Questions

Q1.

The diagram shows bond angles in ammonia and water.

Explain why the bond angle in water is less than the bond angle in ammonia.

(2)

.....

.....

.....

.....

(Total for question = 2 marks)

Q2.

This question is about methanol, CH_3OH .

Draw a dot-and-cross diagram to show the bonding in a molecule of methanol.
Show outer shell electrons only.

(2)

(Total for question = 2 marks)

Q3.

This question is about the chemistry of hydrated magnesium nitrate, $Mg(NO_3)_2.xH_2O$.

In an experiment, a sample of hydrated magnesium nitrate, $Mg(NO_3)_2.xH_2O$, with a mass of 0.765 g, was dissolved in water and reacted with an excess of sodium hydroxide solution, NaOH(aq).
The precipitate of magnesium hydroxide, $Mg(OH)_2$, produced was removed and dried. The mass of the dried sample was 0.174 g.

(i) Draw dot-and-cross diagrams for the ions in magnesium hydroxide.
Show the outer electrons only.

(2)

(ii) Use the experimental data to calculate the value for x in the formula $Mg(NO_3)_2.xH_2O$.
You **must** show all your working.

(5)

(Total for question = 7 marks)

Q4.

This question is about compounds of Group 5 elements.

Phosphorus forms two chlorides with the formulae PCl_3 and PCl_5.

(i) Explain the shape of the PCl_3 molecule. The bond angle is not required.

(3)

.....

.....

.....

.....

.....

.....

(ii) Draw a diagram to show the three-dimensional shape of the PCl_5 molecule in the gas phase.

Include bond angles and the name of the shape.

(3)

(iii) Explain why phosphorus forms PCl_5 but nitrogen does not form NCl_5.

(2)

.....

.....

.....

.....

(Total for question = 8 marks)

Q5.

This question is about aluminium chloride.

Aluminium chloride exists as a dimer, Al_2Cl_6, just above its boiling temperature.

(i) Draw a diagram to show how two $AlCl_3$ molecules are joined together in the dimer.

(1)

(ii) State the type of bond that joins the two $AlCl_3$ molecules together.

(1)

.....

(Total for question = 2 marks)

Q6.

This question is about covalent bonds.

(i) Ammonia and boron trifluoride react to form a compound NH_3BF_3 which contains a dative covalent bond. Each of the molecules, NH_3 and BF_3, has a different feature of its electronic structure that allows this to happen. Use these two different features to explain how a dative covalent bond is formed.

(2)

.....

.....

.....

.....

.....

.....

(ii) During this reaction, the bond angles about the nitrogen atom and the boron atom change.

State the new H—N—H and F—B—F bond angles.

(2)

.....

.....

(Total for question = 4 marks)

Q7.

This question is about covalent bonds.

Draw a diagram of the ammonia molecule, clearly showing its shape.
Include any lone pairs of electrons and the value of the bond angle.

(2)

(Total for question = 2 marks)

Q8.

This question is about carbon monoxide, CO, which is a toxic and colourless gas used widely in the chemical industry.

Draw a dot-and-cross diagram of a molecule of carbon monoxide.

Use dots (•) for the carbon electrons and crosses (×) for the oxygen electrons.

(2)

(Total for question = 2 marks)

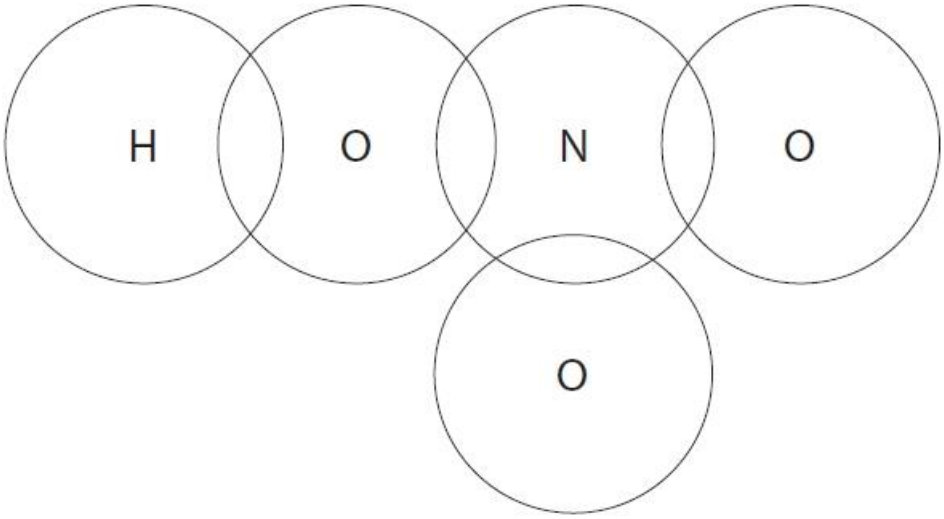
Q9.

Complete the dot-and-cross diagram for the bonding in nitric acid, showing only outer shell electrons.

Use (•) for the oxygen electrons,

(x) for the nitrogen electrons and (*) for the hydrogen electron.

