3 Chemical Bonding

This topic introduces the different ways by which chemical bonding occurs and the effect this can have on physical properties.

3.1 Ionic Bonding ☐

3.4 Metallic Bonding ☐

3.5 Bonding and physical properties ☐

BONDING: OTHER

3 Chemical bonding

This topic introduces the different ways by which chemical bonding occurs and the effect this can have on physical properties.

	Learning outcomes Candidates should be able to:
3.1 Ionic bonding	a) describe ionic bonding, as in sodium chloride, magnesium oxide and calcium fluoride, including the use of 'dot-and-cross' diagrams
3.4 Metallic bonding	a) describe metallic bonding in terms of a lattice of positive ions surrounded by delocalised electrons
3.5 Bonding and physical properties	a) describe, interpret and predict the effect of different types of bonding (ionic bonding, covalent bonding, hydrogen bonding, other intermolecular interactions, metallic bonding) on the physical properties of substances b) deduce the type of bonding present from given information c) show understanding of chemical reactions in terms of energy transfers associated with the breaking and making of chemical bonds

IONIC BONDING

Ionic bonding involves a transfer of one or more electrons from one atom to another, leading to the formation of an ionic bond.

The strong electrostatic attraction that prevails between the oppositely charged ions in a crystal lattice is referred to as ionic bonding.

Positive ions, known as cations, are formed when electrons are removed from atoms. They are smaller than the original atom. The energy associated with the process is known as the ionisation energy

Negative ions, known as anions, are larger than the original atom. Energy is released as the nucleus pulls in an electron. This energy is the **electron affinity**.

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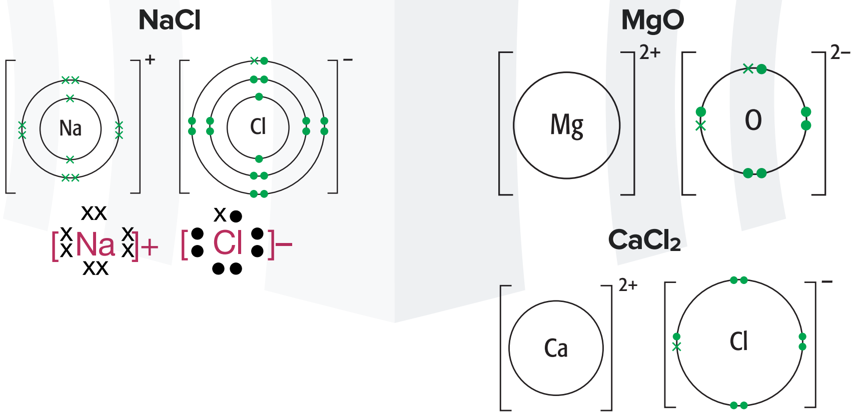
'DOT – AND – CROSS' DIAGRAMS



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SKILL CHECK

(a) Define ionic bonding.

(b) Explain in terms of electrons, how an **ionic bond** forms between atoms of **calcium** and atoms of **fluorine**.

(c) Draw electron configuration diagrams for a **calcium ion** and for a **fluoride ion**, showing their charges and outer electrons.

3

SKILL CHECK

Draw 'dot-and-cross' diagrams for:

(a) lithium fluoride

(b) magnesium chloride

(c) lithium oxide

(d) calcium oxide

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SKILL CHECK

In a historically famous experiment Wohler heated "inorganic" ammonium cyanate in the absence of air. The only product of the reaction was "organic" urea, $CO(NH_2)_2$. No other products were formed in the reaction.

What is the formula of the cyanate ion present in ammonium cyanate?

A CNO^- **B** CNO^{2-} **C** CO^- **D** NO^-

IONIC COMPOUNDS

The compounds formed by ionic bonds do not contain individual molecules, but are formed of an infinite assembly of ions.

The ions due to their mutual attraction arrange themselves in a regular pattern. Thus they are always crystalline solids at room temperature.

The electrical force binding them being very strong, they are non–volatile with high melting and boiling points. Every bond in the lattice needs to be broken down to melt the ionic compound.

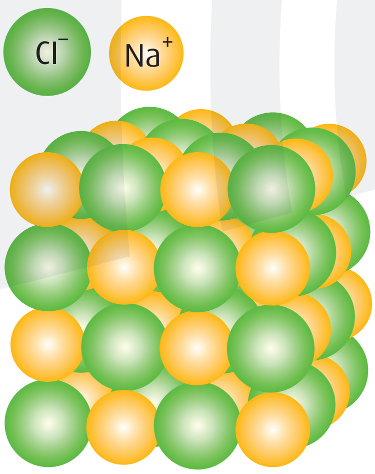
IONIC COMPOUNDS

Because they comprised of ions they conduct electricity in the molten or aqueous state, once the ions are made mobile.

