Q14.

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)

Q15.

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)

Q16.

Sodium thiosulfate reacts with dilute hydrochloric acid as shown.

$$Na_2S_2O_3(aq) + 2\ HCl(aq) \rightarrow 2\ NaCl(aq) + SO_2\ (g) + S(s) + H_2O(l)$$

(a) Give the simplest ionic equation for this reaction.

_____

(1)

(b) The gas SO_2 is a pollutant.

State the property of SO_2 that causes pollution when it enters rivers.

Give an equation to show the reaction of SO_2 with water.

Property _____

Equation _____

(2)

(c) Draw a diagram to show the shape of a molecule of H_2O
Include any lone pairs of electrons.

State the H-O-H bond angle.

Explain this shape and bond angle.

Diagram

Bond angle _____

Explanation _____

_____

_____

_____

_____

_____

_____

_____

(4)

(d) The initial rate of the reaction between sodium thiosulfate and hydrochloric acid can be monitored by measuring the time taken for a fixed amount of sulfur to be produced.

Describe an experiment to investigate the effect of temperature on the initial rate of this reaction.

Include

- a brief outline of your method
- how you will measure the time taken for a fixed amount of sulfur to be formed
- how you will present your results in graphical form
- a sketch of the graph that you would expect.

(6)

(Total 13 marks)

Q17.

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 _____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 8 marks)

Q18.

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)

Q19.

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)

Q20.

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		

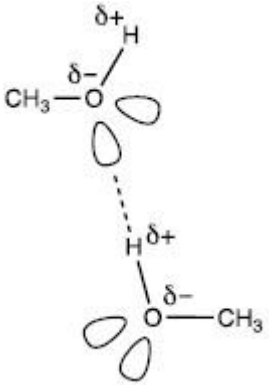
(4)

(Total 7 marks)

Mark Scheme

Q14.

(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

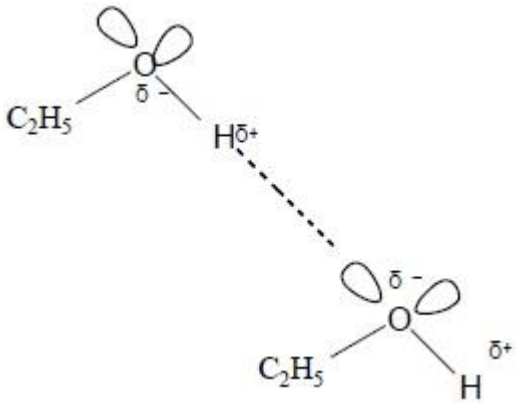
Stage 2
Describes the effect of pressure
2a higher pressure gives a higher equilibrium yield
2b higher pressure gives a faster rate
2c the higher the pressure, the greater the cost

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]

Q15.



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

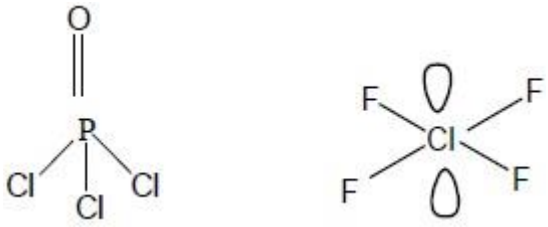
1

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]

Q16.

(a) $S_2O_3^{2-} + 2\ H^+ \rightarrow SO_2 + S + H_2O$

Allow $S_2O_3^{2-} + 2H_3O+ \rightarrow SO_2 + S + 3H_2O$

Allow $½S_2O_3^{2-} + H^+ \rightarrow ½SO_2 + ½S + ½H_2O$

Allow $½S_2O_3^{2-} + H_3O + \rightarrow ½SO_2 + ½S + 1½H_2O$

Ignore state symbols

NOT multiples

NOT if any spectator ions included (unless crossed out)

1

(b) **M1** acid(ic) / acidity / produces H^+

***M1** Allow low(ers) pH*

Ignore toxic / soluble

Ignore sulfurous / sulfuric / H_2SO_4

Ignore rain

Ignore proton donor (unless qualified, e.g. reacts with water to form a proton donor)