(3)



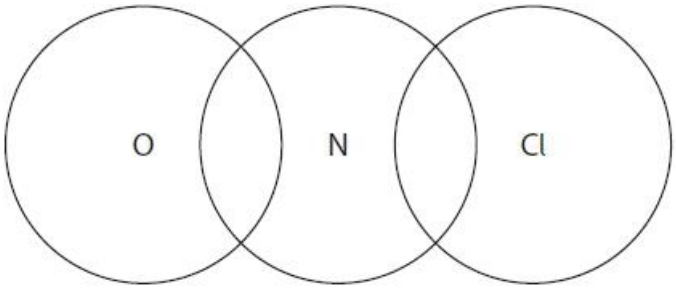
(Total for question = 3 marks)

Q10.

Nitrogen monoxide and chlorine react together to form nitrosyl chloride.

$$2NO(g) + Cl_2(g) \rightarrow 2NOCl(g)$$

Draw a dot-and-cross diagram for nitrosyl chloride, showing only the outer shell electrons.



(Total for question = 2 marks)

Q11.

Magnesium bromide, $MgBr_2$, is an ionic compound.

(i) Draw a dot-and-cross diagram to show the bonding in magnesium bromide.
Only outer shell electrons are required.

(1)

(ii) State all the conditions under which magnesium bromide conducts electricity.

(1)

.....

.....

(Total for question = 2 marks)

Q12.

This question is about aluminium chloride.

At high temperatures, aluminium chloride exists as $AlCl_3$ molecules.

(i) Draw a dot-and-cross diagram of an aluminium chloride molecule, $AlCl_3$. Show the outer shell electrons only.

(1)

(ii) Predict the shape of an $AlCl_3$ molecule and the Cl−Al−Cl bond angle.

(2)

Shape of $AlCl_3$	
Cl–Al–Cl bond angle	

(iii) Aluminium chloride is used as a catalyst in the alkylation of benzene.

Draw the mechanism for the reaction between benzene and chloromethane using aluminium chloride as the catalyst.
Include an equation for the formation of the electrophile, and any relevant curly arrows.

(4)

(Total for question = 7 marks)

Q13.

This question concerns the combustion of fossil fuels in power stations.

Draw a dot-and-cross diagram for sulfur dioxide, showing outer electrons only.

(1)

(Total for question = 1 mark)

Q14.

Tablets containing potassium manganate(VII), $KMnO_4$, are dissolved in water forming an antiseptic solution to treat skin conditions. The manufacturers claim that each tablet contains 400 mg of $KMnO_4$.

To check the claim, the titration procedure outlined was carried out.

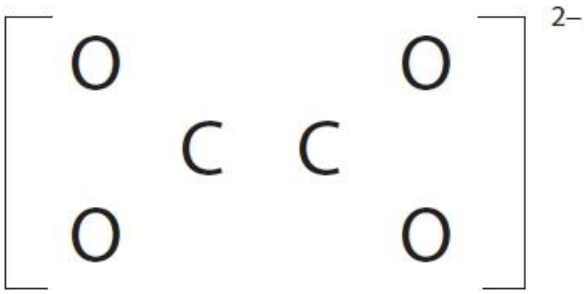
- Five tablets were dissolved in distilled water to make 100.0 cm^3 of solution.
- Some of the $KMnO_4$ solution was used to fill a burette.
- 25.0 cm^3 of sodium ethanedioate solution, $Na_2C_2O_4(aq)$, of concentration 0.200 mol dm^{-3}, was added to a conical flask and warmed.
- Sulfuric acid, of concentration 2 mol dm^{-3}, was also added to the conical flask.
- The $KMnO_4$ solution was added to the flask from the burette, until the end-point.

The equation for the reaction between MnO_4^- ions from the $KMnO_4$ and $C_2O_4^{2-}$ ions from the sodium ethanedioate solution is shown.

$$16H^+(aq) + 2MnO_4^-(aq) + 5C_2O_4^{2-}(aq) \rightarrow 2Mn^{2+}(aq) + 10CO_2(g) + 8H_2O(l)$$

(i) Complete the dot-and-cross diagram for the ethanedioate ion.
Show the outer electrons only.

(2)



(ii) Determine the oxidation number of carbon in the ethanedioate ion, $C_2O_4^{2-}$.

(1)

.....

(Total for question = 3 marks)

Q15.

This question is about ionic bonding.

The elements sodium and fluorine react together to form an ionic compound.

(i) Select the correct equation for this reaction.

(1)

- ☒ **A** $Na(s) + F(g) \rightarrow NaF(s)$
- ☒ **B** $2Na(s) + F_2(g) \rightarrow 2NaF(s)$
- ☒ **C** $Na(s) + F_2(g) \rightarrow NaF_2(s)$
- ☒ **D** $2Na(s) + F(g) \rightarrow Na_2F(s)$

(ii) Draw dot-and-cross diagrams of the ions in sodium fluoride, showing all the electrons.

Use your diagram to explain why the ions are described as isoelectronic.

(3)

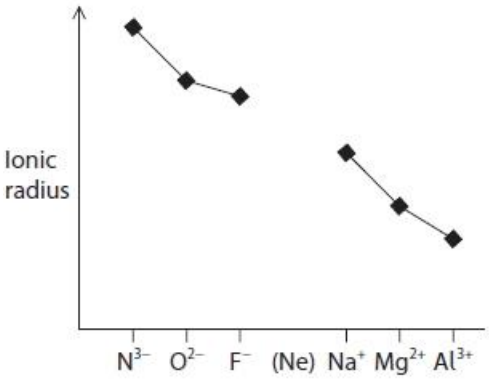
.....

