Topic 2: Bonding, structure and the properties of matter

AQA GCSE Chemistry (8462), topic 4.2

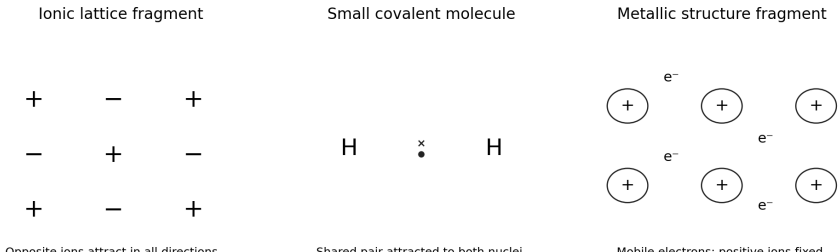
Bonding, structure and the properties of matter

- describe ionic, covalent and metallic bonding in terms of electrons;
- draw dot-and-cross diagrams for ions and small molecules, and say what the diagrams leave out;
- explain melting points and electrical conductivity from structure and bonding;

Bonding, structure and the properties of matter (2)

- explain the properties of **diamond**, **graphite**, **graphene** and fullerenes;
- (chemistry only) calculate surface-area-to-volume ratios and weigh the uses and risks of nanoparticles.

Figure: Bonding, structure and the properties of matter



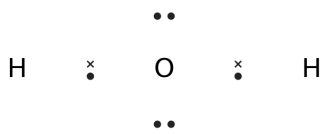
- Ionic: opposite ions. Covalent: shared pair. Metallic: positive ions and delocalised electrons.
- Use the model to explain a property, then name its limitation.

Three kinds of strong bond

- All chemical bonds come from the same force: the **electrostatic force** of attraction between opposite charges.
- What changes from one kind of bond to another is where the electrons go.
- **Ionic bonding.** In an **ionic bond** , a metal atom loses its outer electrons and becomes a positive ion; a non-metal atom gains them and becomes a negative ion.
- The opposite ions then attract each other.

Figure: Three kinds of strong bond

water: dots from O; crosses from H

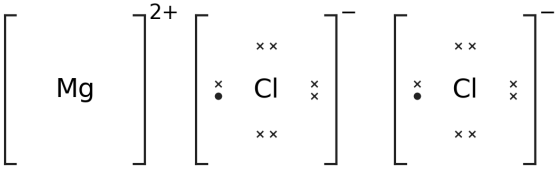


Flat electron model: positions do not establish the 3D shape.

- H_2O has two shared pairs and two oxygen lone pairs.
- Use the model to explain a property, then name its limitation.

Figure: Three kinds of strong bond ·

$MgCl_2$: one Mg^{2+} and two Cl^- ions



Each chloride: seven crosses + one magnesium dot.
Mg^{2+} has configuration 2,8; its old third shell is empty.

- Each Cl^- has seven original outer electrons and one gained magnesium electron.
- Use the model to explain a property, then name its limitation.

How structure decides properties

- **States of matter.** A substance melts and freezes at its melting point, and boils and condenses at its boiling point.
- In the particle model, particles are small solid spheres.
- To melt or boil a substance you must overcome the forces between its particles, so the stronger those forces, the higher the melting and boiling points. (Higher tier) The particle model has limits: it shows no forces, and real particles are not solid spheres.
- State symbols are (s) solid, (l) liquid, (g) gas and (aq) dissolved in water.

Carbon: one element, four structures

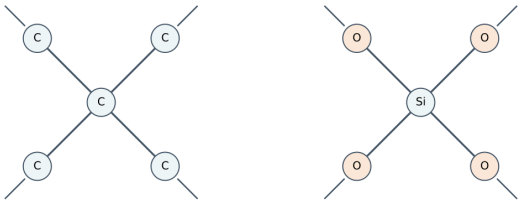
- **Diamond** is a **giant covalent structure** in which every carbon atom is bonded to four others. It is very hard, has a very high melting point and does not conduct electricity, because all its outer electrons are in bonds.
- **Graphite** is made of layers of hexagonal rings. Each carbon is bonded to three others, so one electron per atom is delocalised. There are no covalent bonds between the layers, only weak forces, so the layers slide: **graphite** is soft and slippery and is used in pencils and as a lubricant. The delocalised electrons let it conduct electricity.

Carbon: one element, four structures (2)

- **Graphene** is a single layer of **graphite**. It is very strong and conducts electricity, so it is useful in electronics and composite materials.
- A **fullerene** is a hollow molecule of carbon atoms in rings of five, six or seven atoms. The first discovered, buckminsterfullerene (C_{60}), was made in 1985 and is shaped like a football. A **carbon nanotube** is a cylinder-shaped **fullerene** that is very long compared with its width, which makes it strong and useful in electronics and for strengthening materials.

