Education Services Ltd

EB Education Revision Guide

How to work with Covalent Bonding: Part 2

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Properties of Covalent Molecules

Covalent bonding

Covalent bonds form between non-metal atoms. Each bond consists of a shared pair of electrons and is very strong. Covalently bonded substances fall into two main types:

- Simple molecules
- Giant covalent structures

A covalent **molecule** consists of two or more non-metal atoms joined together by covalent bonds. A molecule can be:

- an **element**, if its atoms are of the same non-metal
- a **compound**, if its atoms are of different non-metals

A covalent bond is formed when a pair of electrons is shared.

Simple molecules

Simple molecules consist of only a few atoms held together by strong covalent bonds.

Examples of these that you need to know are:

- Oxygen (O_2)
- Hydrogen (H_2)
- Nitrogen (N_2)
- Carbon dioxide (CO_2)
- Water (H_2O)
- Ammonia (NH_3)
- Methane (CH_4)
- Hydrogen Chloride (HCl)

Properties of simple molecular substances

Low Melting and Boiling points

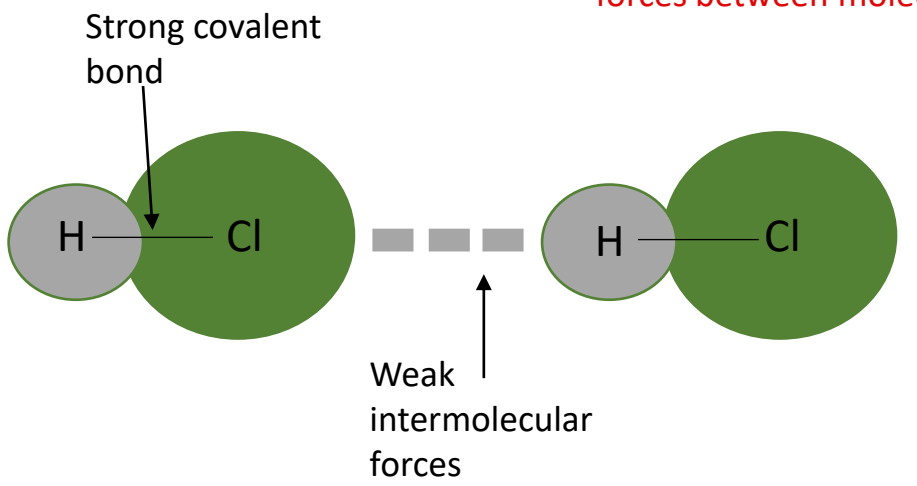
Simple molecules have very strong bonds between the atoms (the covalent bonds), but much weaker forces holding the molecules together (intermolecular forces).

Simple molecular substances are gases, liquids or solids with low melting and boiling points.

When one of these substances melts or boils, it is these weak 'intermolecular forces' that break, not the strong covalent bonds.

Not much energy is needed to break these intermolecular forces, and therefore they have low melting and boiling points.

TOP TIP: Think of intermolecular force as attractive forces between molecules



Properties of simple molecular substances.

Non-conductive

Simple molecular substances do not conduct electricity. This is because they are formed between non-metal atoms by the sharing of electrons.

They do not have any free electrons as the covalent bonds produce full outer shells and there are no ions to flow.

This means they are unable to conduct electricity.

Giant covalent structures

What are they?

Giant covalent structures contain many non-metal atoms, each joined to adjacent atoms by covalent bonds.

The atoms are usually arranged into giant regular **lattices.**

These structures are very strong because of the many strong covalent bonds involved.

You need to be able to recognise the structure of the following substances, and explain their properties:

