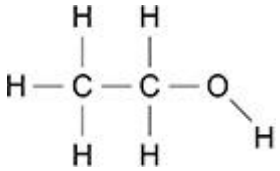
Q1.

This question is about intermolecular forces.

(a) Complete the diagram to show how one molecule of ammonia can form a hydrogen bond with one molecule of ethanol.
Include all lone pairs of electrons and partial charges on atoms involved in the hydrogen bond.



(3)

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

Atom	H	C	N	O	Br
Electronegativity	2.1	2.5	3.0	3.5	2.8

(b) Define the term electronegativity.

_____

_____

_____

(1)

(c) Deduce the **two** atoms from the table above that will form the most polar bond.

_____

(1)

(d) The C–Br bond is polar.

Explain why CBr_4 is **not** a polar molecule.

_____

_____

_____

_____

(2)

(e) Suggest, in terms of the intermolecular forces for each compound, why CBr_4 has a higher boiling point than $CHBr_3$

_____

_____

_____

_____

_____

_____

(3)

(Total 10 marks)

Q2.

Which bond has the most unsymmetrical electron distribution?

A H–O ⬭

B H–S ⬭

C H–N ⬭

D H–P ⬭

(Total 1 mark)

Q3.

Which species contains bonds that have different polarities?

A NH_4^+ ⬭

B CCl_4 ⬭

C CH_3Cl ⬭

D H_3O^+ ⬭

(Total 1 mark)

Q4.

Which molecule has a permanent dipole?

A CF_4 ⬭

B PCl_5 ⬭

C CO_2 ⬭

D Cl_2O ⬭

(Total 1 mark)

Q5.

This question is about 1-chloropropane.

(a) Define the term standard enthalpy of formation.

_____

_____

_____

_____

(2)

(b) The equation for a reaction used to manufacture 1-chloropropane is

$$3\ CH_3CH_2CH_2OH(l) + PCl_3(l) \rightarrow 3\ CH_3CH_2CH_2Cl(l) + H_3PO_3(s)$$

The enthalpy change for this reaction, ΔH, is –114 kJ mol^{-1}

The table contains some standard enthalpy of formation data.

Substance	$PCl_3(l)$	$CH_3CH_2CH_2Cl(l)$	$H_3PO_3(s)$
$\Delta f H^{\ominus}$ / kJ mol^{-1}	–339	–130	–972

Calculate a value for the standard enthalpy of formation of propan-1-ol using the enthalpy change for the reaction and data from the table.

Standard enthalpy of formation _____ kJ mol^{-1}

(3)

(c) 1-chloropropane can also be produced by the reaction between propane and chlorine in the presence of ultraviolet light.

State why ultraviolet light is needed for this reaction to occur.

Give an equation for each propagation step in the formation of 1-chloropropane from propane.

Why ultraviolet light is needed _____

_____

_____

Propagation step 1 _____

_____

Propagation step 2 _____

_____

(3)

(d) The C–Cl bond in 1-chloropropane is polar because carbon and chlorine have different electronegativities.

Define the term electronegativity.

_____

_____

_____

(1)

(e) Ammonia reacts with 1-chloropropane to form propylamine.

Name and outline the mechanism for this reaction.

Name of mechanism _____

Outline of mechanism

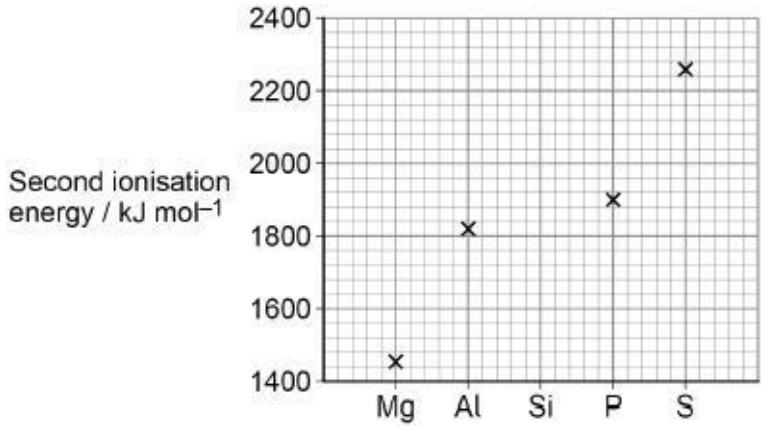
(5)

(Total 14 marks)

Q6.

