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)

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(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)

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(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)

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(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)

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(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)

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(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)

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(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)

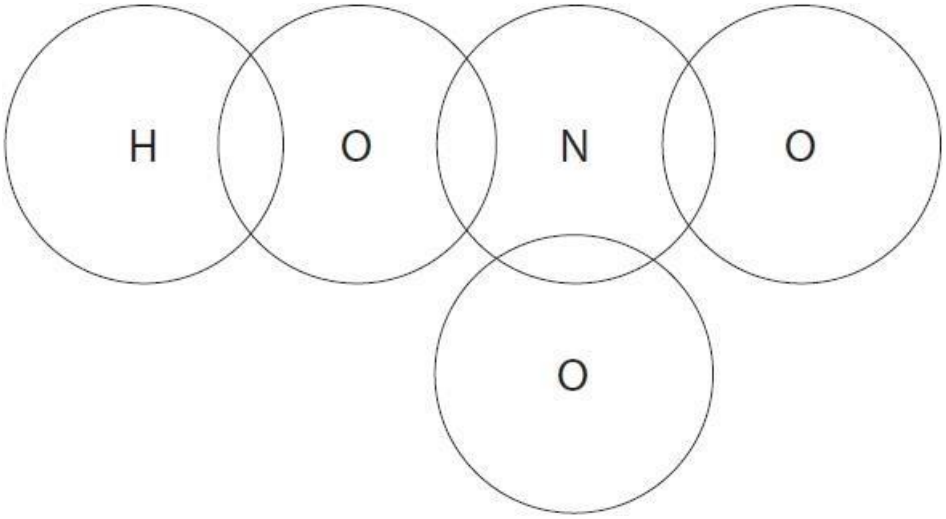
Q9.

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)



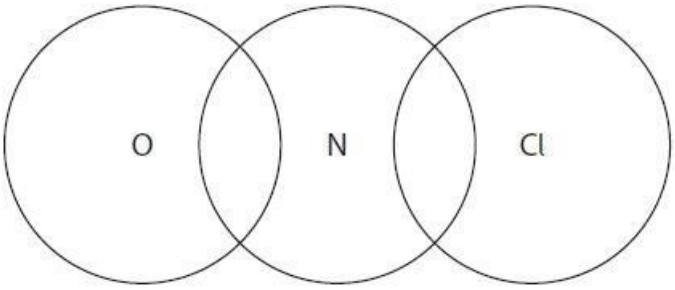
(Total for question = 3 marks)

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)

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(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.

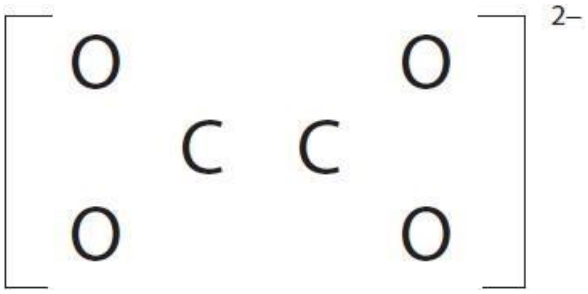
- Five tablets were dissolved in distilled water to make 100.0 cm^3 of solution.
- Some of the $KMnO_4$ solution was used to fill a burette.
- 25.0 cm^3 of sodium ethanedioate solution, $Na_2C_2O_4(aq)$, of concentration 0.200 mol dm^{-3}, was added to a conical flask and warmed.
- Sulfuric acid, of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

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(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)