.....

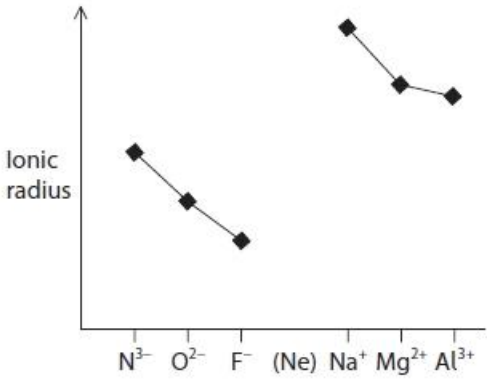
(iii) Which diagram shows the trend in ionic radius for the isoelectronic ions N^{3-} to Al^{3+}?

(1)

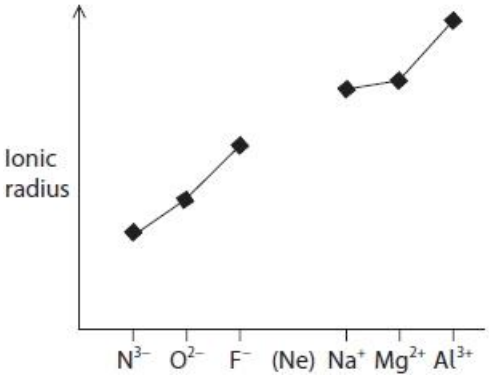
☐ **A**



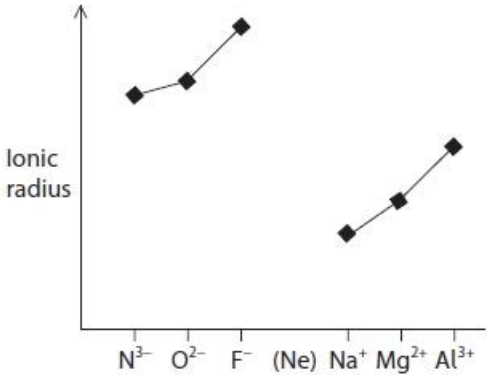
☐ **B**



☐ **C**



☐ **D**



(iv) Explain your answer to (iii) in terms of the structure of the ions.

(2)

.....

.....

.....

.....

.....

.....

.....

(Total for question = 7 marks)

Q16.

This is a question about water.

Pure water ionises to form H_3O^+ and OH^- ions, although only to a very small extent.
Draw the dot-and-cross diagrams of these ions.
Use dots (•) for the hydrogen electrons and crosses (×) for the oxygen electrons.

(2)

(Total for question = 2 marks)

Q17.

This question is about water.

Water is a polar covalent molecule. The strongest intermolecular forces between water molecules are hydrogen bonds.

(i) The O–H bond in water is polar because, when compared with the hydrogen atom, the oxygen atom has

(1)

☒ **A** a higher mass number

☒ **B** a larger atomic radius

☒ **C** greater electronegativity

☒ **D** more electrons

(ii) Draw a diagram of a hydrogen bond between two water molecules in ice.

Show the value of the H–O–H angle within a molecule and the value of the O–H–O angle between the two molecules.

(2)

(iii) Explain why hydrogen bonding causes ice to be less dense than liquid water.

(2)

.....

.....

.....

.....

.....

(Total for question = 5 marks)

Q18.

Boric acid, H_3BO_3, is a weak acid with antiseptic properties.

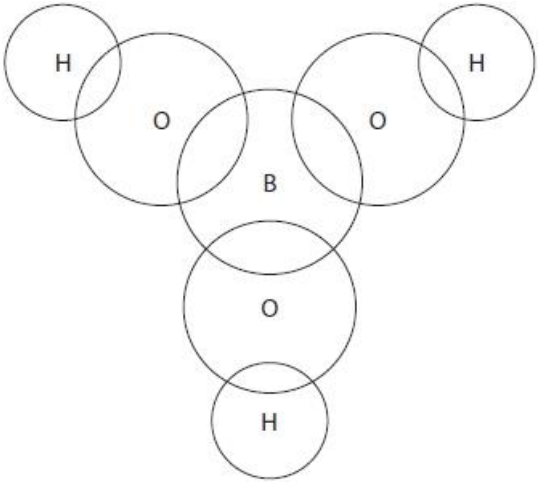
The formula of boric acid can also be written as $B(OH)_3$.

(i) Complete the dot-and-cross diagram of a molecule of boric acid. Show the outer shell electrons only.

(1)

Use dots (•) for the hydrogen electrons, crosses (×) for the oxygen electrons and triangles (△) for the boron electrons.

(2)



(ii) What are the O—B—O and B—O—H bond angles in a molecule of boric acid?

	O—B—O bond angle	B—O—H bond angle
☒ **A**	109.5°	104.5°
☒ **B**	109.5°	180°
☒ **C**	120°	104.5°
☒ **D**	120°	180°

(Total for question = 3 marks)

Q19.

Nitrogen forms several hydrides. In addition to ammonia, NH_3, it forms hydrazine, N_2H_4, in which the two nitrogen atoms are covalently bonded together.

(i) Explain what is meant by a covalent bond.

(2)

.....

.....

.....

(ii) Draw a dot-and-cross diagram for hydrazine, showing the outer electrons only.