In the solid state they do not conduct electricity. Generally ionic compounds are soluble in polar solvents like water.

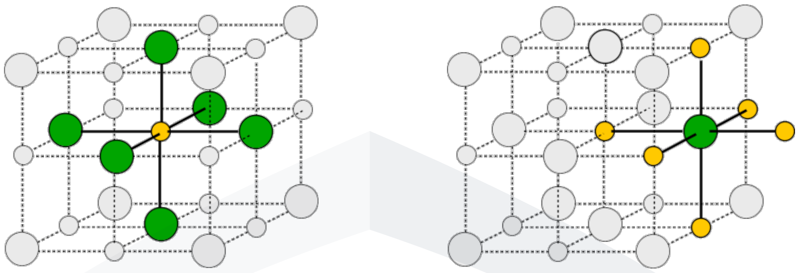
IONIC LATTICE

Oppositely charged ions held in a regular 3-dimensional lattice by electrostatic attraction



IONIC LATTICE

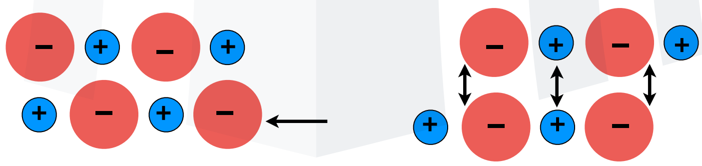
Each Na^+ is surrounded by 6 Cl^- Each Cl^- is surrounded by 6 Na^+



Na+ Sodium ion Cl− Chloride ion

BRITTLE IONIC LATTICES

Ionic compounds are hard. However they are brittle. With a slight deforming force it is possible to slightly displace one layer of ions relative to the next and thereby bring ions of similar charge next to each other. Similar ions repel each other forcing apart the two portions of the crystal.



If you move a layer of ions, you get ions of the same charge next to each other. The laters repel each other and the crystal breaks up

SKILL CHECK

Magnesium oxide may be used for the lining of an electric furnace for making crockery. **Which properties of magnesium oxide help to explain this use?**

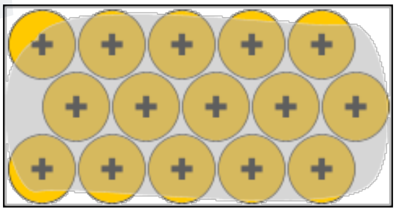
	strong forces between particles	ionic bonding	electrical conductor
A	yes	yes	no
B	yes	no	yes
C	no	yes	no
D	no	no	yes

METALLIC BONDING

Involves a lattice of positive ions surrounded by delocalised electrons

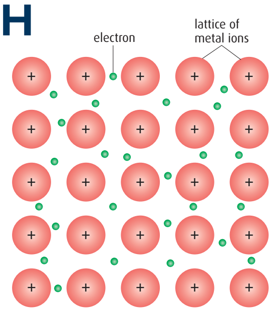
Metal atoms achieve stability by "off-loading" outer shell electrons to attain the electronic structure of the nearest noble gas. These electrons join up to form a mobile cloud which prevents the newly-formed positive ions from flying apart due to repulsion between similar charges.

Metals are excellent conductors of electricity because the ELECTRON CLOUD IS MOBILE, electrons are free to move throughout its structure. Electrons attracted to the positive end are replaced by those entering from the negative end.

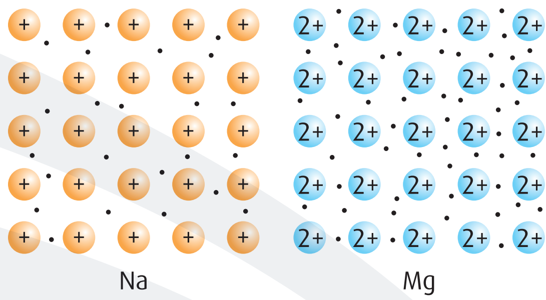


METALLIC BOND STRENGTH

The strength of the metallic bonding in sodium is relatively weak because each atom donates one electron to the cloud. The metallic bonding in potassium is weaker than in sodium because the resulting ion is larger and the electron cloud has a bigger volume to cover so is less effective at holding the ions together.



The metallic bonding in magnesium is stronger than in sodium because each atom has donated two electrons to the cloud. The greater the electron density holds the ions together more strongly.