This question is about Period 3 elements.

The graph shows the **second** ionisation energies of some elements in Period 3.



(a) Draw a cross (x) on the graph above to show the **second** ionisation energy of silicon.

(1)

(b) Identify the element in Period 3, from sodium to argon, that has the highest **second** ionisation energy.

Give an equation, including state symbols, to show the process that occurs when the **second** ionisation energy of this element is measured.

If you were unable to identify the element you may use the symbol **Q** in your equation.

Element _____

Equation

_____

(2)

(c) Explain why the atomic radius decreases across Period 3, from sodium to chlorine.

_____

_____

_____

_____

(2)

(d) Identify the element in Period 3, from sodium to chlorine, that has the highest electronegativity.

_____

(1)

(e) Phosphorus burns in air to form phosphorus(V) oxide.
Give an equation for this reaction.

_____

(1)

(Total 7 marks)

Q7.

The melting point of XeF_4 is higher than the melting point of PF_3

Explain why the melting points of these two compounds are different.

In your answer you should give the shape of each molecule, explain why each molecule has that shape and how the shape influences the forces that affect the melting point.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(Total 6 marks)

Q8.

This question is about 2-bromopropane.

(a) Define the term electronegativity.

Explain the polarity of the C–Br bond in 2-bromopropane.

Electronegativity _____

_____

_____

Explanation _____

_____

_____

(3)

(b) Outline the mechanism for the reaction of 2-bromopropane with an **excess of ammonia**.

(4)

(c) Draw the skeletal formula of the main organic species formed in the reaction between a **large excess of 2-bromopropane** and ammonia.

Give a use for the organic product.

Skeletal formula

Use _____

(2)

(Total 9 marks)

Q9.

Methanol (CH_3OH) is an important alcohol with many uses.

(a) Draw a diagram to show how two methanol molecules interact with each other through hydrogen bonding in the liquid phase.

Include all partial charges and all lone pairs of electrons in your diagram.

(3)

(b) The bond angle around the oxygen atom in methanol is slightly smaller than the regular tetrahedral angle of 109.5°

Explain why this bond angle is smaller than 109.5°

_____

_____

_____

_____

(1)

(c) Methanol is made by the reaction of carbon monoxide with hydrogen.

$$CO + 2\ H_2 \rightleftharpoons CH_3OH \qquad \Delta H = -91\ kJ\ mol^{-1}$$

The reaction uses a copper-based catalyst, a pressure of 10 MPa and a temperature of 550 K

These conditions are used to provide a balance between equilibrium yield, reaction rate and cost.

Describe how the use of a catalyst, and changes in pressure and temperature, each affect equilibrium yield, reaction rate and cost.

(6)

(Total 10 marks)

Q10.

This question is about periodicity, the Period 4 elements and their compounds.

(a) State the meaning of the term periodicity.

(1)

(b) Identify the element in Period 4 with the highest electronegativity value.

_____

(1)

(c) Identify the element in Period 4 with the largest atomic radius.

Explain your answer.

Element _____

Explanation _____

_____

_____

_____

(3)

(d) The equations for two reactions of arsenic(III) oxide are shown.

$$As_2O_3 + 6\ HCl \rightarrow 2\ AsCl_3 + 3\ H_2O$$

$$As_2O_3 + 6\ NaOH \rightarrow 2\ Na_3AsO_3 + 3\ H_2O$$

Name the property of arsenic(III) oxide that describes its ability to react in these two ways.

_____

(1)

(e) Complete the equation for the formation of arsenic hydride.

As_2O_3 + Zn + $HNO_3 \rightarrow$ AsH_3 + $Zn(NO_3)_2$ + H_2O

(1)

(Total 7 marks)

Q11.

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

Isomer **X**

Isomer **Y**

(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.

