

Q1. Chlorine can form molecules and ions that contain only chlorine, or that contain chlorine combined with another element.

- (a) Use your understanding of the electron pair repulsion theory to draw the shape of the AsCl_3 molecule and the shape of the Cl_3^+ ion. Include any lone pairs of electrons that influence the shape.

Name the shape made by the atoms in the AsCl_3 molecule and in the Cl_3^+ ion.

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(4)

- (b) Explain why the AsCl_4^+ ion has a bond angle of 109.5° .

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(2)

(Total 6 marks)

Q2. Fluorine and iodine are elements in Group 7 of the Periodic Table.

(a) Explain why iodine has a higher melting point than fluorine.

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(2)

(b) (i) Draw the shape of the NHF_2 molecule and the shape of the BF_3 molecule. Include any lone pairs of electrons that influence the shape. In each case name the shape.

Shape of NHF_2

Shape of BF_3

Name of shape of NHF_2

Name of shape of BF_3

(4)

(ii) Suggest a value for the F—N—F bond angle in NHF_2

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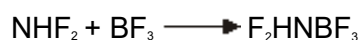
(1)

(c) State the strongest type of intermolecular force in a sample of NHF_2

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(1)

(d) A molecule of NHF_2 reacts with a molecule of BF_3 as shown in the following equation.



State the type of bond formed between the N atom and the B atom in F_2HNBF_3 .

Explain how this bond is formed.

Name of type of bond

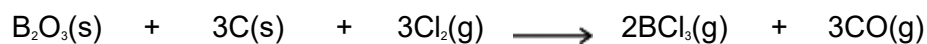
How bond is formed

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(2)
(Total 10 marks)

Q3. (a) Boron trichloride (BCl_3) can be prepared as shown by the following equation.



A sample of boron oxide (B_2O_3) was reacted completely with carbon and chlorine. The two gases produced occupied a total volume of 5000 cm^3 at a pressure of 100 kPa and a temperature of 298 K.

Calculate the mass of boron oxide that reacted.
Give your answer to 3 significant figures.

(The gas constant $R = 8.31 \text{ J K}^{-1} \text{ mol}^{-1}$)

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(5)

(b) Boron trichloride can also be prepared from its elements.

Write an equation for this reaction.

Explain why boron trichloride has a trigonal planar shape with equal bond angles.

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(3)

(c) (i) Boron trichloride is easily hydrolysed to form two different acids as shown in the following equation.



Calculate the concentration, in mol dm⁻³, of hydrochloric acid produced when 43.2 g of boron trichloride are added to water to form 500 cm³ of solution.

Give your answer to 3 significant figures.

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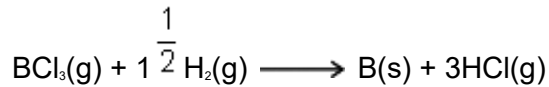
(4)

- (ii) Boric acid (H_3BO_3) can react with sodium hydroxide to form sodium borate and water.
Write an equation for this reaction.

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(1)

- (d) Boron trichloride can be reduced by using hydrogen to form pure boron.



Calculate the percentage atom economy for the formation of boron in this reaction.

Apart from changing the reaction conditions, suggest **one** way a company producing pure boron could increase its profits from this reaction.

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(3)

- (e) A different compound of boron and chlorine has a relative molecular mass of 163.6 and contains 13.2% of boron by mass.

Calculate the molecular formula of this compound.
Show your working.

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(4)
(Total 20 marks)

Q4. Fluorine forms compounds with many other elements.

- (a) Fluorine reacts with bromine to form liquid bromine trifluoride (BrF₃).
State the type of bond between Br and F in BrF₃ and state how this bond is formed.

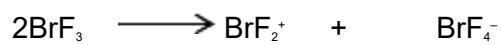
Type of bond

How bond is formed

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(2)

- (b) Two molecules of BrF₃ react to form ions as shown by the following equation.



- (i) Draw the shape of BrF₃ and predict its bond angle.
Include any lone pairs of electrons that influence the shape.

Shape of BrF₃

Bond angle

(2)

- (ii) Draw the shape of BrF_4^- and predict its bond angle.
Include any lone pairs of electrons that influence the shape.

Shape of BrF_4^-

Bond angle

(2)

- (c) BrF_4^- ions are also formed when potassium fluoride dissolves in liquid BrF_3 to form KBrF_4 .
Explain, in terms of bonding, why KBrF_4 has a high melting point.

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(3)

- (d) Fluorine reacts with hydrogen to form hydrogen fluoride (HF).

- (i) State the strongest type of intermolecular force between hydrogen fluoride molecules.

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(1)

- (ii) Draw a diagram to show how two molecules of hydrogen fluoride are attracted to each other by the type of intermolecular force that you stated in part (d)(i). Include all partial charges and all lone pairs of electrons in your diagram.

(3)

- (e) The boiling points of fluorine and hydrogen fluoride are $-188\text{ }^{\circ}\text{C}$ and $19.5\text{ }^{\circ}\text{C}$ respectively. Explain, in terms of bonding, why the boiling point of fluorine is very low.

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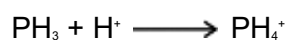
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(Total 15 marks)

Q5. The following equation shows the reaction of a phosphine molecule (PH_3) with an H^+ ion.



- (a) Draw the shape of the PH_3 molecule. Include any lone pairs of electrons that influence the shape.

(1)

- (b) State the type of bond that is formed between the PH_3 molecule and the H^+ ion. Explain how this bond is formed.

Name of bond

How bond is formed

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(2)

(c) Predict the bond angle in the PH_4^+ ion.

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(1)

(d) Although phosphine molecules contain hydrogen atoms, there is no hydrogen bonding between phosphine molecules. Suggest an explanation for this.

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(1)

(Total 5 marks)