Cambridge (CIE) A Level Chemistry

Your notes

Bonding & Structure

Contents

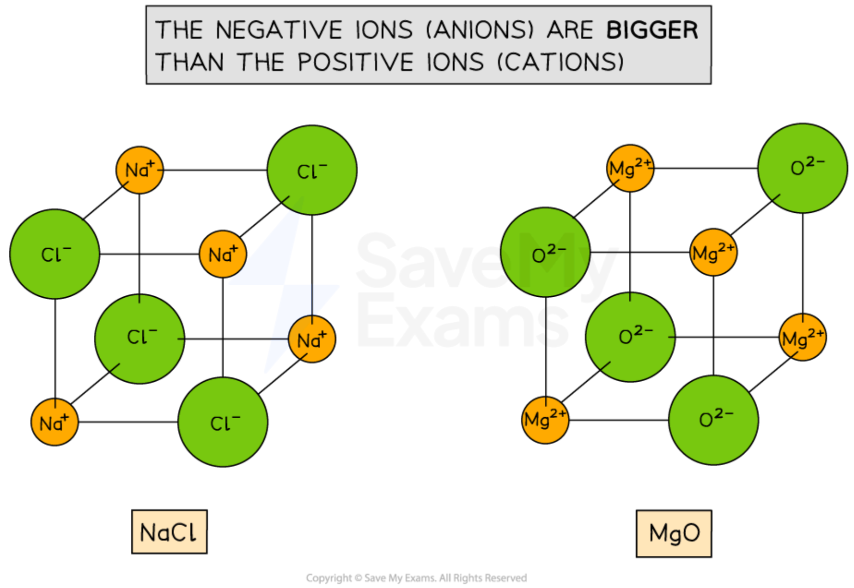
Lattice Structures

- Most ionic, metallic and covalent compounds are **crystalline lattice**
- The ions, atoms or molecules are arranged in a **regular and repeating arrangement**

Giant ionic lattices

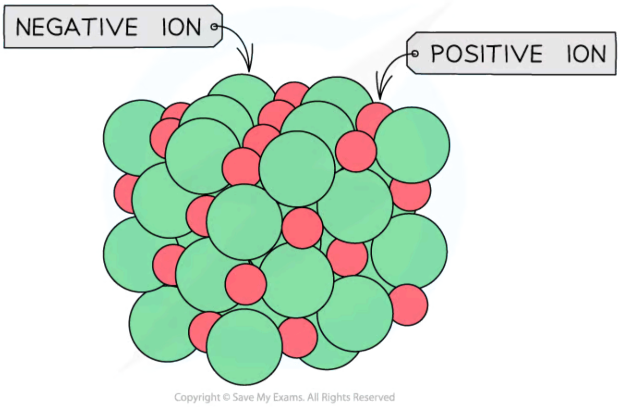
- An **ionic bond** is an electrostatic force between a positively charged metal (**cation**) ion and a negatively charged non-metal (**anion**) ion
  - The metal becomes positively charged as it transfers electrons to the non-metal becomes negatively charged
- Ionic compounds are arranged in giant **ionic lattices** (also called **giant ionic structures**)
- The type of lattice formed depends on the sizes of the **positive** and **negative** ions which are arranged in an **alternating** fashion
  - The ionic lattice of MgO and NaCl are **cubic**

Ionic lattices of the ionic compounds NaCl and MgO



The ionic lattices for NaCl and MgO are similar due to the ratio of 1 cation : 1 anion

General ionic lattice



A general ionic lattice shows the actual packing of the ions based on their relative size

Covalent lattices

- **Covalent bonds** are bonds between non-metals in which electrons are **shared** between the atoms
- Covalent compounds can be arranged in **simple molecular** or **giant molecular lattices**
  - Simple molecular lattices: Iodine, buckminsterfullerene (C_{60}) and ice
  - Giant molecular: silicon(IV) oxide, graphite and diamond

