Q1.

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)

Q2.

This question is about intermolecular forces.

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

_____

_____

_____

_____

_____

_____

(2)

Q3.

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)

(Total 10 marks)

Q4.

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

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

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)

Q5.

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

A CH_3Br ○

B CH_2Br_2 ○

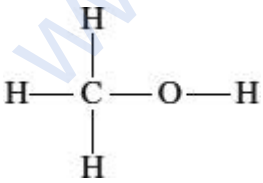
C $CHBr_3$ ○

D CBr_4 ○

(Total 1 mark)

Q6.

(a) Methanol has the structure



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

_____

_____

_____

(2)

(b) The boiling point of methanol is +65 °C; the boiling point of oxygen is –183 °C.

Methanol and oxygen each have an M_r value of 32. Explain, in terms of the intermolecular forces present in each case, why the boiling point of methanol is much higher than that of oxygen.

(3)

(Total 5 marks)

Q7.

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

(7)

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

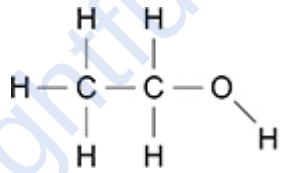
(4)

(Total 11 marks)

Q8.

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

(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 $CHBr_3$

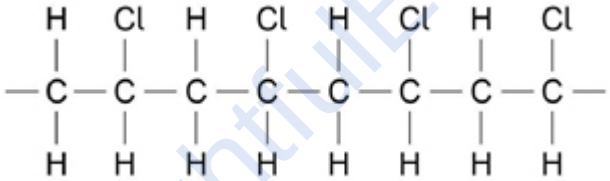
(3)

(Total 10 marks)

Q9.

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)

Q10.

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

Ammonia is very soluble in water.

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

_____

(1)

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

(3)

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

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

_____

_____

(1)

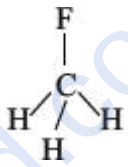
(Total 5 marks)

Q11.

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

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

	F–F		H–F
Boiling point/K	85	194	293

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

Liquid F_2 _____

Liquid CH_3F _____

Liquid HF _____

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

_____

_____

_____

_____

(6)

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

	HCl	HBr	HI
Boiling point / K	188	206	238

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

_____

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

(3)

(Total 11 marks)

Q12

Van der Waals' forces exist between all molecules.

Explain how these forces arise?

(3)

Q13

This question is about intermolecular forces in some organic compounds.

The table below gives some information about three organic compounds.

Compound	dichloromethane	tetrachloromethane	propan-1-ol
Boiling point / °C	40	77	97
Polarity of molecules	polar	non-polar	polar

(c) Explain why tetrachloromethane has a higher boiling point than dichloromethane.

(2)

(d) Propan-1-ol has a higher boiling point than the other two compounds because of hydrogen bonding.

Describe the hydrogen bonding in propan-1-ol.

_____

_____

_____

_____

_____

_____

(2)

14

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

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

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

Force 1 _____

Force 2 _____

Force 3 _____

(3)

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

_____

_____

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

_____

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

_____

_____

(4)

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

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

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

(5)

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

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

(3)

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

(2)

(Total 17 marks)

15 (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)

16

This question is about pentan-2-ol and pent-1-ene.

(a) The boiling point of pentan-2-ol is 119 °C
The boiling point of pent-1-ene is 30 °C

Explain why pentan-2-ol has a higher boiling point than pent-1-ene.

(3)

Mark schemes

Q1.

B

[1]

Q2.

(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

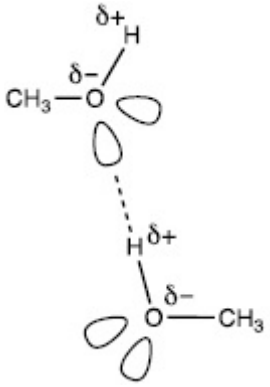
If shapes are drawn rather than named then penalise first mark gained

4

[7]

Q3.

(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]

Q4.

A

[1]

Q5.

D

[1]

Q6.

(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]

Q7.

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

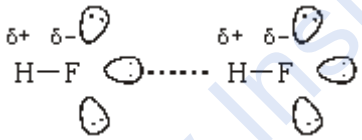
1

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 **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 <u>ionic</u> (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

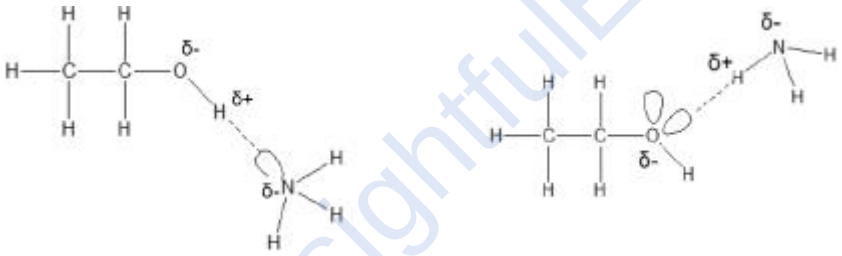
(References to van Der Waals' bonds breaking lose M3/M4)

1

[11]

Q8.

