1 This question is about compounds of Group 3 elements.

(a) Aluminium will combine directly with fluorine.

Write the equation for the reaction between aluminium and fluorine.

..... **[1]**

(b) Solid aluminium fluoride has a giant ionic lattice structure.

(i) Describe what is meant by the term *ionic lattice*, in terms of the type and arrangement of particles present.

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..... **[2]**

(ii) Draw a '*dot-and-cross*' diagram for aluminium fluoride.

Show outer electrons only.

[2]

(c) Solid boron tribromide has a simple molecular lattice structure. The atoms are held together by covalent bonds.

(i) What is meant by the term *covalent bond*?

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..... **[1]**

(ii) Draw a '*dot-and-cross*' diagram to show the bonding in a boron tribromide molecule.

Show outer electrons only.

[1]

(d) State whether the following substances conduct electricity when solid or molten, and explain your answers in terms of the particles involved:

- aluminium
- aluminium fluoride
- boron tribromide.

In your answer you should use appropriate technical terms, spelled correctly.

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..... **[5]**

(e) Aluminium has 13 successive ionisation energies.

(i) Write the equation for the **third** ionisation energy of aluminium.

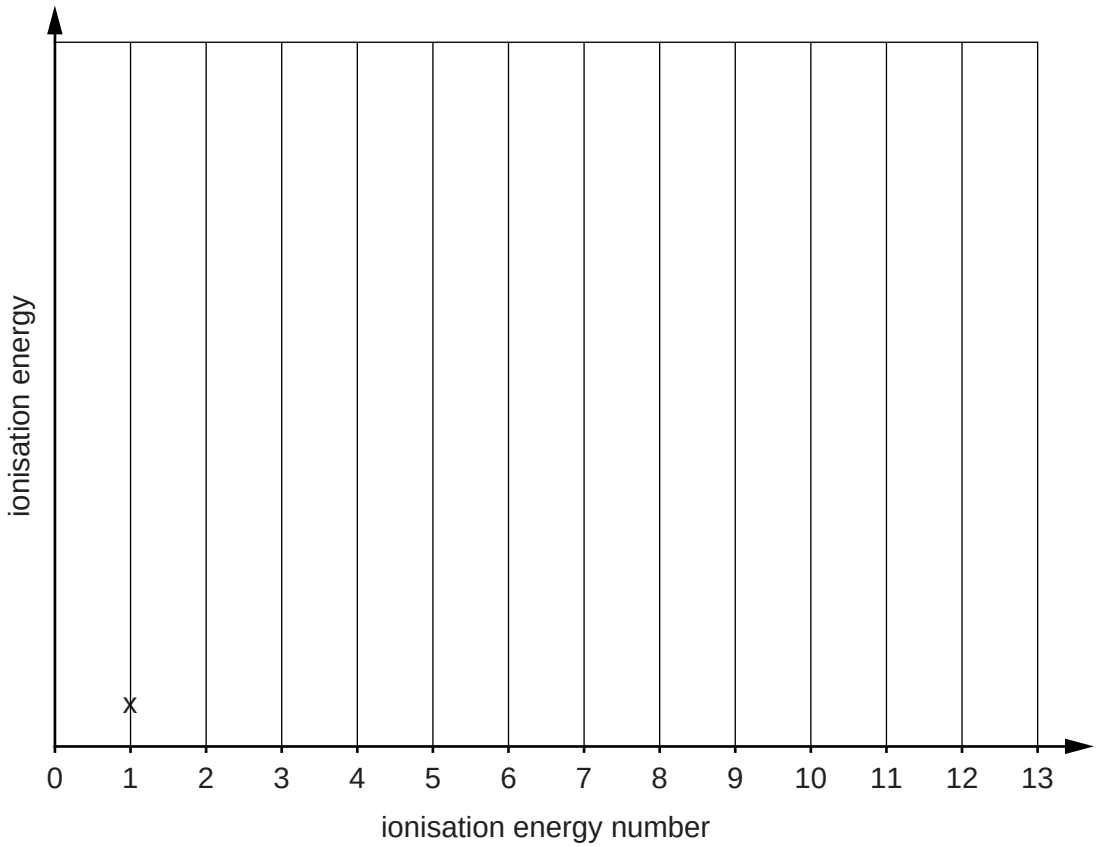
Include state symbols.

..... **[1]**

(ii) On the axes below, add crosses to show the 13 successive ionisation energies of aluminium.

The value for the first ionisation energy has been completed for you.

You do not have to join the crosses.



[2]

[Total: 15]

2 This question is about the attraction between particles.

(a) State how and explain why the attraction between nuclei and outermost electrons in gaseous atoms varies across Period 3.

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..... **[2]**

(b) The table shows the boiling points of ammonia, fluorine and bromine.

	Boiling point / °C
ammonia, NH_3	– 33
fluorine, F_2	– 188
bromine, Br_2	59

Explain the different boiling points of NH_3, F_2 and Br_2.