Use crosses (×) to represent the electrons from nitrogen and dots (•) to represent the electrons from hydrogen.

(1)

(iii) Estimate the H—N—H bond angle in hydrazine.

(1)

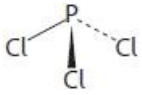
Bond angle = ...

(Total for question = 4 marks)

Q20.

A phosphorus atom has mass number 31.

Phosphorus(III) chloride molecules are pyramidal with a bond angle less than 109.5°.



(i) Explain why a phosphorus(III) chloride molecule has this shape and bond angle.

(2)

.....

.....

.....

.....

.....

.....

(ii) Which describes the polarity of the P—Cl bond and the polarity of the phosphorus(III) chloride molecule?

(1)

	Polarity of P—Cl bond	Polarity of molecule
☒ **A**	non-polar	non-polar
☒ **B**	non-polar	polar
☒ **C**	polar	non-polar
☒ **D**	polar	polar

(Total for question = 3 marks)

Q21.

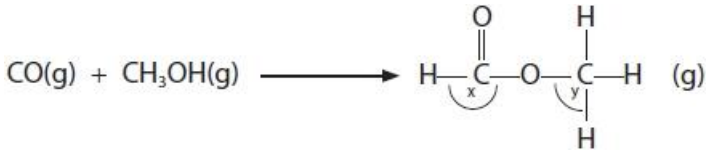
Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A mixture of ethanoic acid, ethanol and a catalyst was left for several days to reach equilibrium.

$$CH_3COOH(l) + CH_3CH_2OH(l) \rightleftharpoons CH_3COOCH_2CH_3(l) + H_2O(l)$$

The equilibrium constant, K_c, **under these conditions**, was 0.28.

Another ester, methyl methanoate, can be formed by the reaction between methanol and carbon monoxide in the gaseous phase.



(i) The two O−C−H bond angles, x and y, in the ester are approximately

(1)

☒ **A** 180° and 90°

☒ **B** 120° and 90°

☒ **C** 120° and 109.5°

☒ **D** 109.5° and 109.5°

(ii) The reaction often forms an equilibrium mixture.

Which could be the units for the equilibrium constant, K_p?

(1)

☒ **A** mol dm^{-3}

☒ **B** dm^3 mol^{-1}

☒ **C** atm

☒ **D** atm^{-1}

(iii) Describe what effect, if any, increasing the pressure would have on the equilibrium constant, K_p. Justify your answer.

(2)

.....

.....

.....

.....

.....

(Total for question = 4 marks)

Q22.

Boron and aluminium are in the same group of the Periodic Table. Both form compounds with chlorine and with fluorine.

Boron reacts directly with chlorine to produce a covalently bonded compound, BCl_3.

(i) Write the equation for this reaction. State symbols are not required.

(1)

(ii) Draw a dot-and-cross diagram for BCl_3 showing only the outer shell electrons of the atoms.

(1)

(iii) Use your diagram to explain why BCl_3 has a trigonal planar shape with bond angles of 120°.

(2)

.....

.....

.....

.....

.....

.....

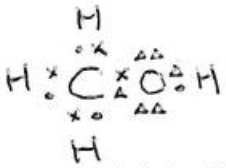
(Total for question = 4 marks)

Mark Scheme

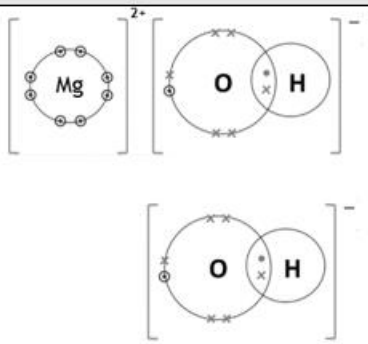
Q1.

Question Number	Acceptable Answers	Additional Guidance	Mark
	An explanation that makes reference to the following points: • oxygen has one more lone pair (of electrons than nitrogen)/oxygen has two lone pairs (of electrons) but nitrogen only has one **(1)** • so the **repulsion** from the oxygen lone pairs is greater (and reduces the bond angle) or lone pair – lone pair **repulsion** is greater than lone pair – bonded pair (and reduces the bond angle) **(1)**	Check for lone pairs drawn on the molecules if not explicitly stated on the lines provided Allow water/ it has one more lone pair of electrons (than ammonia) Ignore any stated shapes even if incorrect Do not award atoms 'pushed together'	**(2)**

Q2.

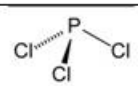
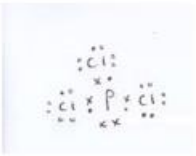
Question Number	Answer	Additional Guidance	Mark
	• all bonding pairs of electrons correct **(1)** • 2 lone pairs of electrons on oxygen **(1)**	Example of diagram  Allow any symbols for electrons, including all dots or all crosses Allow electrons either side of a line for a bond e.g. x Electrons can be in overlapping circles, on the lines, inside the lines or in the gaps between the lines Non-bonding electrons on O can be shown as 2 pairs, all 4 together or as 3 and 1 Ignore inner shell electrons	**(2)**

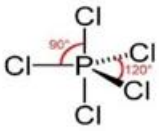
Q3.

