Edexcel GCSE Chemistry

Your notes

Types of Substance

Contents

Your notes

Types of Substance

Classifying Substances

- All matter is composed of atoms which are bonded together, either by ionic, covalent or metallic bonds
- The identity of the elements and bonding present influences the structure and physical properties of a substance
- The vast majority of known substances can be classified by their type of bonding and hence their structures into four main categories
- These are:
  - Ionic
  - Simple molecular (covalent)
  - Giant covalent
  - Metallic

Ionic compounds

Bonding

- Ionic compounds consist of a metal bonded to a non-metal via **electron transfer**
- They form regular shaped giant ionic lattices in which strong **electrostatic forces** act in all directions

Properties

- A lot of energy is required to break so many strong bonds hence they have **high melting** and **boiling** points, so ionic compounds are usually **solid** at room temperature and are **non-volatile**
- They are usually **water soluble**
- Ionic compounds can conduct electricity in the **molten** state or in **solution** as they have ions that can move and carry charge
- They cannot conduct electricity in the solid state

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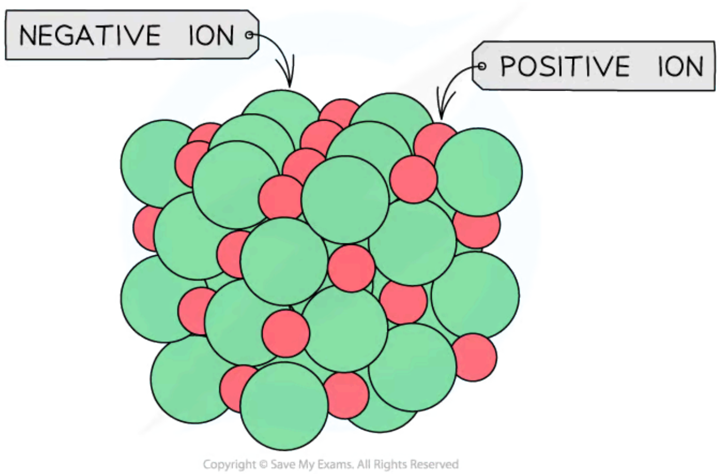

A giant ionic lattice

Simple covalent molecules

Bonding

- Small covalent compounds consist of non-metal elements which have bonded together via **electron sharing**

Properties

- They have **low melting** and **boiling** points so covalent compounds are usually **liquids** or **gases** at room temperature.
- This is because the weak intermolecular forces are easily overcome, meaning that these compounds are usually **volatile**, which is why many covalent organic compounds have distinct aromas
- The intermolecular forces increase with **molecular size**, hence large molecules have **higher** melting and boiling points
- Most covalent compounds are insoluble as they tend to be **non-polar** but can dissolve in **organic solvents**
- Some do dissolve in water by forming intermolecular attractions between the water molecules
- They cannot conduct electricity as all electrons are involved in bonding so there are no free electrons or ions to carry the charge

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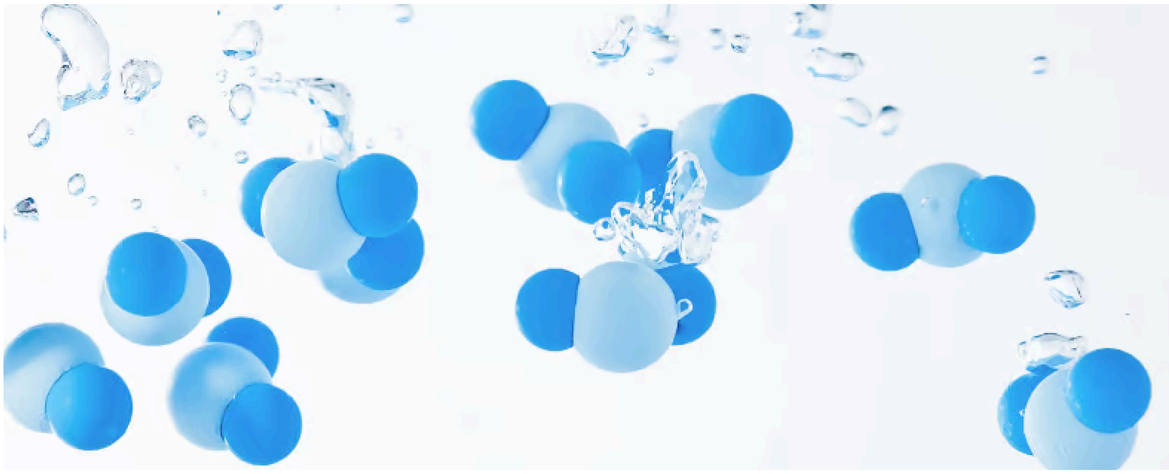