Simple molecular lattices

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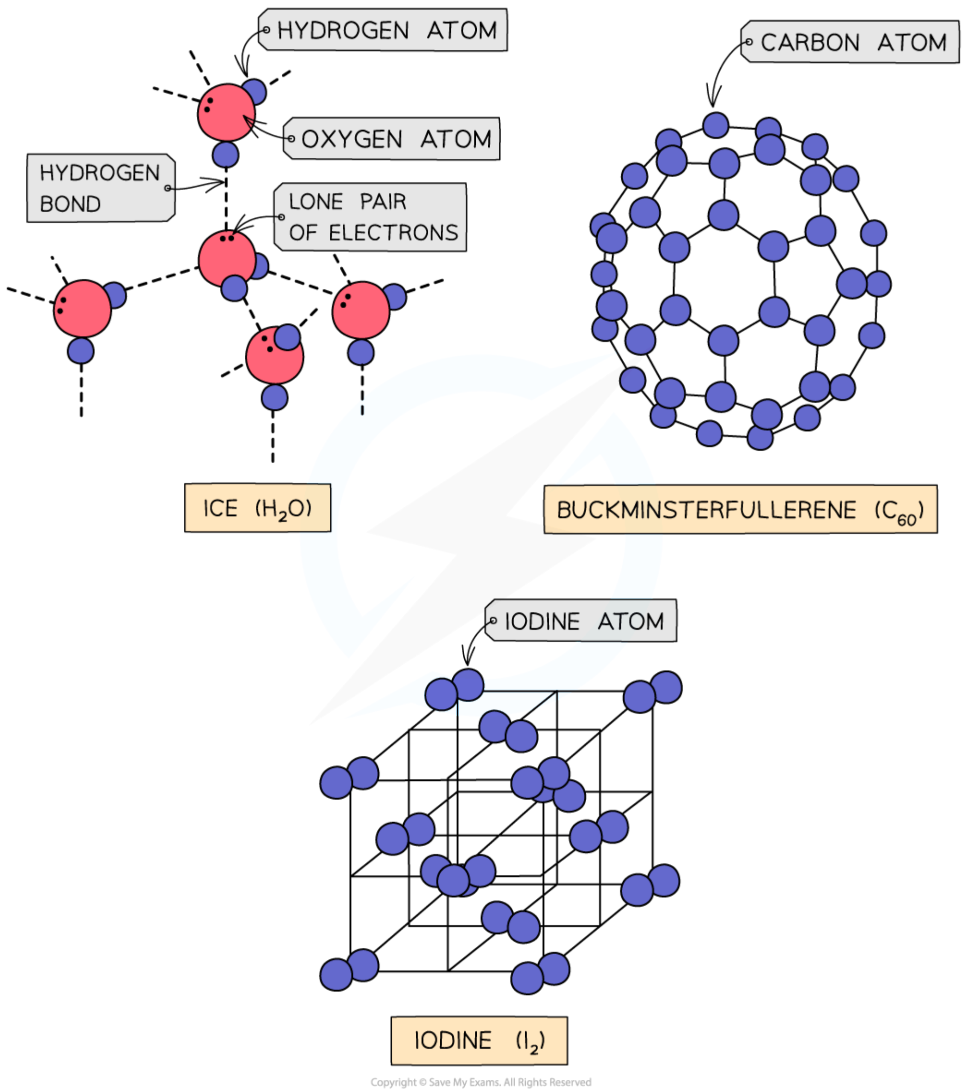

Ice, buckminsterfullerene and iodine all have different simple molecular lattices due to the different structures and intermolecular forces

Giant molecular lattices

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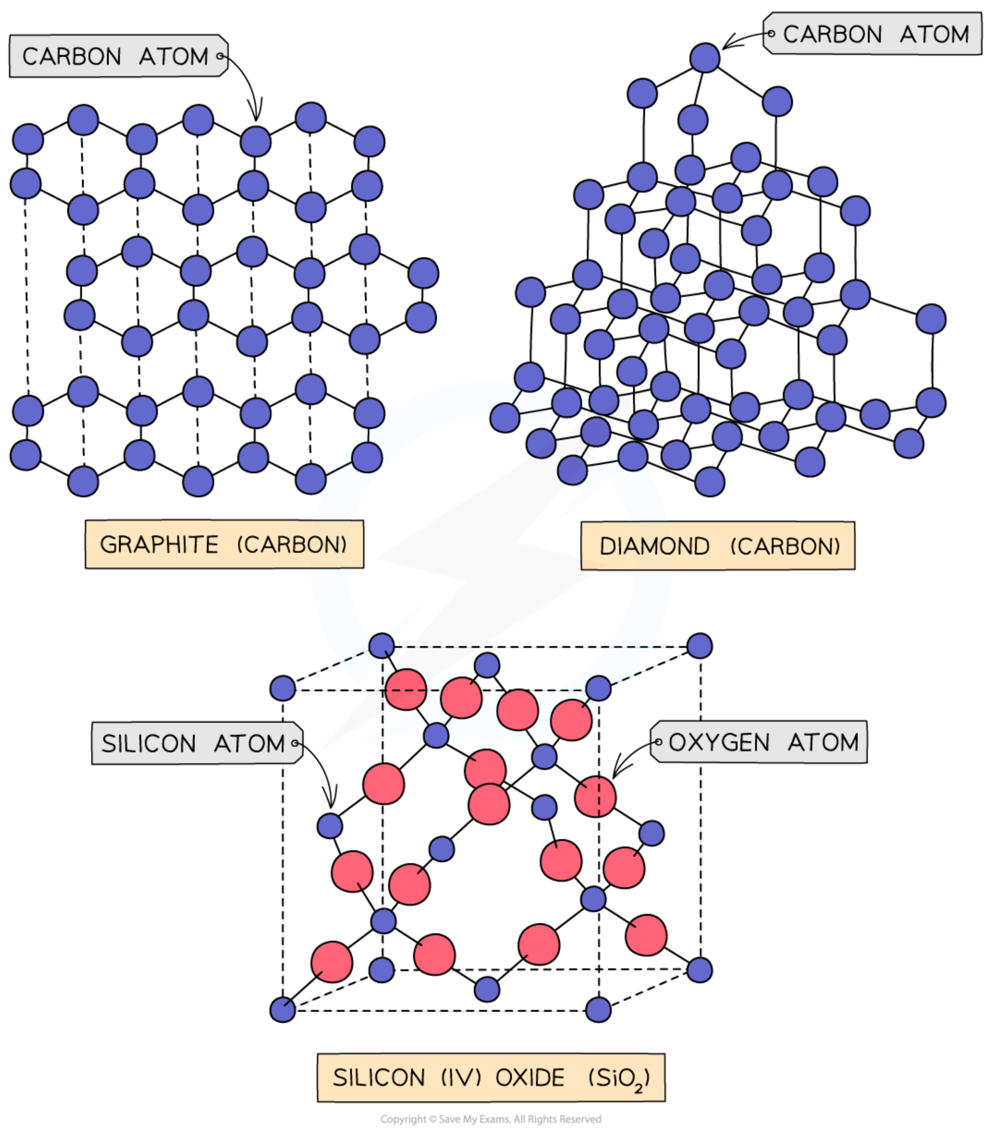