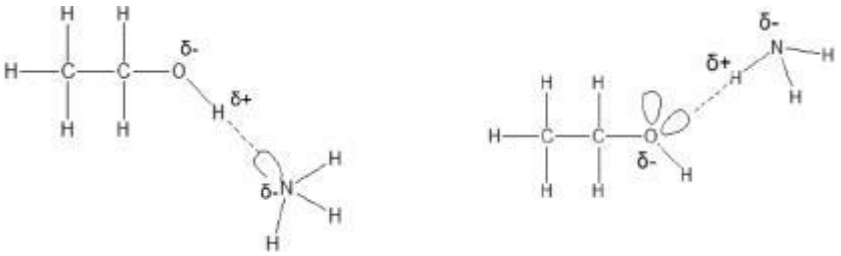
(6)

(Total 7 marks)

Mark schemes

Q1.

(a)



M1 – lone pairs and partial charges (δ−, δ+, δ−) on atoms involved in the hydrogen bond

1

M2 – dotted line between lone pair on N/O to correct H

1

M3 – linear O–H·····N / linear N–H···O

1

Ignore partial charges on C-H

(b) The (relative) tendency of an atom to attract a pair of electrons/ the electrons/ electron density in a covalent bond

Allow

Nucleus instead of atom

Power of an atom to attract a bonding/shared pair of electrons

Power of an atom to withdraw electron density from a covalent bond

Not lone pair / element

1

(c) H and O

O−H

1

(d) M1 the molecule is completely symmetrical / the molecule is tetrahedral / there is an even distribution of electron density

1

M2 the dipoles cancel out

1

Do not allow

The polar bonds cancel out / no dipole moment / partial charges cancel

(e) M1 CBr_4 has van der Waals' forces between molecules

1

M2 $CHBr_3$ has van der Waals' forces and dipole-dipole intermolecular forces

1

M3 The van der Waals' between CBr_4 molecules are stronger than the dipole-dipole and van der Waals' forces between $CHBr_3$ (because it has a larger mass/more electrons/larger electron cloud)
OR
The intermolecular forces between CBr_4 molecules are stronger than the intermolecular forces between $CHBr_3$

M3 cannot be awarded if mention of breaking bonds

1

[10]

Q2.

A

H–O

[1]

Q3.

C

CH_3Cl

[1]

Q4.

D

Cl_2O

[1]

Q5.

(a) **M1** The enthalpy / heat energy change when 1 mol (of a substance / compound / product) is formed from its (constituent) elements

***M1** energy change is not sufficient – must refer to enthalpy change or heat energy change*

1

M2 with (all) reactants and products / all substances in standard states

***M2** or with (all) reactants and products / substances in normal states under standard conditions / 100 kPa and any specified temperature (usually 298 K)*

Ignore reference to 1 atmosphere

*If enthalpy of combustion given rather than formation, then mark **M1** and **M2** independently, and **M2** could score.*

1

(b) **M1** ΔH = [sum $\Delta_f H$ products] – [sum $\Delta_f H$ reactants]

or –114 = [3(–130) – 972] – [3X – 339]

or 3X = 3(–130) – 972 + 339 + 114

–303 scores 3 marks (+303 scores 2 marks)

–909 scores 2 marks (+909 scores 1 mark)

ignore units

1

M2 3X = –909

***M2** No ECF from **M1** (except +909 or arithmetic error)*

1

M3 X = –303 (kJ mol^{-1})

***M3** ECF from **M2**, ie **M3** ÷ 3*

1

(c) **M1** provides energy to break (covalent) bond in chlorine / Cl_2 or to form chlorine free radicals

1

M2 $CH_3CH_2CH_3 + \bullet Cl \rightarrow \bullet CH_2CH_2CH_3 + HCl$

1

M3 $\bullet CH_2CH_2CH_3 + Cl_2 \rightarrow ClCH_2CH_2CH_3 + \bullet Cl$

***M2** and **M3**:*

- *must show structure of $\bullet CH_2CH_2CH_3$ in at least one of the equations to score both marks (dot must be on or around the end CH_2 group), but only penalise $\bullet C_3H_7$ once across both equations if both equations otherwise correct*
- *on this occasion, molecular formula of propane can be allowed for **M2***
- *on this occasion, molecular formula of 1-chloropropane can be allowed for **M3***
- *penalise absence of radical dots once*
- *allow equations in either order*

1

(d) the ability/power of atom to attract/withdraw the 2/pair of electrons in a covalent bond