Simple molecules like water have low melting and boiling points

Giant covalent structures

Bonding

- Giant covalent structures consist of many non-metals atoms bonded to other non-metal atoms via strong covalent bonds

Properties

- They have **high** melting and boiling points as they have many strong covalent bonds
- Large amounts of heat energy are needed to overcome these forces and break down bonds
- Most cannot conduct electricity as they do not have free electrons but there are some exceptions such as graphite

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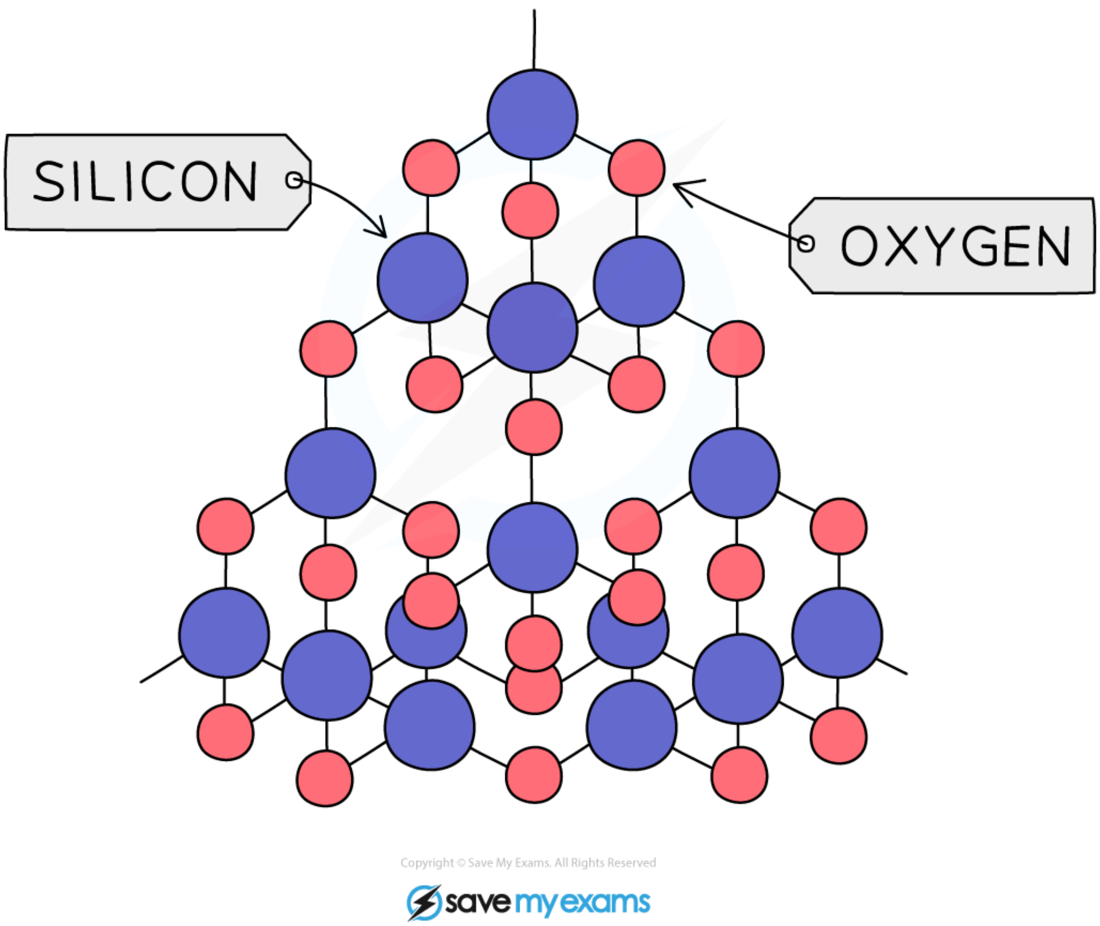