Figure: Carbon: one element, four structures

Local coordination projections; bonds continue into giant 3D structures



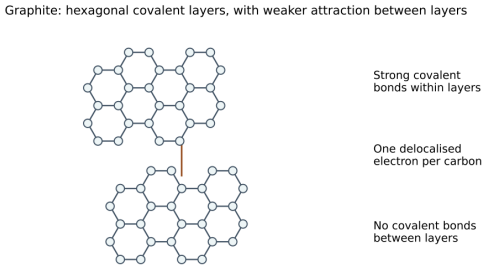
Diamond: four C neighbours

Silica: four O neighbours; each O bridges to another Si

2D projection does not show actual bond angles. Silica oxygens are shared: SiO_2 overall.

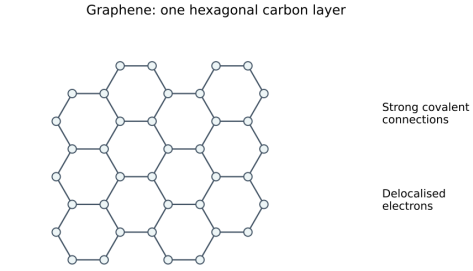
- Four neighbours per carbon; strong covalent connections extend through a giant network.
- Use the model to explain a property, then name its limitation.

Figure: Carbon: one element, four structures ·



- Strong covalent layers can slide; delocalised electrons carry electrical charge.
- Use the model to explain a property, then name its limitation.

Figure: Carbon: one element, four structures ..

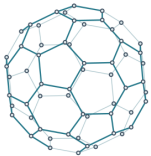


Carbon atoms shown at vertices; cut edges continue. Single-layer schematic.

- One carbon layer combines strong covalent connections with delocalised electrons.
- Use the model to explain a property, then name its limitation.

Figure: Carbon: one element, four structures · · ·

C_{60} carbon-bond projection and schematic nanotube shape



C_{60}: spherical cage
60 carbon atoms



Nanotube: long hollow cylinder
large length/diameter ratio

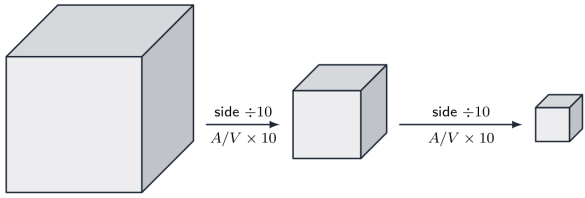
C_{60}: 60 vertices, 90 bonds; rear edges pale. Nanotube outline omits its carbon-ring bonds.

- C_{60} is a spherical cage; a nanotube has a very large length-to-diameter ratio.
- Use the model to explain a property, then name its limitation.

Nanoparticles (chemistry only)

- Nanoscience studies structures from 1 to 100 nanometres (nm) across; 1 nm is 10^{-9} m.
- A **nanoparticle** contains only a few hundred atoms.
- A typical atom is about 0.2 nm across, so a 20 nm particle is about 100 atoms wide.
- Nanoparticles are smaller than fine particles (PM2.5, 100 to 2,500 nm), which are smaller than coarse particles, or dust (PM10, 2,500 to 10,000 nm, that is 2.5×10^{-6} to 1×10^{-5} m).

Figure: Nanoparticles (chemistry only)



Drawings shrink by half each step for visibility; the real cubes shrink tenfold.

- A/V = 6/l: side falls tenfold, quotient rises tenfold.
- Use the model to explain a property, then name its limitation.

Sources for this lesson

- AQA, *GCSE Chemistry (8462) specification*, section 4.2.
- K. S. Novoselov, A. K. Geim and others, "Electric field effect in atomically thin carbon films", *Science* (22 October 2004).
- The Nobel Prize in Physics 2010, press release (5 October 2010).
- H. W. Kroto and others, "C_{60}: Buckminsterfullerene", *Nature* (14 November 1985).

Common errors

- Saying that covalent bonds break when a simple molecular substance melts or boils; only the weak intermolecular forces are overcome.
- Saying that solid ionic compounds do not conduct because they have no ions; they have ions, but the ions cannot move.
- Calling an ionic compound a molecule, or reading a lattice drawing such as Mg_6Cl_{12} as a formula.

Common errors (2)

- Saying **graphite** conducts because of its weak forces between layers; it conducts because of its delocalised electrons.
- Forgetting that **diamond** does not conduct: it has no delocalised electrons.
- Saying a **nanoparticle** is a "large atom"; it contains hundreds of atoms.

Key terms

- **Ionic bond**: the electrostatic attraction between oppositely charged ions.
- **Covalent bond**: a shared pair of electrons between two atoms.
- **Metallic bond**: the attraction between positive metal ions and delocalised electrons.

Key terms (2)

- **Delocalised electron**: an electron that is free to move through a structure.
- **Intermolecular force**: a weak force of attraction between molecules.
- **Giant covalent structure**: a large network of atoms all joined by covalent bonds.

Key terms (3)

- **Alloy**: a mixture of a metal with one or more other elements.
- **Nanoparticle**: a particle between 1 and 100 nm across.

Check yourself

- 1.
- What charge does an ion of a Group 2 metal have, and why? 2.
- How many lone pairs does the nitrogen atom in NH_3 have? 3.
- Explain why methane (CH_4) has a low boiling point. 4.