2 **and** HCl (simple) molecules

Stage 2 **forces responsible for melting point**

2a NaCl attractions between + and – ions

2b Cl_2 vdw forces

2c HCl dipole dipole forces

Stage 3 **comparison of melting point**

3a ionic bonds stronger than IMF

3b chlorine/Cl_2 is a bigger (molecule) than HCl
or
chlorine/Cl_2 has more electrons than HCl

3c more/stronger forces between molecules in Cl_2 than those in HCl
or
more/stronger IMF in Cl_2 than those in HCl
or
vdw between molecules in Cl_2 > dipole dipole between molecules in HCl

[15]

Q2.

(a) Bright light / white light / white powder/ash/solid

1

$Mg(s) + H_2O(g) \rightarrow MgO(s) + H_2(g)$

State symbols essential

1

(b) M1: Attraction between (lattice of) Mg^{2+} ions

M1 attraction between nucleus and delocalised electrons or between + ions and delocalised electrons

1

M2: And delocalised electrons

M2 outer shell electrons delocalised

1

(c) (Giant) ionic lattice / lots of Mg^{2+} and Cl^- ions

1

Strong (electrostatic) forces of attraction

1

Between Mg^{2+} and Cl^- ions

Allow oppositely charged ions

1

(d) Indigestion relief / laxative / neutralise (excess stomach) acid

Allow milk of magnesia

1

[8]

Q3.

B

graphite

[1]

Q4.

A

[1]

Q5.

(a) Fluoride ion has (two) fewer protons/lower nuclear charge

Do not allow fluorine, but allow fluorine ion.

Any reference to different numbers of electrons in the ions loses M1

1

Weaker attraction between nucleus and (outer) electrons

Allow answers in terms of sodium ion but must be explicit.

Ignore references to atomic radius

1

(b) (Electrostatic) forces of attraction between oppositely charged ions/Na^+ and F^-

Mention of IMF, covalent, macromolecular, metallic, electronegativity of ions loses both marks

1

Lots of energy needed to overcome/break forces

Allow strong ionic bonding

Allow strong forces/bonds of attraction (need to be broken)

1

(c) Type of Bond: Coordinate bond / dative (covalent) bond

If just covalent, then do not award M1 but mark on

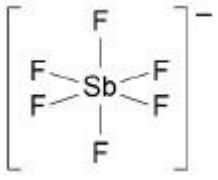
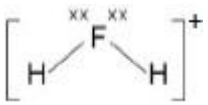
1

Explanation: A (lone) pair of electrons is donated from F

Allow both electrons (in the shared pair) come from F

1

(d)

Shape		
Name of shape	Octahedral	Bent / V-shaped / angular

Lone pairs on H_2F^+ are essential (can be shown in lobes)

Ignore missing charges

Mark independently

4

(e) ΔH = ΣΔH(Bonds broken) - ΣΔH(Bonds Formed)

Allow M1 if 2785 and 1996 seen (or allow M1 if 1961 and 1172 seen)

-179 = 2(412) + 837 + 2(562) – [348 + 4(412) + 2(C—F)]

1

-179 = 2785 – (1996 +2(C—F))

2(C—F) = 968

M3 consequential on any M2 if it is clear that M2 is for 2(C-F)

1

C—F = 484

-484 scores 2

1

[13]

Q6.

A

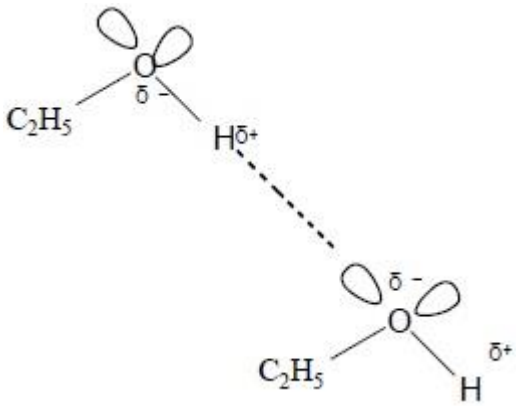
[1]

Q7.