Giant covalent structures have very high melting and boiling points

Metals

Bonding

- Metals consist of metal atoms are held together strongly by metallic bonding
- Within the metal lattice, the atoms lose their **valence electrons** and become **positively** charged
- The valence electrons no longer belong to any metal atom and are said to be **delocalised**, creating what is known as a **sea of free electrons**
- The free electrons move freely in between the positive metal atoms

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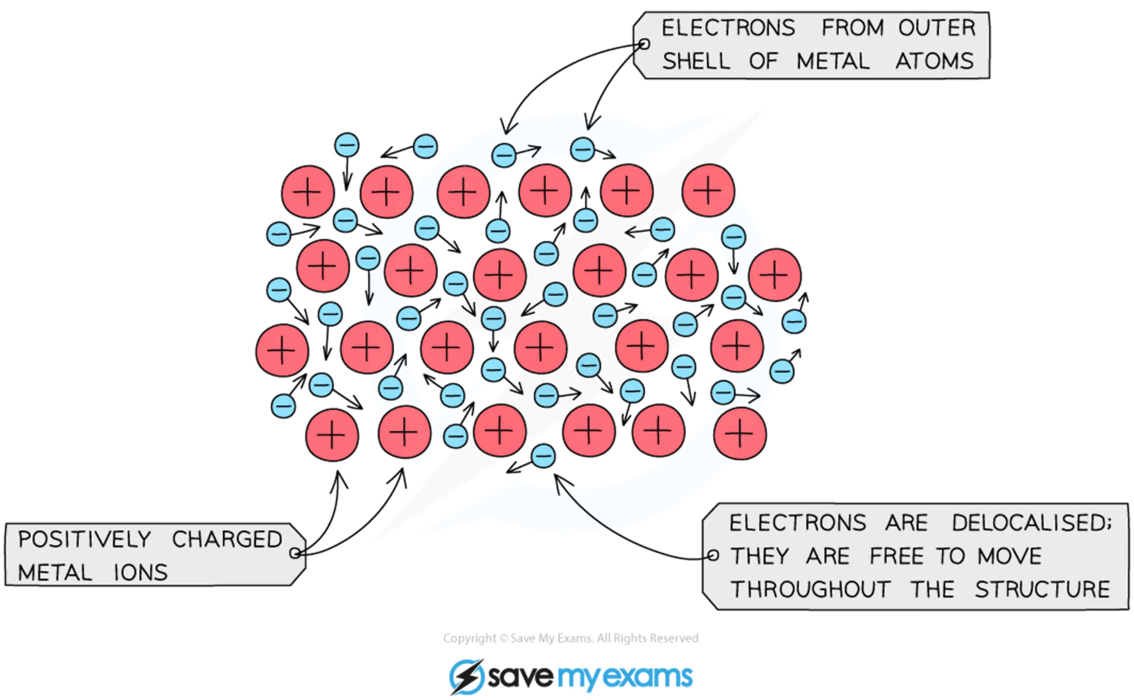
Properties

- Metallic bonds are **very strong** and are a result of the attraction between the positive metal ions and the negatively charged delocalised electrons
- Metals thus have **very high** melting and boiling points
- They are usually **insoluble** in water although some do react with water
- They can conduct **heat** and **electricity** due to the delocalised electrons
- The layers of atoms in metals can **slide** over each other meaning metals are **malleable** and can be hammered and bent into shapes