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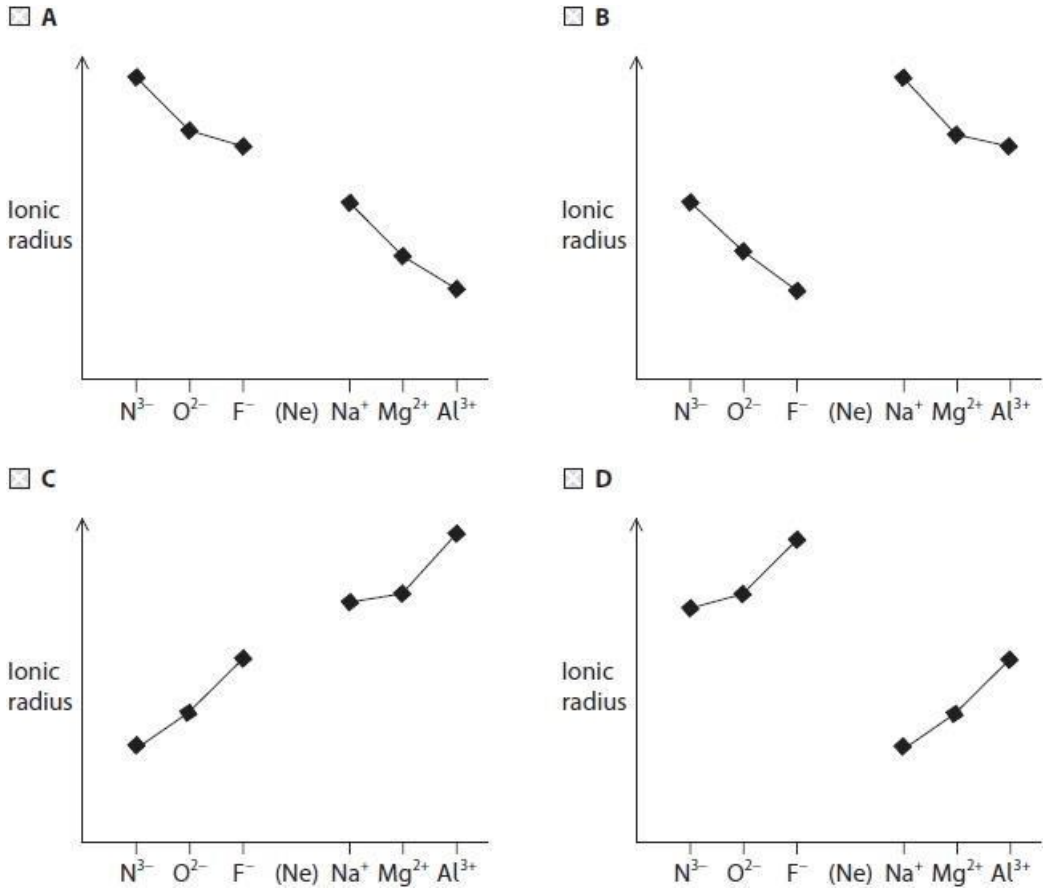
(iii) Which diagram shows the trend in ionic radius for the isoelectronic ions N^{3-} to Al^{3+}?

(1)



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

(2)

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(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)

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(Total for question = 5 marks)

Q18.

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

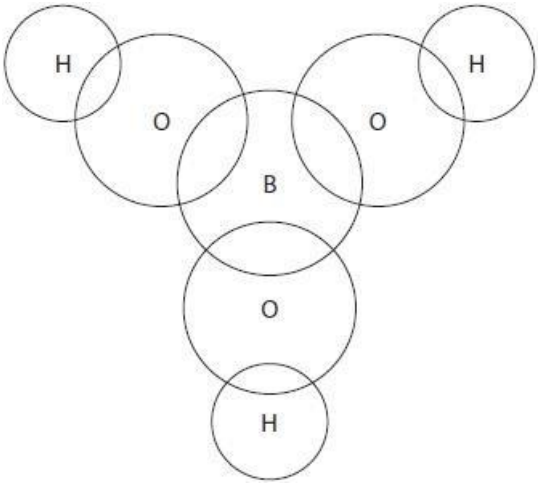
The formula of boric acid can also be written as $B(OH)_3$.

(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)

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(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)

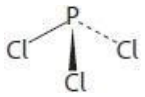
Bond angle = ...

(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)

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(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.

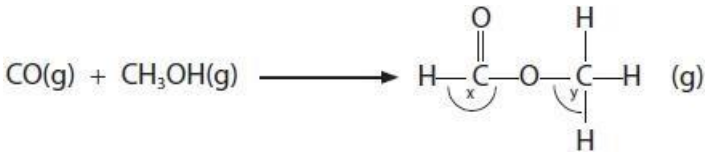
Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

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)

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(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)

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(Total for question = 4 marks)