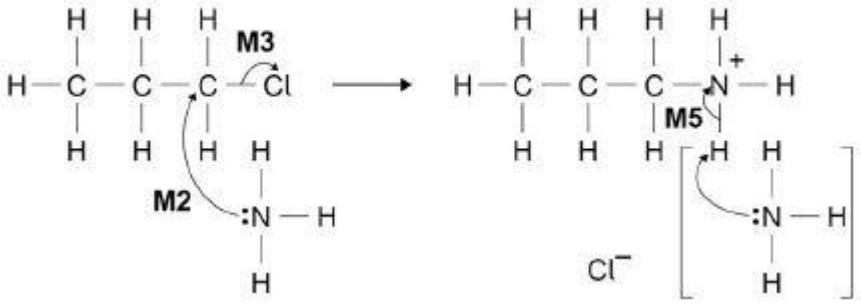
allow nucleus in place of atom

1

(e) **M1** nucleophilic substitution

1

M4 Structure



M2 curly arrow from lone pair on N of NH_3 to the correct C atom

*Penalise **M2** if negative charge on ammonia*

1

M3 must show the movement of a pair of electrons from the C−Cl bond to the Cl atom;

mark **M3** independently provided it is from <u>their original molecule</u>

*Penalise **M3** for formal charge on C and/or Cl of C–Cl or incorrect partial charges on C–Cl; ignore other partial charges on uncharged atoms*

*Penalise **M3** for any additional arrow(s) to/from the Cl to/from anything else*

1

M4 is for the structure of the alkylammonium ion, which could be a condensed formula; a positive charge must be shown on, or close to, the N atom

1

M5 is for an arrow from the N−H bond to the N atom

*The second molecule of NH_3 is not essential for **M5**, but penalise **M5** if used incorrectly (but only penalise once in **M2** and **M5** for negative charge on ammonia)*

1

<u>SN1 mechanism alternative</u> (loss of Cl first followed by attack by NH_3) :

***M2** curly arrow from C–Cl bond to the Cl*

***M3** curly arrow from lone pair of NH_3 to correct C on the correct carbocation*

[14]

Q6.

(a) Cross at 1580

Allow a cross drawn for Si that is between the values for Mg and Al

1

(b) **M1** Na

1

M2 $Na^+(g) \rightarrow Na^{2+}(g) + e^-$

***M2** Allow $Q^+(g) \rightarrow Q^{2+}(g) + e^-$*

State symbols essential

Allow correct equation consequential on their element

1

(c) The number of protons increases OR nuclear charge increases

1

Shielding is similar/same OR electrons are added to the same shell

Allow same number of shells

1

(d) Chlorine/Cl

1

(e) $4P + 5O_2 \rightarrow P_4O_{10}$ OR $P_4 + 5O_2 \rightarrow P_4O_{10}$

Allow multiples

Ignore state symbols

Do not allow equations with P_2O_5

1

[7]

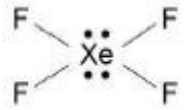
Q7.

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 the description 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 and these are presented in a logical order.
Level 0 **0 marks**	**0 marks** Insufficient correct chemistry to gain a mark.

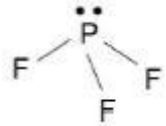
Indicative chemistry content

Stage 1 electron pairs
1a XeF_4 4BP and 2LP around Xe
1b PF_3 3BP and 1LP around P

Stage 2 explanation of shapes
2a XeF_4 is square planar
Or



2b PF_3 is pyramidal (allow tetrahedral)
Or



2c Electron pairs repel as far as possible or Lone pair repels more than bonding pairs

Stage 3 IMF
The relative strength of the intermolecular forces in the molecules must be explained to gain maximum marks.
3a XeF_4 has vdw forces and PF_3 has dipole-dipole forces (and vdw)

3b Stronger/more intermolecular forces in XeF_4
3c Due to larger M_r or more electrons or larger molecules or packs more closely together

[6]

Q8.

