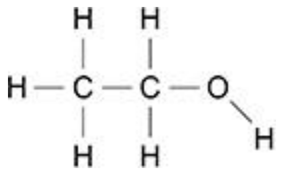
Q1.

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 $CHBr_3$

____

____

____

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(3)

(Total 10 marks)

Q2.

Which compound has the highest boiling point?

A $CH_3COCH_2CH_3$ ⬭

B $CH_3CH_2CH_2CH_2OH$ ⬭

C $CH_3CH_2CH_2CHO$ ⬭

D $CH_3CH_2CH_2CH_2CH_3$ ⬭

(Total 1 mark)

Q3.

This question is about the identification of ions in unknown solutions.

A student completes a number of test-tube reactions on solutions **A**, **B** and **C**.

The table below shows the student's observations.

	Test 1	**Test 2**	**Test 3**
	Add H_2SO_4(aq)	Warm with NaOH(aq)	Add acidified $AgNO_3$(aq)
A	white precipitate	no visible change	no visible change
B	effervescence	a gas is formed that turns damp red litmus blue	effervescence
C	no visible change	no visible change	off-white precipitate

(a) Suggest the identity of the positive ion in solution **A**.

Give the simplest ionic equation for the formation of the white precipitate in **Test 1** for solution **A**.

Identity of positive ion in **A** ____

Ionic equation

____

(2)

(b) Different gases are formed when solution **B** reacts in **Test 1** and in **Test 2**.

Suggest the identity of each gas.

Give the simplest ionic equation for the formation of the gas in **Test 2**.

Gas formed in **Test 1** ____

Gas formed in **Test 2** ____

Ionic equation for the formation of the gas in **Test 2**

____

(2)

(c) The student thinks that solution **C** contains either chloride ions or bromide ions.

Describe a further test, or tests, to show whether solution **C** contains chloride or bromide ions.

(3)

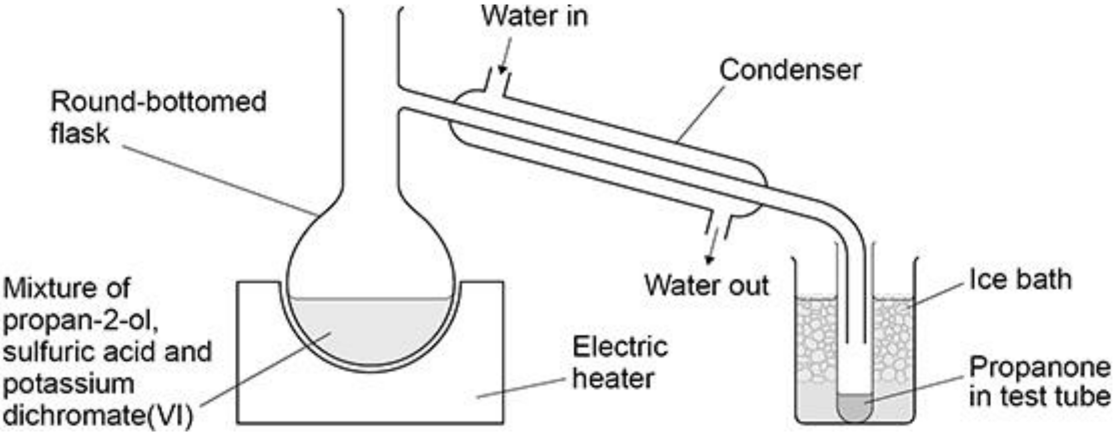
(Total 7 marks)

Q4.

Propanone can be made by reacting propan-2-ol with an excess of acidified potassium dichromate(VI).

The propanone is removed from the reaction mixture by distillation.

(a) The figure below shows the apparatus set up by a student to make propanone by this method. Suitable clamps are used to hold all the apparatus firmly in place.



There are **three** problems with the apparatus set up in the figure above.

For each problem:

- identify the problem
- describe the issue it would cause
- suggest how the problem can be solved.

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(6)

Another student completes the experiment using apparatus that is set up correctly.

(b) The student reacts 2.0 cm^3 of propan-2-ol ($CH_3CH(OH)CH_3$) with an excess of acidified potassium dichromate(VI). The student obtains 0.954 g of propanone (CH_3COCH_3).

Calculate the percentage yield of propanone in this experiment.
Give your answer to the appropriate number of significant figures.

Density of propan-2-ol = 0.786 g cm^{-3}

Percentage yield ____________________

(4)

(c) Molecules of propan-2-ol and propanone each contain three carbon atoms.

Complete the table below to suggest the shape and a bond angle around the central C atom in a molecule of each compound.

Compound	propan-2-ol $CH_3CH(OH)CH_3$	propanone CH_3COCH_3
Shape around central C atom		
Bond angle around central C atom		

(2)

(d) Explain why propanone has a lower boiling point than propan-2-ol.

____

____

____

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____

____

(3)
(Total 15 marks)

Q5.

Which polymer has hydrogen bonding between the polymer chains?