Giant molecular lattices have higher melting and boiling points because they require more energy to overcome the intramolecular and / or intermolecular forces

Metallic lattices

- Metals form **giant metallic lattices** in which the metal ions are surrounded by a 'sea' of **delocalised** electrons
- The metal ions are often packed in **hexagonal layers** or in a **cubic arrangement**

The layered structure of copper atoms

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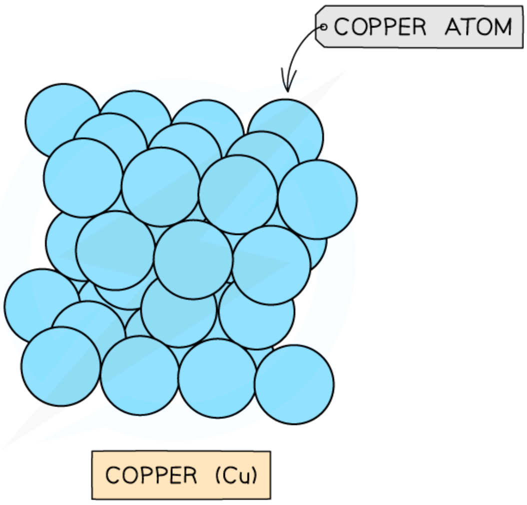


Copper cations are arranged in regular layers (the delocalised electrons are not shown in the diagram)

Examiner Tips and Tricks

- Graphite, diamond and buckminsterfullerene are **allotropes** of carbon.
- They are different **structural forms** of the same element (which is carbon).

How Bonding Affects Physical Properties

- Different types of **structure** and **bonding** have different effects on the **physical properties** of substances such as their **melting** and **boiling points**, **electrical conductivity** and **solubility**

Ionic bonding & giant ionic lattice structures

- Ionic compounds are **strong**
  - The **strong electrostatic forces** in ionic compounds keep the ions strongly together
- They are **brittle** as ionic crystals can split apart
- Ionic compounds have **high melting** and **boiling** points
  - The strong electrostatic forces between the ions in the lattice act in all directions and keep them strongly together
  - Melting and boiling points increase with charge density of the ions due to the greater **electrostatic attraction** of charges
  - $Mg^{2+}O^{2-}$ has a higher melting point $Na^{+}Cl^{-}$
- Ionic compounds are **soluble** in water as they can form **ion – dipole bonds**
- Ionic compounds only **conduct electricity** when **molten** or in **solution**
  - When molten or in solution, the ions can freely move around and conduct electricity
  - In the solid state they're in a fixed position and unable to move around

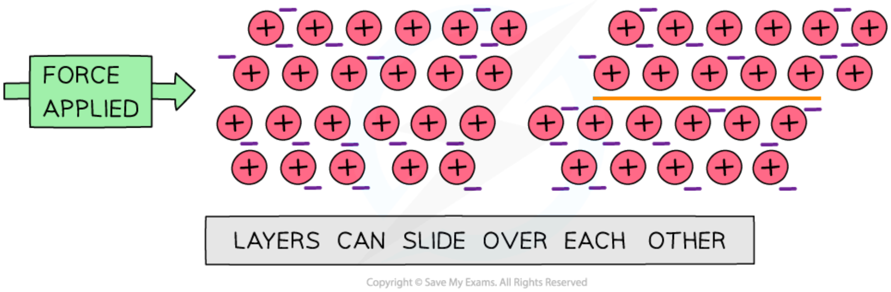
Metallic bonding & giant metallic lattice structures