Question Number	Answer	Additional Guidance	Mark
(i)	• magnesium ion (1) • hydroxide ion (1)	 Allow all dots or all crosses Allow M1 for magnesium ion outer shell shown with no electrons Allow M2 even if only 1 hydroxide ion is shown Ignore inner shells Ignore absence of square brackets and circles Ignore any indication of 2 hydroxide ions e.g. 1 hydroxide ion with '2' preceding it Penalise missing charges once only	(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	• calculation of moles of $Mg(OH)_2$ **(1)**	Example of calculation $0.174 \div 58.3 = 2.98456 \times 10^{-3}$ (mol)	**(5)**
	• calculation of mass of $Mg(NO_3)_2$ **(1)**	$2.98456 \times 10^{-3} \times 148.3 = 0.44261$ (g)	
	• calculation of mass of H_2O **(1)**	$0.765 - 0.44261 = 0.32239$ (g)	
	• calculation of moles of H_2O **(1)**	$0.32239 \div 18 = 0.017911$ (mol)	
	• deduction of $Mg(NO_3)_2 : H_2O$ ratio (and hence formula) **(1)**	$0.017911 \div 2.98456 \times 10^{-3} = 6.0011$ 1:6, (so $Mg(NO_3)_2.6H_2O$)	
	OR		
	• Calculation of moles of $Mg(OH)_2$ **(1)**	$0.174 \div 58.3 = 2.98456 \times 10^{-3}$ (mol)	
	• deduction of moles of $Mg(NO_3)_2.xH_2O$ **(1)**	1:1 so $= 2.98456 \times 10^{-3}$ (mol)	
	• expression for / calculation of molar mass of $Mg(NO_3)_2.xH_2O$ **(1)**	$148.3 + 18x$ / $0.765 \div 2.98456 \times 10^{-3} = 256.3$	
	• expression for moles of $Mg(NO_3)_2.xH_2O$ in terms of mass and molar mass / calculation mass of water in 1 mole **(1)**	$0.765 \div (148.3 + 18x) = 2.98456 \times 10^{-3}$ (mol) / $256.3 - 148.3 = 108$ $0.32239 = 0.0537x$, so $x =$ $0.32239 \div 0.0537 = 6.0035$ / $108 \div 18$ so $x = 6$; (so $Mg(NO_3)_2.6H_2O$)	
	• calculation of x (and hence formula) **(1)**	Correct answer with no working scores M5 only. Ignore SF from M1 to M4, allow TE throughout	

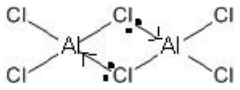
Q4.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to • **M1** PCl_3 is (trigonal) pyramidal (1) • **M2** has 3 bond pairs and 1 lone pair (around central P atom) (1) • **M3** electron pairs repel to positions of minimum repulsion / maximum separation (1)	Marking points 1 and 2 may be shown on diagrams (see below) Award M1 for correct name of shape even if diagram(s) incorrect Ignore lone pair – bond pair repulsions > bond pair – bond pair repulsions Answer must state or imply somewhere that (electron) pairs repel Do not award if specifically stated that 'bonds repel' or 'atoms repel' Ignore any references to bond angles even if incorrect	(3)
Example of diagram for award of M1 (a lone pair may also be shown on the P atom) 			
Example of diagram for award of M2 (must show 3 bond pairs and 1 lone pair) 			

Question Number	Answer	Additional Guidance	Mark
(ii)	• **M1** Diagram showing trigonal bipyramidal shape, with 3D emphasised by use of two wedges or one hatch and one wedge in the central plane (1) • **M2** 90˚ and 120˚ angles labelled (1) • **M3** trigonal bipyramidal (1)	 M2 dependent on correct M1 Ignore 180° Do not award M2 if any incorrect bond angle is shown M3 stand alone mark Both words required Award "trigonal bipyramid"	(3)

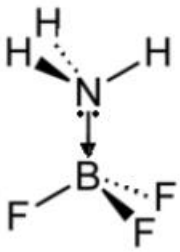
Question Number	Answer	Additional Guidance	Mark
(iii)	An answer that makes reference to the following points: • phosphorus can expand its octet / can expand its (outer) shell / can accommodate more than 8 electrons / can accommodate 10 electrons / has available (3d-) orbitals (for promotion of electrons) (1) • nitrogen does not have (2)d-orbitals / can only accommodate eight electrons (in its outer shell) (1)	**Comment** Award reference to P accommodating 18 electrons Ignore comparisons of size / radius of P and N atoms	(2)

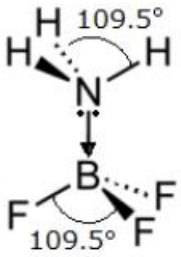
Q5.

Question Number	Answer	Additional Guidance	Mark
(i)	• diagram showing two $AlCl_3$ molecules joined through two chlorine atoms	Example of diagram  Allow dot-and-cross diagram Ignore missing arrows / direction of arrows Ignore missing lone pairs	(1)

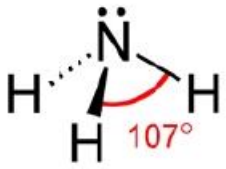
Question Number	Answer	Additional Guidance	Mark
(ii)	• dative (covalent) bonds **or** coordinate bonds	Allow this labelled on diagram in (i) Do not award this mark if dative bonds shown as arrows starting from aluminium in (c)(i)	(1)

Q6.