A Kevlar ☐

B PVC ☐

C poly(phenylethene) ☐

D Terylene ☐

(Total 1 mark)

Q6.

Which compound has hydrogen bonding?

A NaH ☐

B NH_3 ☐

C HI ☐

D SiH_4 ☐

(Total 1 mark)

Q7.

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.

____

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(3)

(b) Pent-1-ene is formed by the elimination of water from pentan-2-ol.

State the reagent and condition for this reaction.

Outline the mechanism for this reaction.

Reagent ____

Condition ____

Outline of mechanism

(5)
(Total 8 marks)

Q8.

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.

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(Total 6 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.

Which compound has the highest boiling point?

A $CH_3CH_2CH_2Br$ ⬭

B $CH_3CH_2CH_2F$ ⬭

C CH_3CH_2CHO ⬭

D CH_3CH_2COOH ⬭

(Total 1 mark)

Q11.

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.

____

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(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)

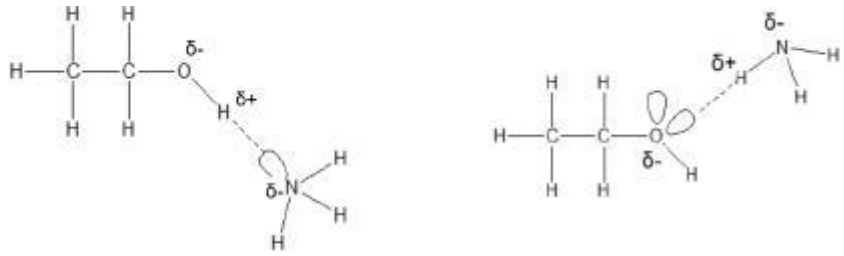
(Total 11 marks)

Mark Scheme

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.

B

$CH_3CH_2CH_2CH_2OH$

[1]

Q3.

(a) Ba^{2+}

Accept Ca^{2+} / Sr^{2+} / Pb^{2+}

1

$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

Ignore state symbols

Conseq on Ca^{2+} / Sr^{2+} / Pb^{2+} for M1

1

(b) Gas in Test 1: CO_2
Gas in Test 2: NH_3

Both gases needed for mark

Allow SO_2 as correct gas for Test 1

1

$NH_4^+(aq) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l)$

Ignore state symbols

1

(c) M1: Add dilute ammonia solution

1

M2: If the precipitate dissolves chloride ions are present

1

M3: If the precipitate does not dissolve then bromide ions are present

Allow M3 if concentrated ammonia is added after dilute ammonia and the precipitate then dissolves to identify presence of bromide ions.

Accept alternative

Add chlorine
If there is no visible change chloride ions are present

If an orange-brown solution forms then bromide ions are present

1

[7]

Q4.

(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.	
Level 3 **5-6 marks**	**All stages are covered and 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.
Level 0	Insufficient correct chemistry to gain a mark.

Stage 1
Anti-bumping granules
1a no anti-bumping granules / add anti-bumping granules
1b to create smaller bubbles / to prevent large bubbles / to prevent mixture jumping into condenser

Stage 2
Open system with no thermometer
2a system should be closed (above flask) to prevent gases escaping
2b should be closed with (bung +) thermometer
2c to allow collection of propanone (only) / to prevent distillation of other components / to stay in suitable temperature range

Stage 3
The water direction in the condenser
3a water flows in wrong direction through condenser / change water direction
3b condenser not cool enough / not full of water
3c product may not condense / comes through as gas

6

(b) **M1** mass of propan-2-ol = 2.0 x 0.786 (= 1.572 g to at least 2sf)

M2 amount of propan-2-ol = $\frac{1.572}{60.0}$ (= 0.0262 to at least 2 sf) mol

M3 mass of propanone expected = 0.0262 x 58.0 (= 1.52 g to at least 2sf)

M4 % yield = $\left(\frac{0.954}{1.52} x\ 100\right)$ = 63% (2sf only)

Alternative for M3/4

M3 *amount of propanone formed =* $\frac{0.954}{58.0}$ *(= 0.0164) mol*

M4 *% yield =* $\left(\frac{0.0164}{0.0262} x\ 100\right)$ *= 63% (2sf only)*

Allow ECF at each step

4

(c) **M1** propan-2-ol: tetrahedral and 109.5°

M1 *allow 104–110°*

1

M2 propanone: trigonal planar and 120°

M2 *allow 115–123°*

Any two correct boxes scores one mark

1

(d) **M1** propan-2-ol has stronger intermolecular forces

Penalise ***M1*** *and* ***M2*** *for any reference to breaking covalent bonds, (but* ***M3*** *could score)*

1

M2 propan-2-ol has hydrogen bonds between molecules

For ***M2*** *ignore reference to dipole-dipole forces in propan-2-ol*

1

M3 propanone has dipole-dipole forces and/or van der Waals' forces

1

[15]

Q5.

A

Kevlar

[1]

Q6.