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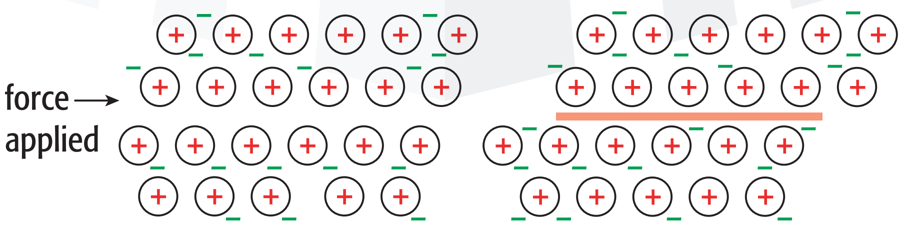
METALLIC BONDING

When force is applied, layers can slide over one another, since attractive forces between metal ions and sea of electrons in every direction, new metallic bonds are easily re-formed, attaining a different shape. This makes metals malleable and ductile.



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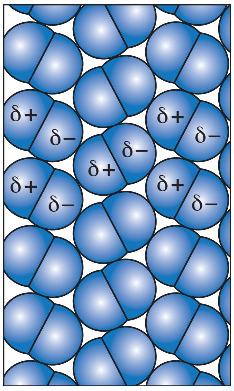
SIMPLE MOLECULAR LATTICE



solid iodine – strong instantaneous dipole forces

Iodine also forms crystals with weak van der Waals' forces between molecules.

This lattice is easily broken down when iodine is heated.

GIANT (MACRO) MOLECULES

Many atoms joined together in a regular array by a large number of covalent bonds, e.g. diamond, graphite, silicon (iv) oxide.

MELTING POINT
- Very high
- structure is made up of a large number of covalent bonds, all of which need to be broken if atoms are to be separated

ELECTRICAL CONDUCTIVITY
- Don't conduct electricity - have no mobile ions or electrons
- but... Graphite conducts electricity

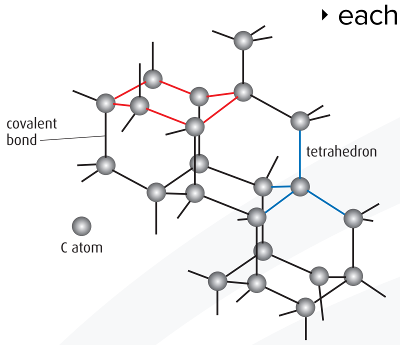
STRENGTH
- Hard - exists in a rigid tetrahedral structure, Diamond and silica (SiO2)...
- but Graphite is soft

DIAMOND

MELTING POINT
- VERY HIGH
- many covalent bonds must be broken to separate atoms

ELECTRICAL CONDUCTIVITY
- NON-CONDUCTOR
- No free electrons - all 4 carbon electrons used for bonding

STRENGTH
- STRONG
- each carbon is joined to four others in a rigid structure



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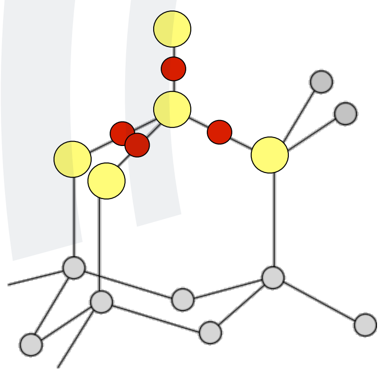
SILICA

MELTING POINT
- VERY HIGH
- many covalent bonds must be broken to separate atoms

ELECTRICAL CONDUCTIVITY
- NON-CONDUCTOR
- No free electrons

STRENGTH
- STRONG
- each silicon atom is joined to four oxygens
- each oxygen atom are joined to two silicons



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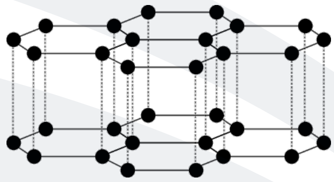
GRAPHITE

MELTING POINT
- VERY HIGH
- many covalent bonds must be broken to separate atoms

ELECTRICAL CONDUCTIVITY
- CONDUCTOR
- Only three carbon electrons are used for bonding which leaves the fourth to move freely along layers

STRENGTH
- SOFT
- each carbon is joined to three others in a layered structure
- layers are held by weak van der Waals' forces
- can slide over each other