NOT any other named acid

1

M2 $SO_2 + H_2O \rightarrow H_2SO_3$ / $H^+ + HSO_3^-$

***M2** Allow $SO_2 + H_2O \rightarrow 2\ H^+ + SO_3^{2-}$*

Allow $SO_2 + 2\ H_2O \rightarrow H_3O^+ + HSO_3^-$

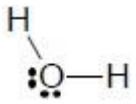
Allow $SO_2 + 3\ H_2O \rightarrow 2\ H_3O^+ + SO_3^{2-}$

Allow multiples

Ignore state symbols

1

(c) **M1**



***M1** bent shape and 2 lone pairs on O*

Allow any suitable representation of lone pairs (e.g. dots, crosses, lobes with/without dots/crosses)

1

M2 104½°

***M2** Allow 104-105°*

1

M3 lone pairs repel more (strongly) than bond(ing) pairs

M3 *Allow non-bonding pair for lone pair*

Allow covalent bond for bond(ing) pair

Allow shared pair for bond(ing) pair

Allow OH bond for bond(ing) pair

Allow bond for bond(ing) pair

NOT OH or O-H without the word bond for bond(ing) pair

1

M4 so bond angle reduced from/less than 109½° / tetrahedral

M4 *Allow bond angle reduced from 120° if bent with one lone pair in* ***M1***

Allow reduced from 109°

Allow reduced by 2.5° per lone pair or 5° if ***M2*** *correct*

1

(d)

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 correct and virtually complete.** (6 v 5) 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 the explanation of each stage may be incomplete or may contain inaccuracies OR two stages covered and the explanations are generally correct and virtually complete** (4 v 3) Answer has some structure. 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 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** (2 v 1) Answer includes statements which are presented in a logical order and/or linked.
0 marks	Insufficient correct Chemistry to warrant a mark

Indicative Chemistry content

Stage 1 Method

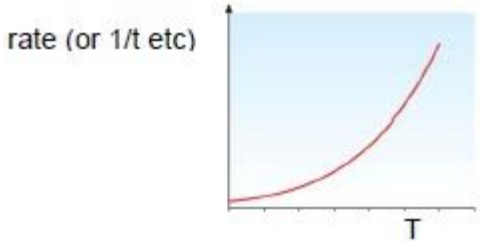
(1a) Idea of using disappearing cross or colorimetry

(1b) Puts acid or thiosulfate into container on/with cross or in colorimeter

(1c) Add second reactant and start timing

Stage 2 Measurements
(2a) Repeat at different temperatures (if number of temperatures stated, must be more than two)
(2b) Record time, t, for cross to disappear / defined reading on colorimeter
(2c) Idea of ensuring other variables (cross, volumes, concentrations) kept constant (apart from T)

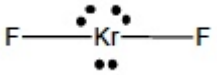
Stage 3 Use of Results
(3a) 1/t (or 1000/time, etc) is a measure of rate
(3b) plot of rate (or 1/t etc) (y-axis) against T (x-axis) (can come from labelled axes on sketch) (IGNORE T against rate)
(3c) sketch of plot as shown (Allow 3c if axes not labelled but NOT if incorrectly labelled)



6

[13]

Q17.

(a) 

Allow diagram with 2 bonds and 3 lone pairs

1

Linear

1

180°

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 induces dipole in neighbouring/another/nearby molecule

1

symmetrical molecule / dipoles cancel

OR

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

1

[8]

Q18.

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

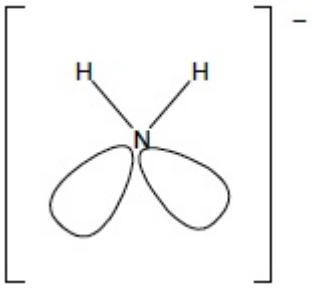
1

(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]

Q19.

B

[1]

Q20.

(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]