C

[1]

Q8.



M1 *two lone pairs on each O atom*
and
δ+ and δ- on each H-O bond

1

M2 *dotted/broken line shown between lone pair on one molecule and the correct H on another*

1

M3 *O·····H–O in straight line, dependent on* ***M2***
Ignore any partial charges on C–H or C–O bonds
For straight line in ***M3****, allow a deviation of up to 15°*

1

If a different molecule containing hydrogen bonding due to O–H bond drawn (e.g. methanol, water) or an incorrect attempt at the structure of ethanol, then maximum of 2 marks (i.e. only penalise if would score all three marks otherwise)

(b) Hydrogen bonds (between ethanol molecules)

1

(permanent) dipole-dipole OR van der Waals force (between methoxymethane molecules)

Allow vdW

1

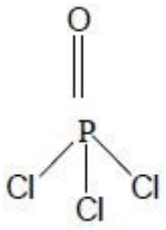
Hydrogen bonds are stronger/est intermolecular force

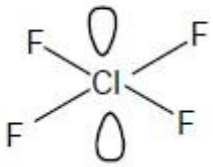
Allow more energy to break/overcome hydrogen bonding

Allow converse arguments

1

(c)





$POCl_3$: allow any shape showing 1 double bond between P and O and 3 P-Cl bonds

1

ClF_4^-: allow any shape showing 4 Cl⁻F bonds and 2 lone pairs

1

(distorted) Tetrahedral

1

Square planar

1

90°

1

[11]

Q9.

(a) Cyclopentanone

Allow cyclopentan -1-one but no other numbers

Ignore spaces, commas and hyphens

1

(b)

This question is marked using Levels of Response. Refer to the Mark Scheme Instructions for Examiners for guidance.	
Level 3	**All stages are covered and each stage is generally**

5-6 marks	**correct and virtually complete.** Answer is well structured with no repetition or irrelevant points. Accurate and clear expression of ideas with no errors in use of technical terms.
Level 2 **3-4 marks**	**All stages are covered but stage(s) may be incomplete or may contain inaccuracies OR two stages are covered and are generally correct and virtually complete.** Answer shows some attempt at structure Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. Some minor errors in use of technical terms
Level 1 **1-2 marks**	**Two stages are covered but stage(s) may be incomplete or may contain inaccuracies OR only one stage is covered but is generally correct and virtually complete.** Answer includes isolated statements and these are presented in a logical order. Answer may contain valid points which are not clearly linked. Errors in the use of technical terms.
0 marks	Insufficient correct chemistry to gain a mark.

Indicative Chemistry content

Stage 1: boiling points
1a) **Y** has a higher bp
1b) **Y** has H-bonds between molecules and **X** has dip-dip imf
1c) More energy required to overcome H-bonds

Mention of covalent bond breaking loses 1c

Stage 2: ^{13}C NMR
2a) Both have 3 peaks/absorptions in their ^{13}C NMR
2b) **X** has peaks at 20-50 **OR** 190-220ppm
2c) **Y** has peaks at 50-90 **OR** 90-150ppm

(Ignore peaks at 5-40ppm - present in both)

Stage 3: ir
3a) **X** has a peak (for C=O) at 1680-1750 cm^{-1}
3b) **Y** has peak (for O−H) at 3230-3550 cm^{-1}
OR peak (for C=C) at 1620-1680 cm^{-1}
3c) They would have different fingerprint regions (below 1500 cm^{-1})

6

[7]

Q10.

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
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

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

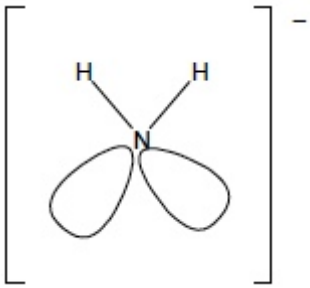
1

(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]