Metallic structures have high melting and boiling points, are malleable and conduct electricity

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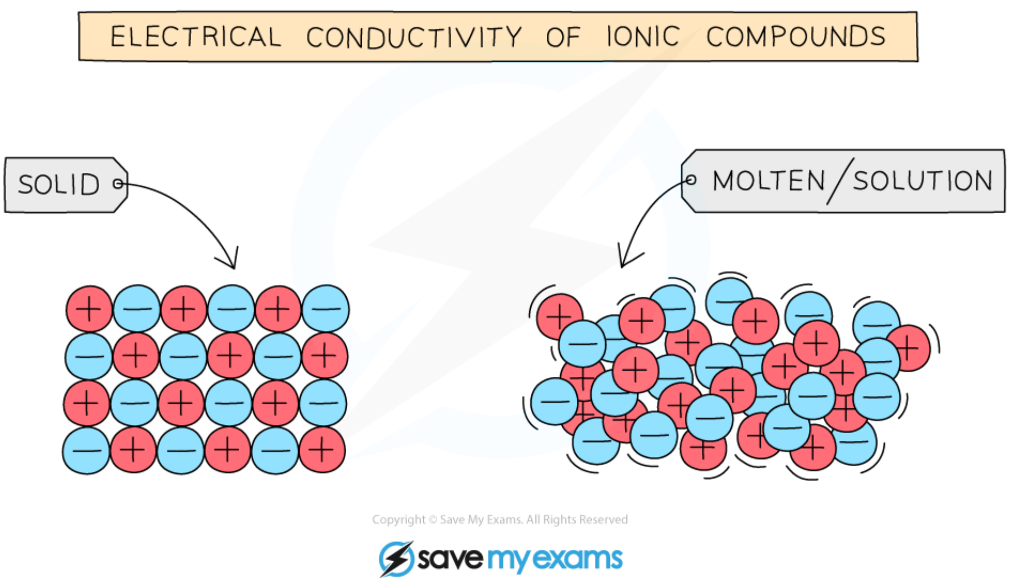
Comparing Ionic & Covalent Compounds

Comparing Ionic & Covalent Compounds

- Ionic compounds have **high** melting and boiling points
- This is because the oppositely charged ions in the lattice structure are attracted to each other by **strong electrostatic forces** which hold them firmly in place
- **Large** amounts of energy are needed to overcome these forces so the m.p. and b.p. are high
- Ionic substances can **conduct** electricity when in either the **molten** state or when **dissolved** in solution. In both cases the ions must be able to move and carry the charge
- In solid ionic substances the ions are in fixed positions and cannot move, hence they do not conduct electricity



Particles in solution/molten form can move and conduct electricity but in solid form they are in fixed positions and are unable to conduct

- Simple covalent substances, such as carbon dioxide and methane, have very strong covalent bonds **between** the atoms in each molecule, but much **weaker intermolecular forces** between individual molecules

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- When one of these substances melts or boils, it is these weak **intermolecular forces** that break, not the strong covalent bonds
- Less energy is needed to break the molecules apart, so they have **lower** m.p. and b.p. than ionic compounds
- They are poor conductors of electricity as there are no free ions or electrons to move and carry charge
- Most covalent compounds do not conduct at all in the solid state and are thus insulators
- Common insulators include the plastic coating around household electrical wiring, rubber and wood

