

IONIC, COVALENT and METALLIC BONDING

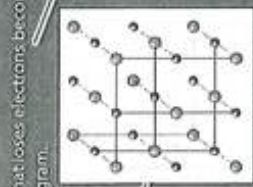
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BONDING IN IONIC CRYSTALS

Ionic bonds form when at least one electron is **transferred** from one atom to another. An atom that loses electrons becomes a positive ion; one that gains electrons becomes a negative ion, as shown in this **dot-and-cross** diagram.

The **electrostatic** attraction between positive and negative ions is the ionic bond. The force acts in **all directions**. Ionic compounds consist of very many positive and negative ions in giant lattices. They have **high melting points** because the many strong forces need a lot of energy to overcome.

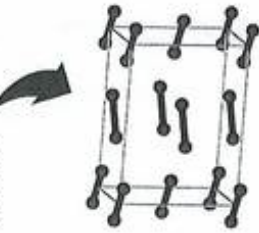
Ionic solids **do not conduct electricity** because ions are fixed in a lattice and cannot carry charge from place to place. When molten or in solution, however, the ions can move and so **do** conduct electricity.



Na and Cl ions in a lattice

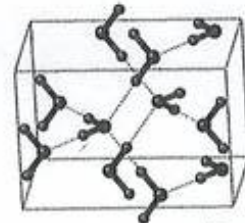
BONDING IN MOLECULAR CRYSTALS

The **dot-and-cross** diagram shows a Cl-Cl bond forming from two Cl atoms. Iodine atoms bond in the same way to form iodine molecules (I₂). At room temperature, Cl₂ is a gas but I₂ is a solid. The I₂ molecules are arranged in a lattice called a **molecular crystal** as shown here.



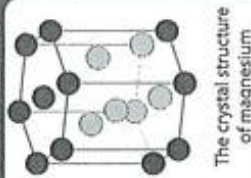
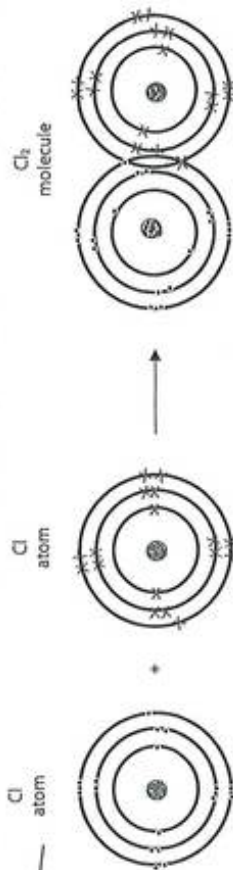
Although the covalent bonds within each molecule are strong, the forces between molecules (in this case induced dipole-dipole) are weak and so molecular crystals have quite low melting points. Since the molecules do not have electrical charge, they never conduct electricity (even when molten or in solution).

Ice is a molecular crystal. The forces between H₂O molecules are **hydrogen bonds**. These are stronger than induced dipole-dipole forces but weaker than covalent bonds. Water has a melting point that is unusually high for a small molecule, but nowhere near as high as a macromolecule like diamond.



BONDING IN METALLIC CRYSTALS

Metals form crystal structures in which the **outer-shell** electrons of the metal atoms are **delocalised** throughout a lattice, allowing metals to **conduct electricity**. Positive metal ions are held in the lattice by forces of **electrostatic attraction** to the negative, delocalised electrons. These forces are strong, giving metals **high melting points**.



The crystal structure of magnesium

EXAM TIP

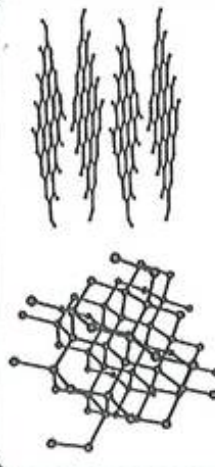
You may be asked to draw any of the diagrams of crystals on this page

MACROMOLECULAR (GIANT COVALENT) CRYSTALS

Macromolecular crystals are different from molecular crystals because the entire crystal is made of one giant molecule. All of the bonding is covalent, which is much stronger than the intermolecular forces in molecular crystals. This means that the melting points of macromolecular crystals are **very high**.

In most macromolecular crystals there are no charged particles that can move (no matter what state the macromolecule is in) and so they usually do not conduct electricity.

One exception to this is **graphite**, which is a macromolecular crystal formed of layers of carbon atoms. The atoms in a layer are all held together by strong covalent bonds, and this gives graphite a **high melting point**. The forces between layers, however, are weak induced dipole-dipole. Each carbon atom makes three covalent bonds, using three of its outer-shell electrons. The fourth electron from each atom becomes **delocalised** in the plane of a layer. This allows graphite to conduct electricity in a similar way to a metallic crystal.



Diamond is a macromolecular crystal

Graphite is a macromolecule with a layered structure

CHANGING STATE: MELTING AND BOILING

When any solid is heated, the heat energy is transferred to **kinetic** energy in the crystal lattice. At first this causes particles to **vibrate** about their **fixed** lattice positions faster and faster and the **temperature rises**. When the temperature reaches the **melting point** of the solid, particles start to move to different positions. The energy required to free particles from their fixed positions by overcoming some of the forces or bonds between them is called the **enthalpy change of melting**. Since heat energy is becoming potential energy, not kinetic energy, the **temperature remains constant**, until the solid has completely melted, when the temperature begins to rise again as the particles once again start gaining **kinetic** energy and moving **faster**.

The temperature continues to rise until the **boiling point** is reached when the heat energy is used to overcome any remaining forces between particles, freeing them to become a **gas**. This amount of energy is called the **enthalpy change of vaporisation**. Once **boiling** is complete, the temperature will begin to **rise** again. This can be shown on a graph called a heating curve.