(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]

Q9.

(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

***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

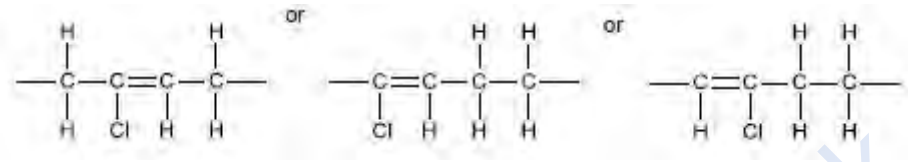
(c) Need both ideas that

- 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]

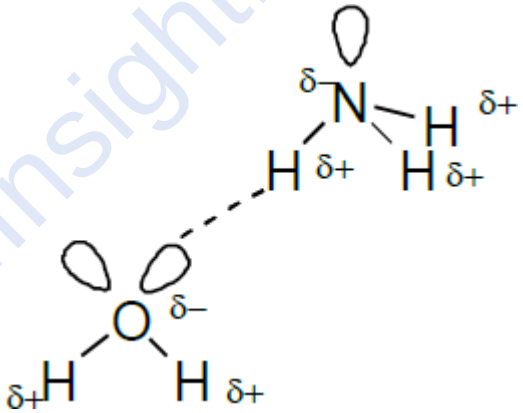
Q10.

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

Not just hydrogen.

1

(b)

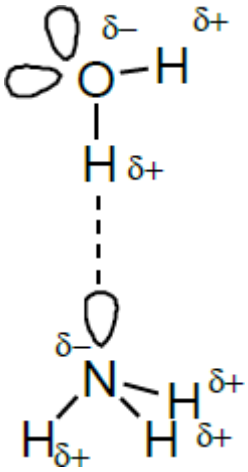


One mark for minimum of 4 correct partial charges shown on the N-H and O-H

One mark for the 3 lone pairs.

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

OR



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

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

3

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

1

[5]

Q11.

(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

$^{\delta+}$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^0 of e^- / size of e^- cloud (in the hydrogen halides)

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

(mark M1 and M2 separately)

1

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

(accept hydrogen bonding is very strong / strongest)

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

(not just 'HF has H-bonding')

1

[11]

12

M1 Electron movement in first molecule / temporary dipole

M2 Induces a dipole in another molecule

M3 (induced-temporary) attraction of delta + attracts delta – in different/adjacent molecules

M3 depends on M1 and M2

Allow electrostatic attraction.

M3 could be scored in diagram.

13

(c) **M1** van der Waals' forces between molecules in CCl_4 stronger than (combined van der Waals' and) dipole-dipole forces between molecules in CH_2Cl_2

M2 as CCl_4 has (many) more electrons than CH_2Cl_2

***M1** must refer to the forces being between molecules at some point*

*NOT **M1** for any reference to bond breaking*

*NOT **M1** for any reference to incorrect intermolecular forces*

Allow London forces or temporary (induced) dipole-dipole forces for van der Waals' forces

*For **M2**, allow CCl_4 has higher mass or higher M_r or bigger than CH_2Cl_2*

2

(d) **M1** attraction between O lone pair

M2 and δ+ H of OH on another molecule

no marks if answer indicates that the hydrogen bond is the O-H bond within a molecule

Marks could be awarded from a suitable diagram

2

14

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

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

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

OR London, Dispersion, temporary dipole

3

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

OR within molecule

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

(ii) molecular **(1)**

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

OR V.dW forces

OR intermolecular forces

Mention of ions CE=0

4

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

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

OR V.dW

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

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

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

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

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

QL mark (Look for unambiguous statements using correct terminology)

5

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

Strong forces between ions **(1)**

OR lots of energy required to break bonds

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

mention of molecules etc CE=0

3

(e) macromolecular **(1)**

OR giant molecule / lattice or correct diagram

Strong covalent bonds **(1)**

OR lots of energy required to break bonds

2

[17]

15

(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

16

(a) **M1** idea that pentan-2-ol has stronger intermolecular forces

***M1** idea that hydrogen bonds are stronger than van der Waals' forces*

*Penalise **M1** for any reference to idea of breaking covalent bonds*

1

M2 pent-1-ene has van der Waals' forces (only)

***M2** allow London forces or temporary/induced dipole forces or vdW forces for van der Waals' forces*

1

M3 pentan-2-ol (also) has hydrogen bonds

***M3** Ignore reference to dipole-dipole forces in pentan-2-ol*

1