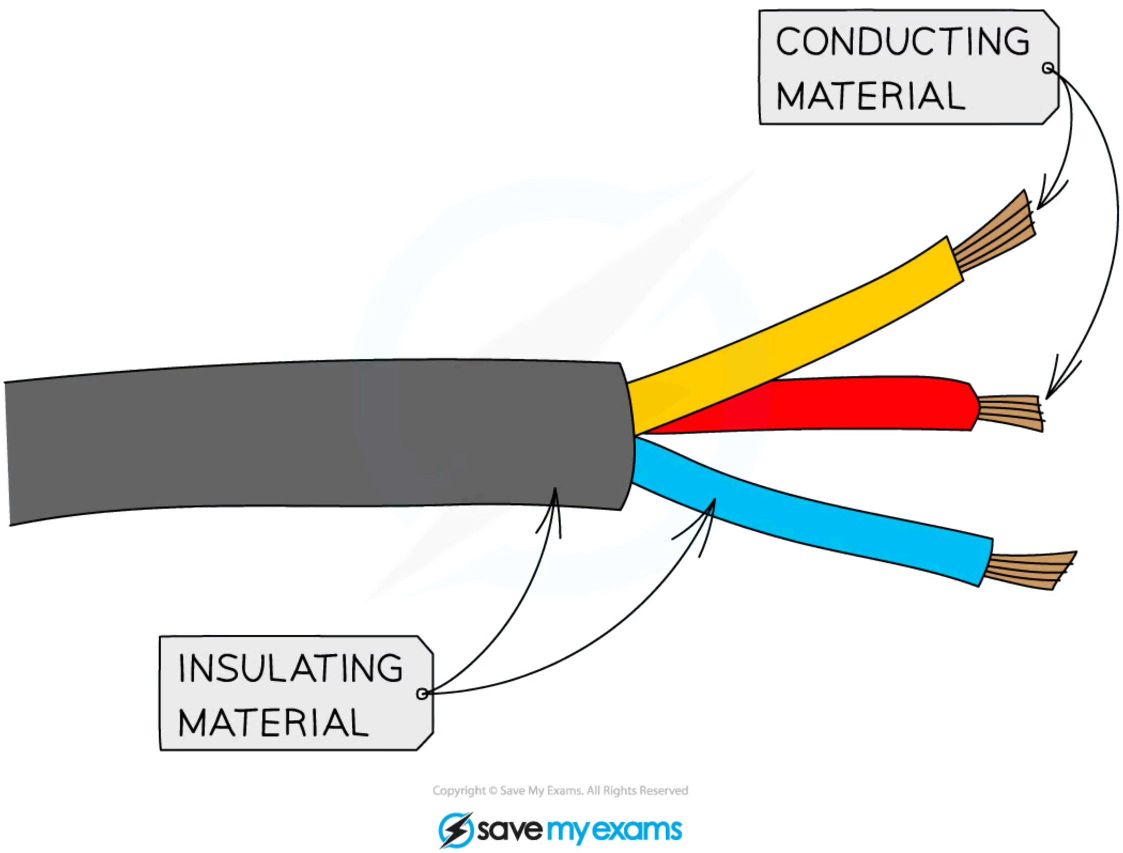

Diagram showing the plastic coating surrounding the conducting metal wires in an electric cable

Examiner Tips and Tricks

Simple molecules are small and can be separated into individual units without breaking any bonds.Giant ionic and covalent structures form huge continuous networks of atoms that are bonded together and which cannot be separated into individual units without breaking bonds.

Your notes

Giant Covalent Substances

Your notes

Diamond & Graphite

- Giant covalent structures are giant lattices that consist of a huge number of non-metal atoms with strong covalent bonds in a fixed ratio
- Examples of giant covalent structures includee:
  - Diamond
  - Graphite
  - Fullerenes
  - Graphene
- These examples are allotropes of carbon
  - Allotropes are different structural forms of the same element

Diamond

- Diamond and graphite are **allotropes** of carbon
- Both substances contain only carbon atoms but due to the differences in bonding arrangements they are physically completely different
- In diamond, each carbon atom bonds with four other carbons, forming a **tetrahedron**
- All the covalent bonds are identical, very strong and there are no **intermolecular forces**