B

NH_3

[1]

Q7.

(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

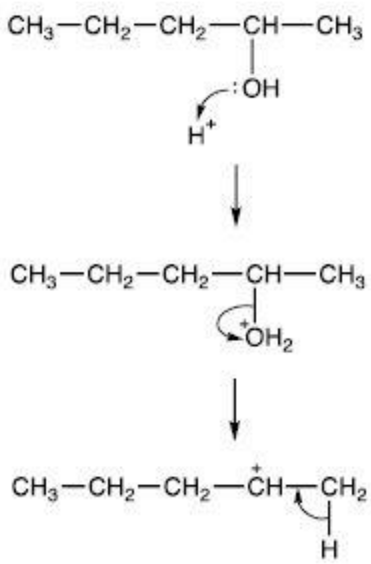
1

(b) **M1** reagent = <u>conc</u> sulfuric acid or <u>conc</u> phosphoric acid

__M1__ penalise incorrect name or formula (even if both name and formula are given)

1

M2 condition = hot / temperature in range 150-200°(C)



__M2__ allow high temperature

__M2__ reagent must indicate an acid in some way in order for __M2__ to be awarded

__M1/2__ allow 1 mark if H_2SO_4/H_3PO_4 given as reagent and conc(entrated) given as condition

1

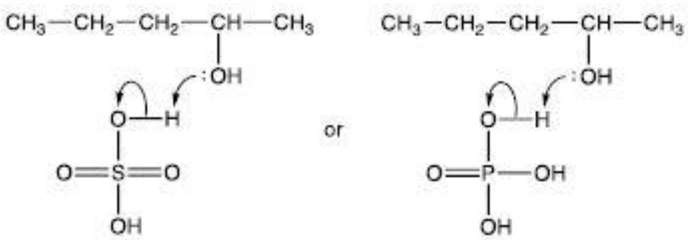
M3 curly arrow from lone pair on alcohol O to H^+

M3-5

penalise __M3/4/5__ for any additional arrow(s) in addition to the correct one at each stage

If incorrect reactant (or product if shown), maximum 2 marks of __M3-5__

Alternatives for M3



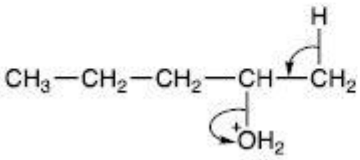
1

M4 curly arrow from C-O bond to O on correct intermediate

1

M5 arrow from C-H bond on C1 to C-C bond between C1 and C2 on correct carbocation

*allow **M4** and **M5** concurrent:*



1

[8]

Q8.

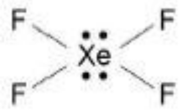
This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.	
Level 3 **5-6 marks**	All stages are covered and the description of each stage is generally correct and virtually complete. Answer is communicated coherently 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

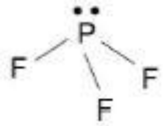
<u>Stage 1 electron pairs</u>
1a XeF_4 4BP and 2LP around Xe

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



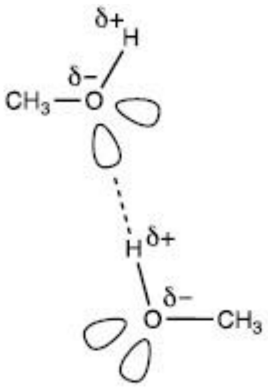
2c Electron pairs repel as far as possible or Lone pair repels more than bonding pairs

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]

Q9.

(a)



M1 on at least one O atom two lone pairs <u>and</u>
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.	
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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]

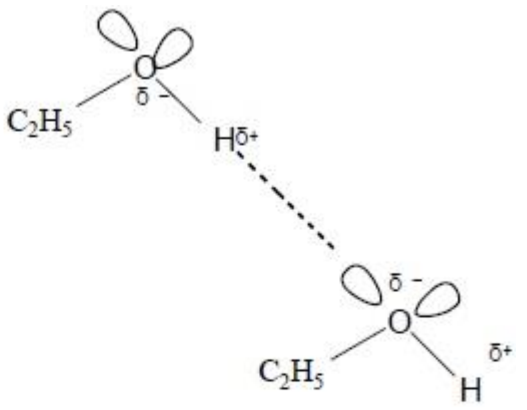
Q10.

D

CH_3CH_2COOH

[1]

Q11.



M1 *two lone pairs on each O atom*
<u>and</u>
δ+ and δ- on each H-O bond

1

M2 *<u>dotted/broken</u> 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 <u>OR</u> van der Waals force (between methoxymethane molecules)

Allow vdW

1

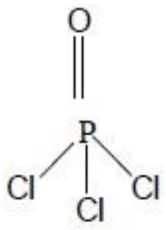
Hydrogen bonds are stronger/est intermolecular force

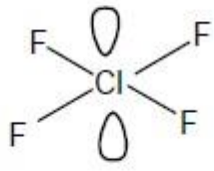
Allow more energy to break/overcome hydrogen bonding

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]