- Diamond
- Graphite
- Graphene
- Buckminster Fullerene

Allotropes of carbon

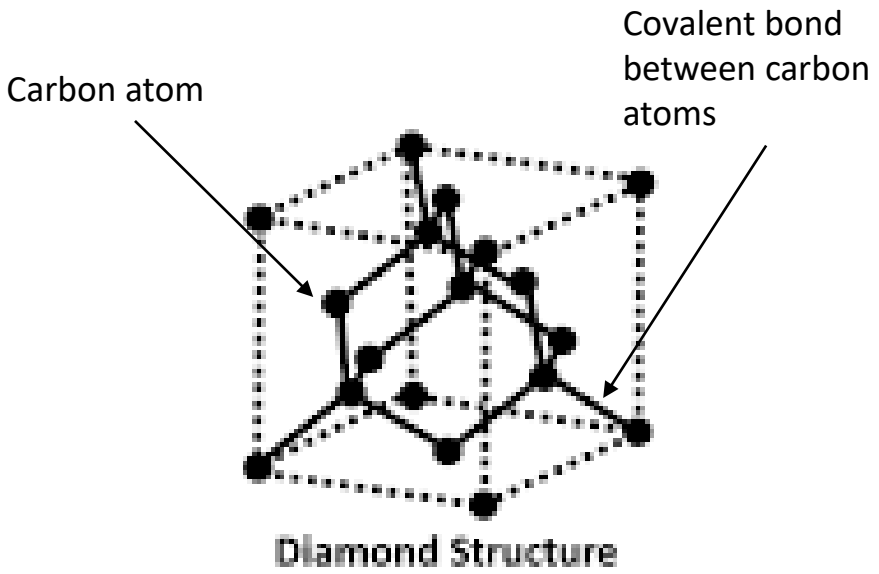
Diamond

Diamond is a form of carbon in which each carbon atom is joined to four other carbon atoms, forming a giant covalent structure. It is a solid at room temperature and the carbon atoms form a regular tetrahedral network structure.

Due to the high number of covalent bonds, diamond is very hard. This makes it useful for cutting tools, such as diamond-tipped glass cutters and oil rig drills.

It has a high melting point and boiling point, as a large amount of energy is needed to break all the covalent bonds.

It does not conduct electricity as there are no charged particles (free electrons or ions) which are free to move.



Diamond Structure

Allotropes of carbon

Graphite

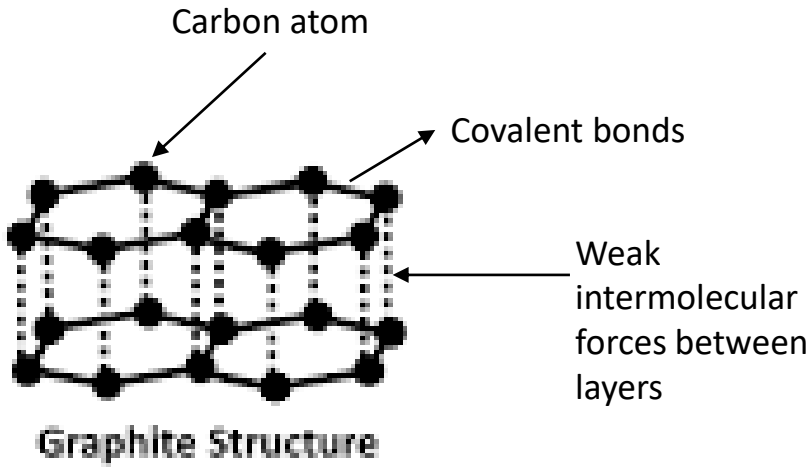
Graphite is a form of carbon in which each carbon atom forms three covalent bonds with other carbon atoms

The carbon atoms form layers of hexagonal rings.

There are no covalent bonds between the layers. The layers can slide over each other, which makes graphite slippery and it can be used as a lubricant.

As the carbon atoms in graphite only form three bonds, there is one non-bonded, or **delocalised**, electron from each atom. These electrons are free to move, which means that graphite can conduct electricity.

As it can conduct electricity, graphite is useful for electrodes in electrolysis and in batteries.



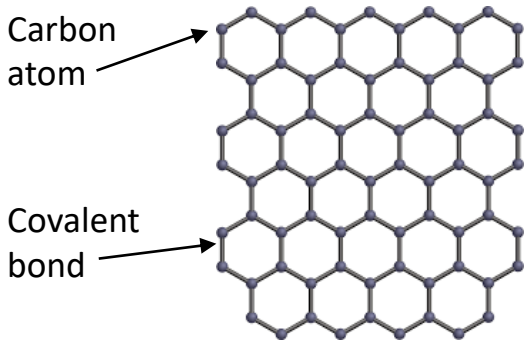
Graphite Structure

Allotropes of carbon

Graphene

Graphene is a single layer of graphite. Graphene is very strong and has a very high melting point because of the strong covalent bonds between the carbon atoms.

It has delocalised electrons that are free to move so it can conduct electricity.

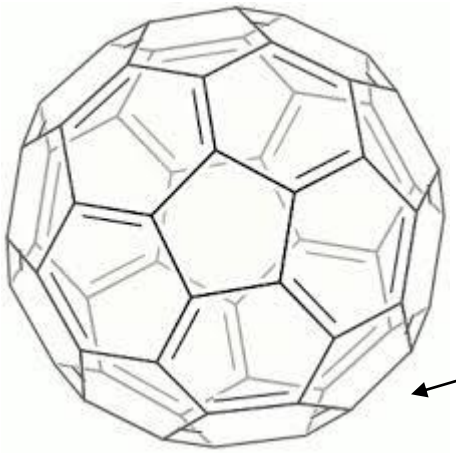


Buckminsterfullerene

Fullerenes are molecules of carbon atoms with hollow shapes. Their structures are based on hexagonal rings of carbon atoms joined by covalent bonds.