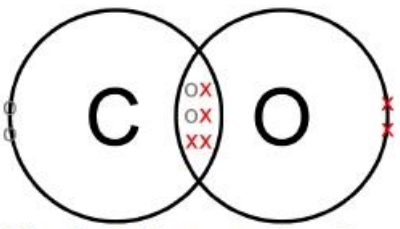
Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	An answer that makes reference to the following points: • donation of **lone pair** (of electrons) from nitrogen / **lone pair** from ammonia **(1)** • to the boron (atom) which is electron deficient / has only 6 electrons in outer shell / has 6 valence electrons / can accept two electrons to complete octet /can accept two electrons to get a full (outer) shell **(1)**	Allow 'non-bonding pair' for lone pair Allow 'sharing' for donation Do not penalise donation to F atoms, but can only score M1 in this case Allow just 'boron has an incomplete outer shell' Allow boron has an empty (p-)orbital Do not award M2 for just 'nitrogen shares lone pair with boron atom' or similar M1 may be scored from a diagram here **OR** a diagram in **(d)(ii)** e.g.  scores only M1	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• HNH angle is (approximately) 109.5° **(1)** • FBF angle is (approximately) 109.5° **(1)**	May be shown on a diagram, including on a diagram in **(i)** e.g  Allow 1 for just 109.5° if it has not been made clear that this angle applies to BOTH bond angles Both angles change to 109.5° scores 2 Allow 109-110°	**(2)**

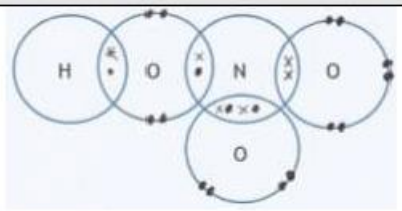
Q7.

Question Number	Acceptable Answer	Additional Guidance	Mark
	• diagram showing 3-D shape of ammonia, including **two bonds** with one 'wedge' and one 'hatch' and one N-H bond 'in plane' **(1)** • lone pair of electrons on nitrogen atom **and** • bond angle of 107° labelled **(1)**	Example of diagram:  Allow any direction of the wedge and/or hatch This mark can be scored on a dot and cross diagram Allow any angle between 106 and 108° inclusive. Do not award M2 if the 107° bond angle is shown as that between the lone pair and a bonding pair Ignore name of shape even if incorrect	**(2)**

Q8.

Question Number	Answer	Additional Guidance	Mark
	• 3 bond pairs showing triple bond, one of which must be a dative bond (1) • both lone pairs on C and O (1)	Example of dot and cross diagram:  Allow 1 mark if correct number of electrons shown, but all as crosses or all as dots Ignore lines showing covalent bonds	**(2)**

Q9.

Question Number	Acceptable Answers	Additional Guidance	Mark
	 • hydrogen and oxygen on the left, all pairs of electrons correct **(1)** • nitrogen and one oxygen joined by a double bond, all pairs of electrons correct **(1)** • all other electron pairs correct **(1)**	Allow 2N=O scores M2 but not M3 The arrangement on the oxygen atoms bonded solely to the nitrogen can be shown the other way round. Lone pairs of electrons do not have to be grouped together	**(3)**

Q10.

Question Number	Answer	Additional Guidance	Mark
	• electrons for double bond, single bond and lone pair around N (1) • rest of electrons on Cl and O (1)	Example of dot-and-cross diagram  Allow any combination of dots/crosses/triangles for electrons Allow bond pairs in double bond shown horizontally Ignore lines drawn between atoms to show covalent bonds	**(2)**

Q11.

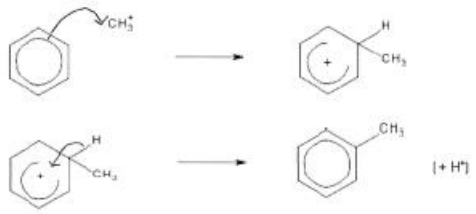
Question Number	Answer	Additional Guidance	Mark
(i)	• dot-and-cross diagram **and** charges	Example of diagram  Circles are not needed Allow no electrons or 8 electrons on outer shell of Mg Allow dots or crosses for all electrons Allow diagrams without square brackets, provided charges are shown Allow alternative ways of showing that there are 2 bromide ions Ignore inner shell electrons	(1)

Question Number	Answer	Additional Guidance	Mark
(ii)	• (conducts electricity when) molten / liquid **and** dissolved in water / (in) aqueous (solution)	Both needed for the mark Ignore gaseous Allow 'in solution / dissolved'	(1)

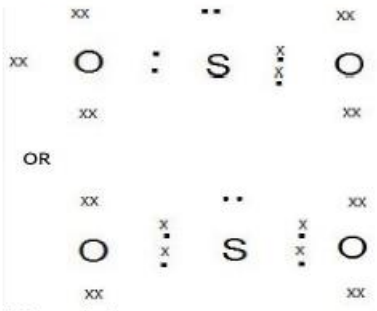
Q12.