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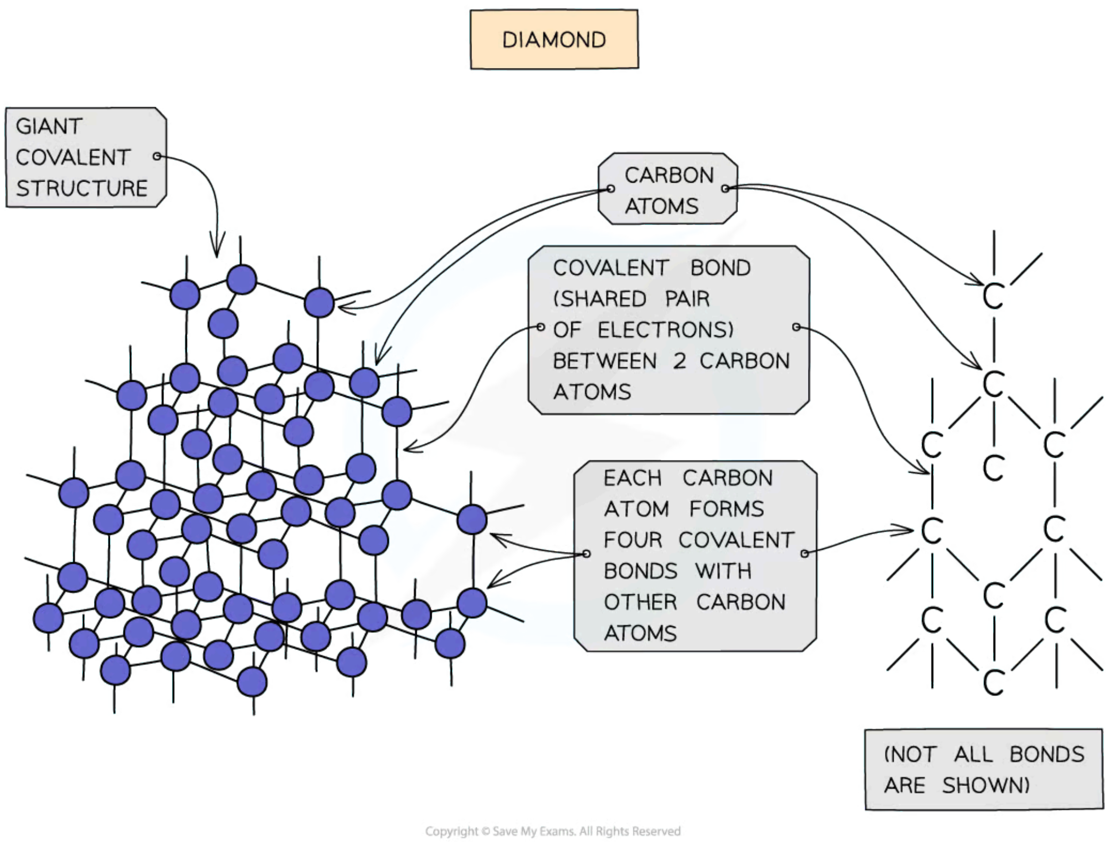


Diagram showing the structure and bonding arrangement in diamond

Properties of Diamond

- Diamond has the following physical properties:
  - It does not conduct electricity
  - It has a very high melting point
  - It is extremely hard and has a density of 3.51 g / cm^3 – a little higher than that of aluminium
- All the outer shell electrons in carbon are held in the four covalent bonds around each carbon atom, so there are no freely moving charged particles to the current
- The four covalent bonds are very strong and extend in a giant lattice, so a very large amount of heat energy is needed to break the lattice
- Diamond ́s hardness makes it very useful for purposes where extremely tough material is required