(a) **M1** The (relative) tendency of an atom to attract a pair of electrons/ the electrons/ electron density in a covalent bond

1

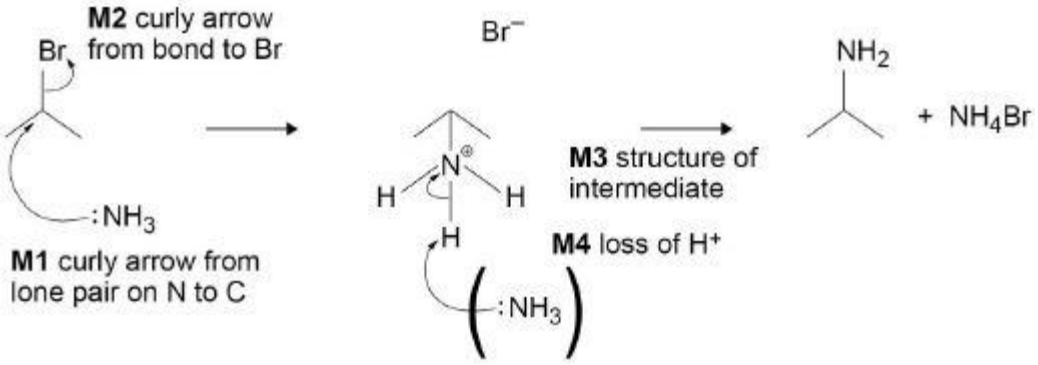
M2 Br is more electronegative than C (or vice versa)

1

M3 So Br is δ- and C is δ+

1

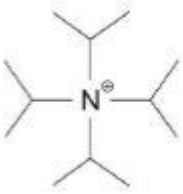
(b)



M4 *Penalise loss of H^+ using Br^-*
Allow S_n1

4

(c) **M1**



Allow + outside square brackets

1

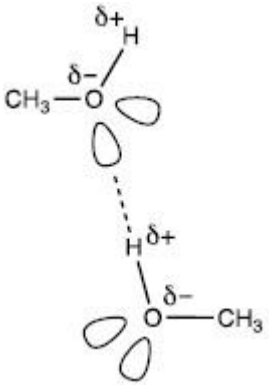
M2 Use: (Hair) conditioner / (Cationic) surfactant / disinfectant
Allow fabric softener

1

[9]

Q9.

(a)



M1 on at least one O atom two lone pairs and
on at least one OH δ+ on H and δ- on O

1

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

1

M3 O····H–O in straight line

1

Accept pair of dots or crosses for lone pair in place of orbital shape (orbital shape may or may not include two electrons)

Ignore any partial charges on C–H or C–O bonds

*For straight line in **M3**, allow a deviation of up to 15°*

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

(b) Idea that lone pairs have greater repulsion than bonding pairs

There must be a comparison between the repulsion of a lone pair and bonding pair

Allow covalent bond = bonding pair

1

(c)

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 explanation of each stage is generally correct and virtually complete.** (6 v 5) Answer is well structured, with no repetition or irrelevant points, and covers all aspects of the question. 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 (4 v 3) Answer has some structure and covers most aspects of the question. Ideas are expressed with reasonable clarity with, perhaps, some repetition or some irrelevant points. If any, only 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** (2 v 1) Answer includes statements which are presented in a logical order and/or linked.
0 marks	Insufficient correct chemistry to gain a mark.

Stage 1
Describes the effect of catalyst use
1a use of a catalyst has no impact on equilibrium yield
1b use of a catalyst gives faster rate
1c use of catalyst lowers costs

Stage 2
Describes the effect of pressure
2a higher pressure gives a higher equilibrium yield
2b higher pressure gives a faster rate
2c the higher the pressure, the greater the cost

Stage 3
Describes the effect of temperature
3a lower temperature gives a higher equilibrium yield
3b higher temperature gives a faster rate
3c the higher the temperature, the greater the cost
Note that converse statements are fine (e.g. 1a higher temperature gives a lower equilibrium yield)

6

[10]

Q10.

(a) Repeating pattern/trends (of physical or chemical properties/reactions)

Allow named property

Penalise groups

1

(b) Bromine/Br

Not Br_2

Accept Kr or Krypton

1

(c) Potassium /K

*If Na or Rb lose **M1** but allow access to **M2** and **M3***

If other incorrect elements 0/3

1

Smallest number of protons/smallest nuclear charge

1

Similar shielding / same number of shells (as other elements in period 4)

Allow same shielding

1

(d) Amphoteric

1

(e) $As_2O_3 + 6\ Zn + 12\ HNO_3 \rightarrow 2\ AsH_3 + 6\ Zn(NO_3)_2 + 3\ H_2O$

Accept multiples

1

[7]

Q11.

(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 **5-6 marks**	**All stages are covered and each stage is generally 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]