Buckminsterfullerene molecules are made up of 60 carbon atoms joined together by strong covalent bonds. Molecules of C_{60} are spherical.

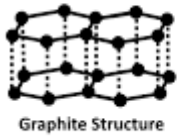
There are weak **intermolecular forces** between molecules of buckminsterfullerene. These need little energy to overcome, so buckminsterfullerene is slippery and has a low melting point.



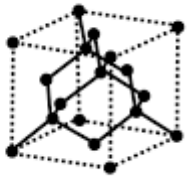
They are also known as “buckyballs”.

Your turn:

1a) The structures of diamond and graphite are show below.



Graphite Structure



Diamond Structure

What is the maximum number of covalent bonds formed by a carbon atom in a diamond crystal?

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b) Which of the statements about diamond and graphite is correct?

A: they are both soluble in water
B: they both cut glass
C: they both have high melting points
D: they are both good conductors of electricity

c) Explain why graphite can be used as a lubricant.

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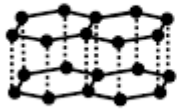
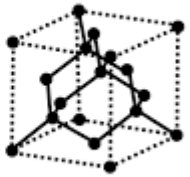
Your turn:

2. The diagrams below show how carbon atoms are arranged in diamond and graphite.



Graphite Structure



Diamond Structure

Using information from the diagrams, compare a use of diamond with a use of graphite. Explain each use in terms of the bonding and structure.

3. Water and sodium chloride have different properties.

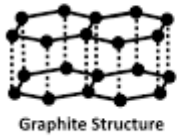
Water is covalently bonded, is a liquid at room temperature, and is a poor conductor of electricity.
Sodium chloride is an ionic substance. It is a crystalline solid at room temperature, has a high melting point, and conducts electricity when molten or in aqueous solution.

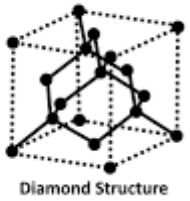
Explain these properties of water and sodium chloride in terms of the particles present and the forces between them.

TOP TIP: You can use our EB How to work with Ionic Bonding guides to help you with this question.

Answers:

1a) The structures of diamond and graphite are show below.


Graphite Structure


Diamond Structure

What is the maximum number of covalent bonds formed by a carbon atom in a diamond crystal?

4

b) Which of the statements about diamond and graphite is correct?

A: they are both soluble in water
B: they both cut glass
C: they both have high melting points
D: they are both good conductors of electricity

c) Explain why graphite can be used as a lubricant.

The layers can slide over each other
This is because there are weak forces between
the layers.

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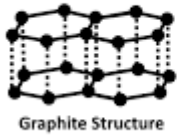
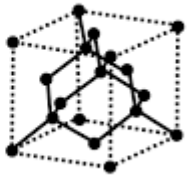
Your turn:

2. The diagrams below show how carbon atoms are arranged in diamond and graphite.


Graphite Structure


Diamond Structure

Using information from the diagrams, compare a use of diamond with a use of graphite. Explain each use in terms of the bonding and structure.

Diamond:

Uses and Properties

- in cutting tools/engraving
- drill bit
- jewellery
- it is very hard/strong
- attractive/lustrous
- high melting point

Explanations

- giant covalent
- each carbon atom bonded to 4 other carbon atoms
- 3D structure
- to break it lots of bonds would need to be broken
- would need a lot of energy/force

Graphite:

Uses and Properties

- to make electrodes
- a lubricant
- sporting equipment
- in pencils/drawing
- it conducts electricity
- soft

Explanations

- giant covalent
- each carbon atom bonded to 3 other carbon atoms
- delocalised electrons move to carry current
- layers of carbon atoms
- weak forces between layers so they can slide over each other

Your turn:

3. Water and sodium chloride have different properties.

Water is covalently bonded, is a liquid at room temperature, and is a poor conductor of electricity.
Sodium chloride is an ionic substance. It is a crystalline solid at room temperature, has a high melting point, and conducts electricity when molten or in aqueous solution.

Explain these properties of water and sodium chloride in terms of the particles present and the forces between them.

Water

- Covalent bonds between hydrogen and oxygen atoms (H_2O)
- Simple molecular compound
- Weak intermolecular forces between molecules so not much energy is needed to break the forces between them, so a liquid at room temperature.
- Does not contain ions or free electrons so does not conduct electricity

Sodium chloride

- Contains ions (Na^+ Cl^-)
- Giant lattice structure – crystalline
- Strong forces of attraction between ions/strong ionic bonds
- A lot of energy is needed to separate the ions, so it has a high melting point
- Ions are free to move so it conducts electricity when molten/dissolved in water

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