Question Number	Answer	Additional Guidance	Mark
(i)	• dot-and-cross diagram	Example of diagram  Allow electrons in overlapping circles Allow all dots / all crosses Ignore inner shell electrons, even if incorrect Ignore lines as bonds e.g. x • Do not award diagram with lone pair on Al	(1)

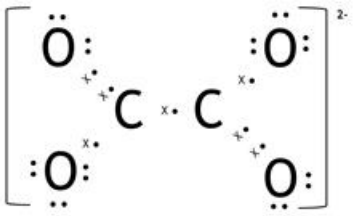
Question Number	Answer	Additional Guidance	Mark
(ii)	An answer that makes reference to the following points: • shape – trigonal planar (1) • bond angle - 120° (1)	Mark independently Both words needed Allow triangular for trigonal – but not just tri Allow marks for labelled diagram **Note** If shape is pyramidal, no mark for M1 but allow (1) for 107° No TE for any other shape	(2)

Question Number	Answer	Additional Guidance	Mark
(iii)	• equation for the formation of the electrophile (1) (1) • curly arrow from on or within the circle to CH_3^+ • structure of intermediate including charge with some part of the charge within the horseshoe **and** horseshoe covering at least 3 carbon atoms **and** facing the tetrahedral carbon (1) (1) • curly arrow from C-H bond to anywhere in the hexagon reforming the delocalised structure	Example of mechanism $CH_3Cl + AlCl_3 \rightarrow CH_3^+ + [AlCl_4]^-$  Allow $AlCl_4^-$ / $^{\delta+}CH_3\text{-}AlCl_4^{\delta-}$ Allow curly arrow from anywhere within the hexagon Allow curly arrow to any part of CH_3^+, including the + charge Do not award curly arrow from outside the hexagon Allow dotted / dashed lines for horseshoe Do not award dotted bonds to H and CH_3 unless clearly part of a 3D structure Ignore any involvement of $AlCl_4^-$ in the final step /HCl **Note** Correct Kekulé structures score full marks	(4)

Q13.

Question Number	Answer	Additional Guidance	Mark
	• correct dot-and-cross diagram	Example of dot-and-cross diagrams  OR Allow all dots or crosses Do not allow 3 electron S-O bonds Ignore lines shown as bonds Ignore inner electrons if shown, provided outer electrons are clear	(1)

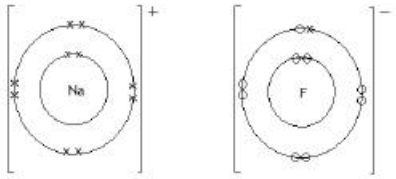
Q14.

Question Number	Answer	Additional Guidance	Mark
(i)	• double C=O bond on left and right hand side **(1)** • rest of diagram **(1)**		(2)

Question Number	Answer	Additional Guidance	Mark
(ii)	• (+) 3	Allow 3+ / +III / III+ / III / three Ignore working out Do not award ±3	(1)

Q15.

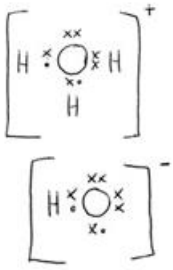
Question Number	Answer	Mark
(i)	**The only correct answer is B** ***A*** *is not correct because fluorine is diatomic* ***C*** *is not correct because sodium is* 1^+ *ion* ***D*** *is not correct because fluorine is diatomic*	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	A diagram which shows the first two points: • electronic configuration for Na is 2.8 and +1 charge **(1)** • electronic configuration for F is 2.8 and -1 charge **(1)** • isoelectronic ions have the same electronic configuration **(1)**	Example of diagram  Allow one mark if both ions have eight electrons in their outer shell if M1 and M2 not scored OR Both with correct charge if M1 and M2 not scored. Do not award either mark for a covalent bond Ignore balancing numbers Allow same number of electrons	**(3)**

Question Number	Answer	Mark
(iii)	**The only correct answer is A** ***B*** *is not correct because diagram has cations larger than anions* ***C*** *is not correct because diagram has cations larger than anions* ***D*** *is not correct because trends in wrong direction*	**(1)**

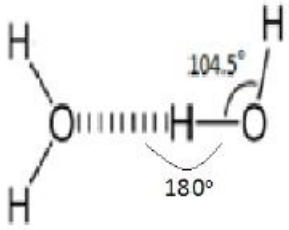
Question Number	Acceptable Answer	Additional Guidance	Mark
(iv)	• increase in number of protons (in the nucleus) **(1)** • increases the attraction for the electrons (bringing them closer to the nucleus) **(1)**	Allow increasing nuclear charge For explanations of graph B allow max (1) for a correct explanation for any downward trend for three ions Allow max (1) for an explanation of the smallest or largest ion without an explanation of the trend e.g. Al^{3+} has the most protons so electrons most attracted to nucleus so smallest scores (1) Discussion of atomic radius max (1)	**(2)**

Q16.

Question Number	Answer	Additional Guidance	Mark
	Two diagrams • oxonium ion **(1)** • hydroxide ion **(1)**	Examples of suitable diagrams  Ignore inner 'shell' of two electrons Ignore missing brackets Ignore covalent circles Penalise all dots or all crosses or use of other symbols for electrons once only Penalise omission of charges once only	**(2)**

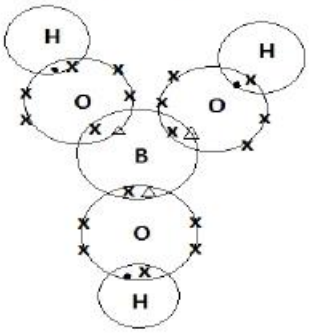
Q17.

