# Structure and bonding in aluminium chloride

## Specification reference

- *2.2.2 a) b) c) d) e) (i) g) h) j) (i)*

## Introduction

Aluminium chloride ($AlCl_3$) is an unusual compound. Aluminium, in Group 3 of the periodic table is a metal and chlorine is a non-metal, so you would expect the bonding in aluminium chloride to be ionic; however this is not always the case. In this activity you will investigate the bonding of aluminium chloride in its different states, applying knowledge that you have gained throughout 'Chapter 5: Electrons and bonding'.

## Learning outcomes

After completing the worksheet you should be able to:

- construct dot-and-cross diagrams for ionic and covalent compounds
- explain the structure of giant ionic lattices, resulting from oppositely charged ions strongly attracted in all directions
- explain the effect of structure and bonding on the physical properties of ionic and covalent compounds
- predict and explain the shapes of molecules, using electron pair repulsion theory
- draw 3-D diagrams of molecules.

## Background

In solid aluminium chloride ionic bonding is observed, and solid aluminium chloride shows the expected properties of an ionic solid. However, when aluminium chloride is heated to temperatures above 180 °C, it sublimes (turns directly from a solid to a gas) and the structure and bonding changes dramatically. Covalent bonds now exist between aluminium and chlorine atoms. As a result, molecules of aluminium chloride are formed. These are found to have the formula $Al_2Cl_6$, and are also found in liquid aluminium chloride. At higher temperatures still, molecules of $AlCl_3$ are formed.

Chemists have found that the $Al_2Cl_6$ is a dimer – that is, it consists of two $AlCl_3$ molecules joined together. The structure is thought to be that shown in Figure 1.

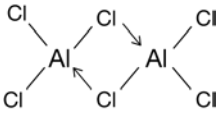


**Figure 1** *The structure of the aluminium chloride dimer*

The ability of aluminium to bond covalently under certain circumstances means that aluminium chloride can show some unusual chemical reactions. It reacts violently with water releasing HCl gas and eventually forming hydrated aluminium ions, $Al(H_2O)_6^{3+}$. It is also a very important catalyst in a reaction called the Friedel–Crafts reaction, which is used in the synthesis of organic molecules, allowing carbon chains to join onto benzene rings.

## Questions

**1** **a** Draw a dot-and-cross diagram to show the structure of the ions in solid aluminium chloride (outer shell only). (*2 marks*)

**b** The ionic lattice has a structure in which six chloride ions surround one aluminium ion, in an octahedral arrangement. Draw a 3D diagram to show this arrangement. (*2 marks*)

**c** Solid aluminium chloride has the empirical formula $AlCl_3$. Use the information in part **b** to suggest how many aluminium ions surround each chloride ion in the ionic lattice. Explain your answer. (*2 marks*)

**2** At high temperatures, molecules of $AlCl_3$ are formed.

**a** Draw a dot-and-cross diagram to show the bonding in an $AlCl_3$ molecule, showing outer electrons only. (*2 marks*)

**b** Predict, using your dot and cross diagram, the shape of the $AlCl_3$ molecule, and suggest a value for the bond angle. (*1 mark*)

**3** When solid $AlCl_3$ is heated just above 180 °C, molecules of $Al_2Cl_6$ are formed.

**a** Look at the diagram of the $Al_2Cl_6$ molecule shown in Figure 1. Explain the meaning of the arrows pointing from some of the chlorine atoms to the aluminium atom. (*2 marks*)

**b** Draw a dot-and-cross diagram to show the bonding in the molecule $Al_2Cl_6$. (*2 marks*)

**c** Using information from your dot-and-cross diagram, draw the 3D structure of the $Al_2Cl_6$ molecule, making a prediction for any bond angles in the molecule. (*3 marks*)

**4** Aluminium chloride has a relatively low melting point compared to other ionic compounds.

**a** Discuss one way in which you would expect aluminium chloride to be similar to, and one way in which you would expect it to differ from, the typical properties of ionic compounds, other than its melting and boiling points. (*6 marks*)

**b** The bonding in aluminium chloride is sometimes described as ‘ionic with some covalent character’. The bonding in magnesium chloride does not have significant covalent character. Suggest two differences between aluminium and magnesium ions that might explain the different types of bonding observed in these compounds. (*2 marks*)