Layers can slide over each other
Used as a lubricant and in pencils



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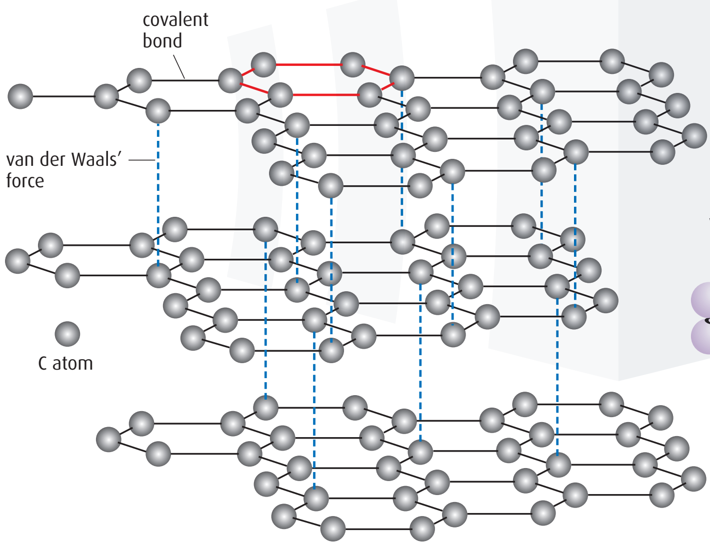
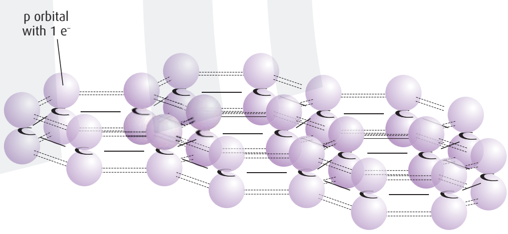
GRAPHITE





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CARBON NANOPARTICLES

Allotropes of carbon, known as fullerenes, have been recently discovered and possess unique and exciting properties.

They are based on rings of carbon, in hexagonal arrangement, similar to the structure of graphite.

They have dimensions between 0.1 to 100 nanometers.

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FULLERENES

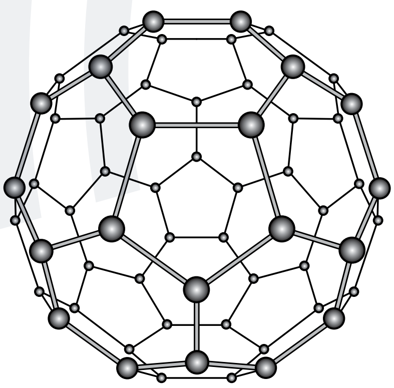
The firsts fullerene discovered was the buckminsterfullerene, C_{60}, which has the shape of a football.

Properties:

Relatively low sublimation point (weak van der Waals between each molecule).

Poor conductor of electricity (extent of electron delocalisation is lower).

More reactive compared to graphite. Reacts with hydrogen, fluorine, chlorine, bromine and oxygen.



Buckminsterfullerene

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NANOTUBES

Nanotubes are fullerenes hexagonally arranged carbon atoms like a single layer of graphite bent into a cylinder.

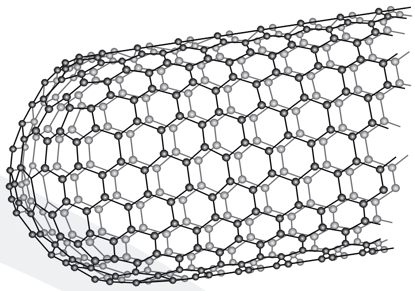
Properties:

High electrical conductivity along axis of cylinder.

High tensile strength.

Very high melting points (3500°C).

Used in tiny electrical circuits as wires, as electrodes in paper thin batteries, treatment of certain types of cancer in drug delivery and to strengthen clothing.



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GRAPHENE

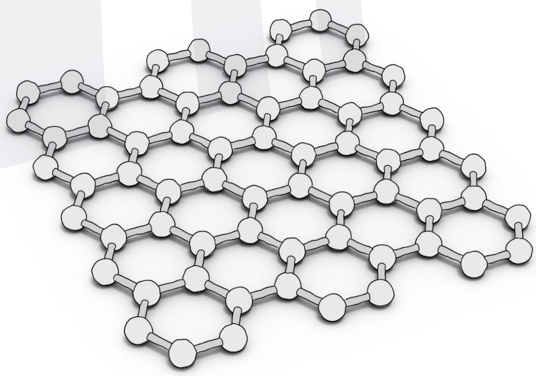
Single isolated layer of graphite.

Not completely rigid and shape can be distorted.

Most reactive form of carbon (low melting point).

Extremely strong.

Conducts electricity.



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STRUCTURES

TYPE	M.P. / B.P.	REASON
ionic lattice	high	A large amount of energy must be put in to overcome the strong electrostatic attractions and separate the giant lattice of ions
simple covalent molecules	low	Van der Waal's forces holding the simple molecules together are weak and can be overcome easily with low amounts of energy
macromolecules	high	Many covalent bonds must be broken to separate atoms
metallic lattice	high	A large amount of energy must be put in to overcome the strong electrostatic attractions between the lattice of cations and the delocalised electrons surrounding them