Question Number	Answer	Mark
(i)	**The only correct answer is C** ***A*** *is not correct because oxygen does have a higher mass number but it is not the cause of polarity* ***B*** *is not correct because oxygen does have a larger atomic radius but it is not the cause of polarity* ***D*** *is not correct because oxygen does have more electrons but this is not the cause of polarity*	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	 • correct shape of two water molecules and hydrogen bond show at about 180 ° but not necessarily labelled **(1)** • HOH bond angle 104.5° and OHO angle 180° **(1)**	Allow about 10° tolerance by eye. Allow 104 – 105°	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to two of the following points: • more open / more space between molecules (making it less dense) **(1)** • due to (3 Dimensional) lattice / ring structure in ice **(1)** • hydrogen bonds longer than the covalent bonds **(1)**	 Do not award MP1 if the gaps are full of air molecules May be shown as a diagram Allow reverse arguments for liquid water	**(2)**

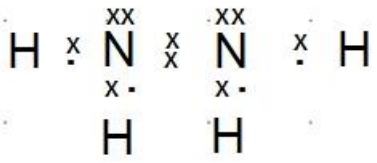
Q18.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	• all 6 bonding pairs correct **(1)** • 2 lone pairs on each O and no additional electrons on boron or hydrogen **(1)**	Example of diagram  Non-bonding electrons on O can be shown as pairs, all 4 together or as 3 and 1 Electrons in overlap regions can be on the lines or the gaps between the lines Allow (1) for electrons in correct places but incorrect symbols for electrons Ignore inner shell electrons shown on B and/or O **Note** If any double bonds are shown the answer scores (0)	**(2)**

Question Number	Answer	Mark
(ii)	**The only correct answer is C** ***A*** *is incorrect because 109.5° is incorrect* ***B*** *is incorrect because 109.5° and 180° are incorrect* ***D*** *is incorrect because 180° is incorrect*	**(1)**

Q19.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	A description that makes reference to the following points: • (electrostatic / electric(al)) attraction of (two) **nuclei** **(1)** • with a shared pair /2 electrons **(1)**	Allow a pair of electrons between the nuclei	**(2)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	• correct dot and cross diagram	 Allow diagram with all dots, all crosses, dots and crosses in reversed order, or a mix of dots and crosses Allow non-bonding pairs on N to be shown separated Allow H at any position around N Ignore circles used to show shells Ignore inner electrons if shown Ignore lines representing bonds	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	• bond angle = 107°	Allow angles in the range 105 to 108°	**(1)**

Q20.

Question Number	Answer	Additional Guidance	Mark
(i)	An explanation that makes reference to the following points: • (pyramidal / this shape) because there are 4 pairs / 3 bond pairs and one lone pair of electrons (around central / P atom) **and** these are arranged to minimise repulsion **(1)** • (bond angle less than 109.5°) as lone pair-bond pair repulsion is greater than bond pair-bond pair repulsion **(1)**	'ions' scores (0) overall Allow the electron pairs are arranged to minimise repulsion Allow (4) pairs of electrons with maximum separation / as far apart as possible Ignore reference to 'bonds' Ignore wrong shape Ignore repel equally Ignore repulsion between electrons There must be a comparison in M2 Allow lone pairs have greater repulsion than bond pairs Ignore just 'the lone pairs repel more' Ignore repetition of the question e.g. 'reduces the bond angle' Ignore incorrect bond angle stated (Data book value is 100.1°) Do not allow bond angle >109.5°	**(2)**

Question Number	Answer	Mark
(ii)	**The only correct answer is D** ***A*** *is not correct because both incorrect* ***B*** *is not correct because non-polar bond is incorrect* ***C*** *is not correct because non-polar molecule is incorrect*	**(1)**

Q21.

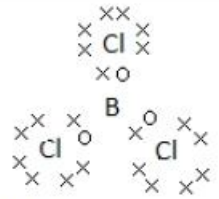
Question Number	Answer	Mark
(i)	**The only correct answer is C** (120° and 109.5°) ***A*** *is incorrect because both angles are incorrect* ***B*** *is incorrect because 90° is incorrect* ***D*** *is incorrect because 109.5° is incorrect for the left hand O–C–H angle*	**(1)**

Question Number	Answer	Mark
(ii)	**The only correct answer is D** (atm^{-1}) ***A*** *is incorrect because it is the inverse of the units for* K_C ***B*** *is incorrect because it is the units for* K_C ***C*** *is incorrect because it is the inverse of the units for* K_p	**(1)**

Question Number	Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following points • K_p will remain unchanged **(1)** • equilibrium moves to right-hand side (to keep K_p constant) / only temperature affects K_p **(1)**	Allow answers in terms of quotient Do not award M2 if K_p is described as changing Ignore comments related to rate	**(2)**

Q22.

Question Number	Acceptable Answer	Additional Guidance	Mark
(i)	$2B + 3Cl_2 \rightarrow 2BCl_3$	Allow multiples Ignore state symbols even if incorrect	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(ii)	 ALLOW All dots or all crosses	Ignore inner shell electrons and circles	**(1)**

Question Number	Acceptable Answer	Additional Guidance	Mark
(iii)	An explanation that makes reference to the following points: • 3 bonding pairs of electrons (bonding environments) (and no non-bonding / lone pairs of electrons in the outer shell of boron) **(1)** • (the bonding pairs of electrons) move apart to minimise repulsion **(1)**	Accept 3 pairs of electrons Do not award 3 bonding pairs repel each other equally Accept move as far apart as possible / maximise separation	**(2)**