- Metallic compounds are **malleable**
  - When a force is applied, the metal layers can slide
  - The **attractive forces** between the metal ions and electrons act in all directions
  - So when the layers slide, the metallic bonds are re-formed
  - The lattice is not broken and has changed shape
- Metallic compounds are **strong** and **hard**
  - Due to the strong attractive forces between the metal ions and delocalised electrons
- Metals have **high melting** and **boiling points**

- Due to the strong attractive forces between the metal ions and delocalised electrons
- The greater the number of delocalised electrons and the smaller the cation, the greater the attractive force between them resulting in a higher melting / boiling point

- **Pure metals** are **insoluble** in water
- Metals can **conduct electricity** when in a **solid** or **liquid** state
  - As both in the solid and liquid state, there are **mobile electrons** which can freely move around and conduct electricity

Explaining the malleability of metals



Metals are malleable as the layers can slide over each and reform

Covalent bonding & simple covalent lattice structures

- **Simple covalent lattices** have low **melting** and **boiling points**
  - These compounds have weak intermolecular forces between the molecules
  - Only little energy is required to break the lattice
- Most compounds are insoluble with water
  - Unless they are polar (such as HCl) or can form hydrogen bonds (such as NH_3)
- They do not **conduct electricity** in the **solid** or **liquid** state as there are no charged particles
  - Some simple covalent compounds conduct electricity in solution such as HCl which forms H^+ and Cl^- ions

Covalent bonding & giant covalent lattice structures

- **Giant covalent lattices** have **high melting** and **boiling points**
  - These compounds have a large number of **covalent bonds** linking the whole structure and intermolecular forces between the molecules
  - A lot of energy is required to break the lattice

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- The compounds can be **hard** or **soft**
  - Graphite is **soft** as the forces between the carbon layers are weak
  - Diamond and silicon(IV) oxide are **hard** as it is difficult to break their 3D network of strong covalent bonds
- Most compounds are insoluble in water
- Most compounds do not **conduct electricity** however some do
  - Graphite has **delocalised** electrons between the carbon layers which can move along the layers when a voltage is applied
  - Diamond and silicon(IV) oxide do not conduct electricity as all four outer electrons on every carbon atom are involved in a **covalent bond** so there are no free electrons available

Characteristics of different compound structure types table

	Giant Ionic	Giant Metallic	Simple Covalent	Giant Covalent
Melting and Boiling Points	High	Moderately high to high	Low	Very high
Electrical Conductivity	Only when molten or in solution	When solid or liquid	Do not conduct electricity	Do not conduct electricity (except for **graphite**)
Solubility	Generally soluble	Insoluble, but some may react	Usually insoluble unless they are polar	Insoluble
Hardness	Hard, brittle	Hard, malleable	Soft	Very hard (**diamond** or **SiO_2**) or soft (**graphite**)
Physical State at Room Temperature	Solid	Solid	Solid, liquid, gas	Solid

Forces	Electrostatic attraction between ions	Delocalised sea of electrons attracting positive ions	Weak intermolecular forces between molecules and covalent bonds within a molecule	Electrons in covalent bonds between atoms
Particles	Ions	Positive ions in a sea of electrons	Small molecules	Atoms
Example	NaCl	Copper	Br_2	Graphite, silicon(IV) oxide

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Worked Example

Bonding & Structure

The table below shows the physical properties of substances **X**, **Y** and **Z**.

Substance	Melting Point (°C)	Electrical Conductivity when Molten	Solubility in Water
X	839	Good	Soluble
Y	95	Very poor	Almost insoluble
Z	1389	Good	Insoluble

Which one of the following statements about **X**, **Y** and **Z** is completely true?

1. **X** has a giant ionic structure, **Y** has a giant molecular structure, **Z** is a metal.
2. **X** is a metal, **Y** has a simple molecular structure, **Z** has a giant molecular structure.
3. **X** is a metal, **Y** has a simple molecular structure, **Z** has a giant ionic structure.
4. **X** has a giant ionic structure, **Y** has a simple molecular structure, **Z** is a metal.

Answer

- The correct answer is 4
    - The relatively high melting point, solubility in water and electrical conductivity when molten suggest that **X** is a **giant ionic structure**
    - The low melting point of **Y** suggests that little energy is needed to break the lattice, which corresponds to a **simple molecular structure**. This is further supported by the low electrical conductivity and its being almost insoluble in water

- Compound **Z** has a very high melting point which is characteristic of either metallic or giant molecular lattices, however since it conducts electricity, compound Z must be a **giant metallic lattice**

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