Your notes

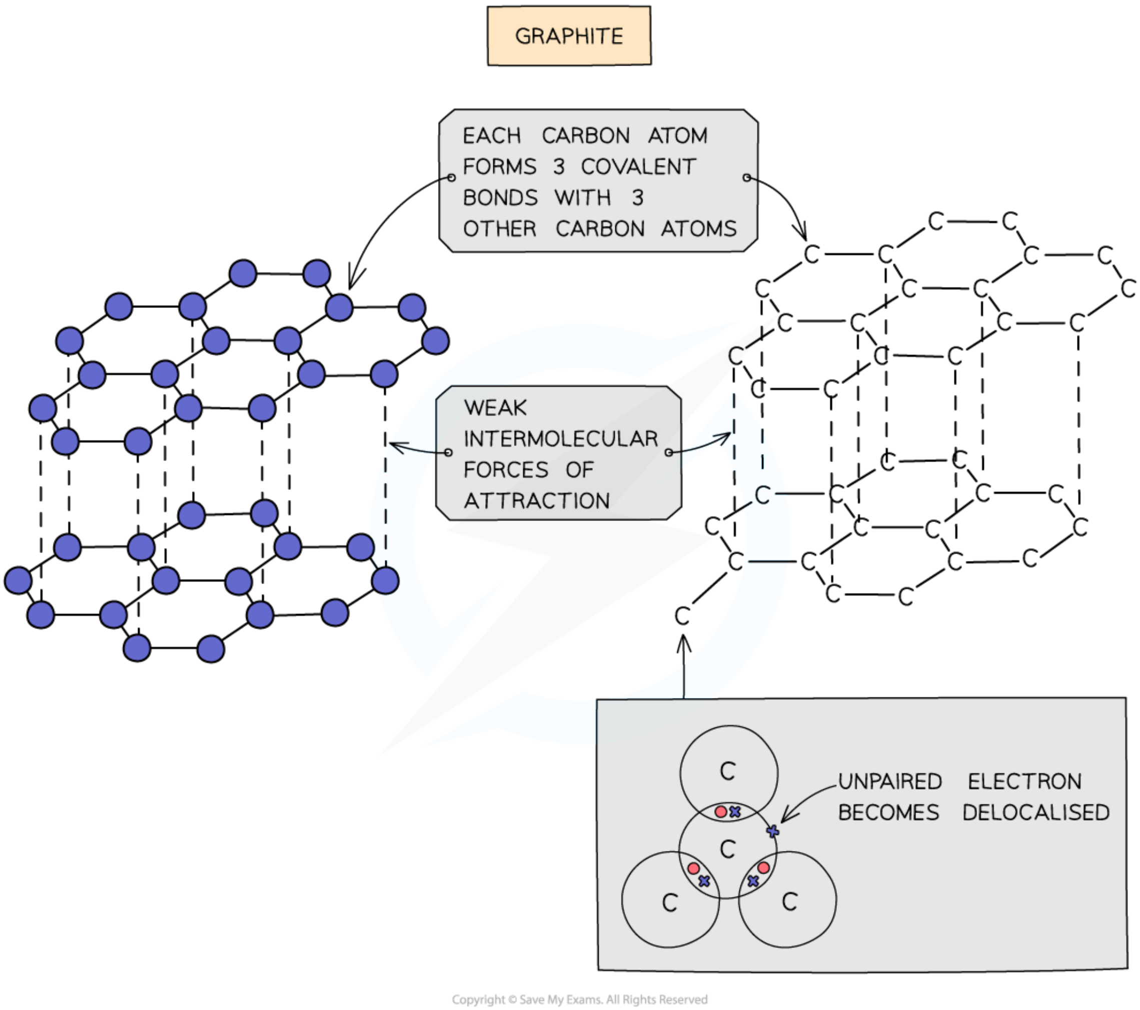
- Diamond is used in **jewellery** and for coating blades in **cutting tools**
- The cutting edges of discs used to cut bricks and concrete are tipped with diamonds
- Heavy-duty drill bits and tooling equipment are also diamond tipped

Examiner Tips and Tricks

Diamond is the hardest naturally occurring mineral, but it is by no means the strongest. Students often confuse **hard** with **strong**, thinking it is the opposites of weak. Diamonds are hard, but brittle – that is, they can be smashed fairly easily with a hammer. The opposite of saying a material is hard is to describe it as **soft**.

