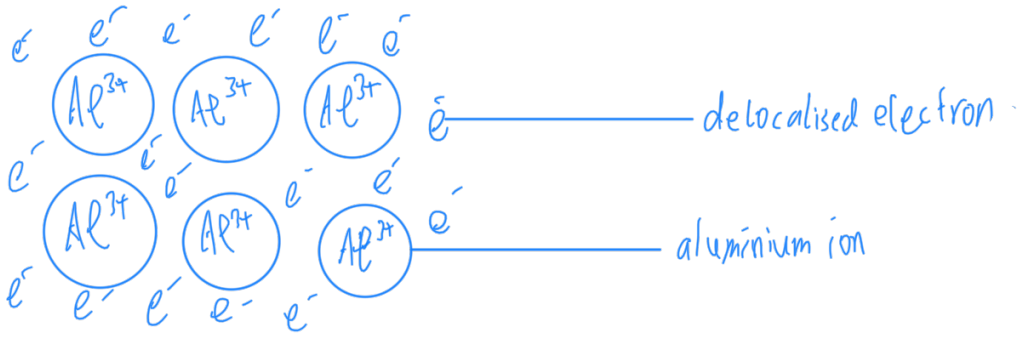
2 Aluminium is a Group III element. Its atomic number is 13.

(a) **(i)** Complete the electronic configuration of an atom of aluminium.

$1s^2$ $2s^2 2p^6 3s^2$ [1]

(ii) Aluminium conducts electricity in the solid state.

With the aid of a labelled diagram of the structure of aluminium, explain how aluminium conducts electricity in the solid state.



When a voltage is applied all the delocalised electrons in aluminium move in one direction, hence conducting an electric current. [2]

(b) The table shows the formulae and melting points of two compounds formed by aluminium.

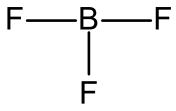
compound	formula	melting point / °C	solubility
aluminium chloride	$AlCl_3$	192	soluble in water
aluminium fluoride	AlF_3	1290	soluble in water

Explain, in terms of structure and bonding, why the melting point of $AlCl_3$ is much lower than that of AlF_3.

Fluorine is more electronegative than chlorine, hence AlF_3 forms stronger ionic bonds than Al-Cl bonds in $AlCl_3$. Due to the low electronegativity value of $AlCl_3$ as a result, $AlCl_3$ is a covalent molecule. Hence, AlF_3 is held in a giant ionic lattice structure where $AlCl_3$ has a simple molecular structure. Therefore, more energy is required to break the strong ionic bonds between aluminium and fluoride ions than the weak intermolecular forces of attraction between $AlCl_3$ molecules, hence $AlCl_3$ has a much lower melting point than AlF_3 [3]

(c) Boron is also a Group III element.

Boron trifluoride, BF_3, is an 'electron deficient' compound formed by boron and fluorine.



(i) State the number of outer electrons surrounding the boron atom in a BF_3 molecule.

Hence, explain why BF_3 is 'electron deficient'.

6 outer electrons are surrounding the boron atom in BF_3. Since B in BF_3 does not form a noble gas electronic configuration with 8 valence electrons, BF_3 is 'electron deficient'. [2]

(ii) Draw a 'dot-and-cross' diagram for BF_3, showing outer electrons only.

[2]

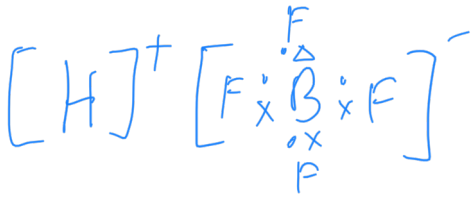
* **(d)** Boron trifluoride reacts with water to give boric acid, $B(OH)_3$, and tetrafluoroboric acid, HBF_4.

(i) $B(OH)_3$ is a Lewis acid.

Write a balanced equation for the ionisation of $B(OH)_3$ in water to form ions.

$B(OH)_3 \rightarrow H^+ + B(OH)_4^-$ [1*]

(ii) Draw a 'dot-and-cross' diagram for HBF_4, showing outer electrons only.



[1*]

[Total: 10 + 2*]

3 One type of airbag used in cars contains solid sodium azide, NaN_3. If the car is involved in a collision, a sensor creates an electric spark in the airbag to cause the sodium azide to decompose, producing solid sodium and nitrogen gas, which inflates the airbag:

$$2NaN_3(s) \rightarrow 2Na(s) + 3N_2(g)$$

100g

(a) An airbag contains 100 g of solid sodium azide.

Calculate the volume of nitrogen gas produced at room temperature and pressure.

[molar mass of NaN_3 = 65.0 g mol^{-1}; one mole of any gas occupies 24.0 dm^3 at r.t.p.]

Number of moles of NaN_3 = 100 ÷ 65.0
= 1.5385 mol

Mole ratio $NaN_3 : N_2 = 2 : 3$

Number of moles of N_2 = (1.5385 ÷ 2) × 3
= 2.3078 mol

Volume of N_2 gas produced = 2.3078 × 24.0
= 55.4 dm^3

[3]

(b) Another type of airbag contains solid sodium azide and solid potassium nitrate. The purpose of the potassium nitrate is to react with the sodium produced in the first reaction to form more nitrogen:

$NaN_3 : Na = 1 : 1$

$$10Na(s) + 2KNO_3(s) \rightarrow K_2O(s) + 5Na_2O(s) + N_2(g)$$

An airbag contains x g of sodium azide and y g of potassium nitrate.

Calculate the ratio of $\frac{x}{y}$ in order that no solid sodium, sodium azide or potassium nitrate remains after the reactions.

Mole ratio $NaN_3 : Na$ in first reaction = 1 : 1
= 5 : 5

Mole ratio $Na : KNO_3$ in second reaction = 5 : 1

∴ Mole ratio $NaN_3 : KNO_3 = 5 : 1$

∴ Mass ratio $NaN_3 : KNO_3 = 5 \times 65.0 : 1 \times (39 + 14 + 16 \times 3)$
= 325.0 : 101

$\therefore \frac{x}{y} = \frac{325}{101}$

[3]

3 **(c)** Suggest the chemical formula of magnesium azide.

$Mg(N_3)_2$

[1]

[Total: 7]