Include the names of any relevant forces and particles.

In your answer you should use appropriate technical terms, spelled correctly.

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..... **[5]**

[Total: 7]

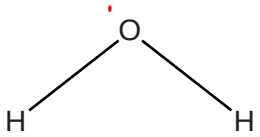
3 Oxides can have different types of bonding.

(a) H_2O has hydrogen bonding.

(i) Complete the diagram below to show hydrogen bonding between the H_2O molecule shown and **one** other H_2O molecule.

Include relevant dipoles and lone pairs.

Label the hydrogen bond.



[2]

(ii) State and explain **two** anomalous properties of ice caused by hydrogen bonding.

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[4]

(b) Draw a *'dot-and-cross'* diagram to show the bonding in CO_2.

Show outer electrons only.

[1]

(c) Silicon dioxide, SiO_2, has the same structure and bonding as diamond.

State the structure and bonding in SiO_2.

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..... **[1]**

(d) Describe and explain the electrical conductivity of sodium oxide, Na_2O, and sodium in their solid and molten states.

In your answer you should use appropriate technical terms, spelled correctly.

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..... **[5]**

[Total: 13]

4 The hydrides of Group 5 elements all exist as gases at room temperature.

(a) Phosphine gas, PH_3, can be prepared by adding phosphorus, P_4, to warm concentrated aqueous sodium hydroxide as shown in the equation below.

$$P_4(s) + 3NaOH(aq) + 3H_2O(l) \rightarrow PH_3(g) + 3NaH_2PO_2(aq)$$

(i) Using oxidation numbers, explain why this is a disproportionation reaction.

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..... **[3]**

(ii) A chemist reacts 1.86 g of P_4 with excess NaOH(aq).

Calculate the volume of phosphine gas, in cm^3, produced at room temperature and pressure, RTP.

volume of phosphine gas = ... cm^3 **[2]**

(b) Phosphine gas burns in air to form an oxide of phosphorus, P_4O_{10}, and water.

Write the equation for this reaction.

..... **[1]**

(c) Phosphoric acid, H_3PO_4, can be made by reacting P_4O_{10} with water.

Sodium phosphate, Na_3PO_4, is a salt that can be prepared by reacting H_3PO_4 with sodium hydroxide, NaOH.

A student prepared a solution of Na_3PO_4 by reacting 15.0 cm^3 of 0.100 mol dm^{-3} H_3PO_4 with 0.200 mol dm^{-3} NaOH.

(i) Why is Na_3PO_4 described as a salt of H_3PO_4?

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..... **[1]**

(ii) Calculate the amount, in moles, of H_3PO_4 in 15.0 cm^3 of 0.100 mol dm^{-3} H_3PO_4.

amount = ... mol **[1]**

(iii) The equation for the preparation of Na_3PO_4 from NaOH and H_3PO_4 is shown below.

$$3NaOH(aq) + H_3PO_4(aq) \rightarrow Na_3PO_4(aq) + 3H_2O(l)$$

Calculate the volume of 0.200 mol dm^{-3} NaOH that reacts exactly with 15.0 cm^3 of 0.100 mol dm^{-3} H_3PO_4.

volume = ... cm^3 **[1]**

(d) Ammonia, NH_3, is another gaseous Group 5 hydride.

NH_3 and PH_3 are both simple molecules. The boiling points of NH_3 and PH_3 are shown in the table below.

Group 5 hydride	Boiling point / °C
NH_3	–33
PH_3	–88

(i) Complete the table below to show the main intermolecular forces present in NH_3 and PH_3.

Group 5 hydride	Main intermolecular force
NH_3	
PH_3	

[2]

(ii) Suggest why PH_3 has a lower boiling point than NH_3.

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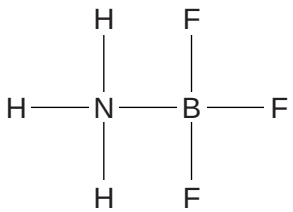
..... **[1]**

(e) NH_3 reacts with molecules of BF_3 to form H_3NBF_3, shown below.

One of the bonds in H_3NBF_3 is a dative covalent bond.



(i) A covalent bond is a shared pair of electrons.

What is a *dative* covalent bond?

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..... **[1]**

(ii) Draw a '*dot-and-cross*' diagram to show the bonding in H_3NBF_3.

Label the dative covalent bond in your diagram.

Show **outer** electrons only.

[2]

(iii) The F–B–F bond angle in BF_3 is different from the F–B–F bond angle in H_3NBF_3.

Complete the table to predict the F–B–F bond angles in BF_3 and in H_3NBF_3.

Molecule	**F–B–F bond angle / °**
BF_3	
H_3NBF_3	

[2]

(iv) The H–N–H bond angle in NH_3 is 107°. A student predicted that the H–N–H bond angle in H_3NBF_3 is larger.

Explain why the student might expect the H–N–H bond angle to be larger in H_3NBF_3 than in NH_3.

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..... **[3]**

[Total: 20]