Graphite

- Each carbon atom in graphite is bonded to **three** others forming **layers** of **hexagons**, leaving one free electron per carbon atom
- These free electrons migrate along the layers and are free to move and carry charge, hence graphite can **conduct electricity**
- The covalent bonds within the layers are very strong, but the layers are attracted to each other by weak **intermolecular forces**, so the layers can **slide** over each other making graphite **soft** and **slippery**



The structure and bonding in graphite

Properties of Graphite

- Graphite has the following physical properties:
  - It conducts electricity and heat
  - It has a very high melting point
  - It is soft and slippery and less dense than diamond (2.25 g / cm^3)
- The weak intermolecular forces make it a useful material
- It is used in **pencils** and as an industrial **lubricant**, in engines and in locks

- It is also used to make **inert electrodes** for **electrolysis**, which is particularly important in the extraction of metals such as aluminium

Examiner Tips and Tricks

Don't confuse pencil lead with the metal lead – they have nothing in common. Pencil lead is actually graphite, and historical research suggests that in the past, lead miners sometimes confused the mineral galena (lead sulfide) with graphite; since the two looked similar they termed both minerals 'lead'.The word graphite derives from the Greek word 'grapho' meaning 'I write', so it is a well named mineral!

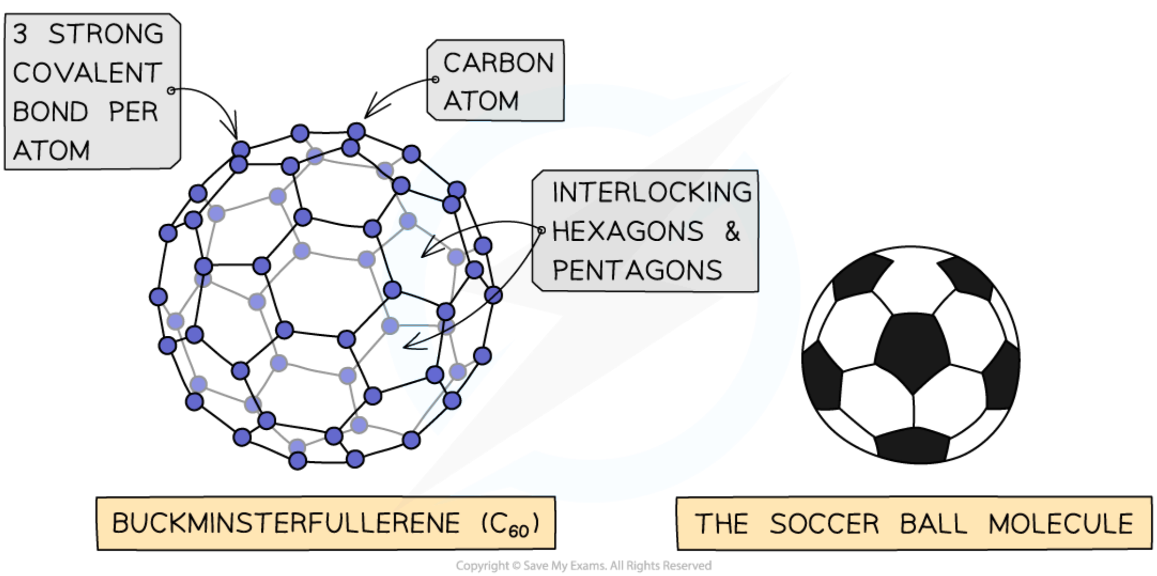
Fullerenes & Graphene

Your notes

Fullerenes & Graphene

C_{60} fullerene

- Fullerenes are a group of carbon allotropes which consist of molecules that form **hollow tubes** or **spheres**
- Fullerenes can be used to trap other molecules by forming around the target molecule and capturing it, making them useful for targeted **drug delivery** systems
- They also have a **huge surface area** and are useful for trapping **catalyst** molecules onto their surfaces making them easily accessible to reactants so catalysis can take place
- Some fullerenes are excellent lubricants and are starting to be used in many industrial processes
- The first fullerene to be discovered was buckminsterfullerene which is affectionately referred to as a "buckyball"
- In this fullerene, 60 carbon atoms are joined together forming 20 hexagons and 12 pentagons which produce a hollow sphere that is the exact shape of a soccer ball

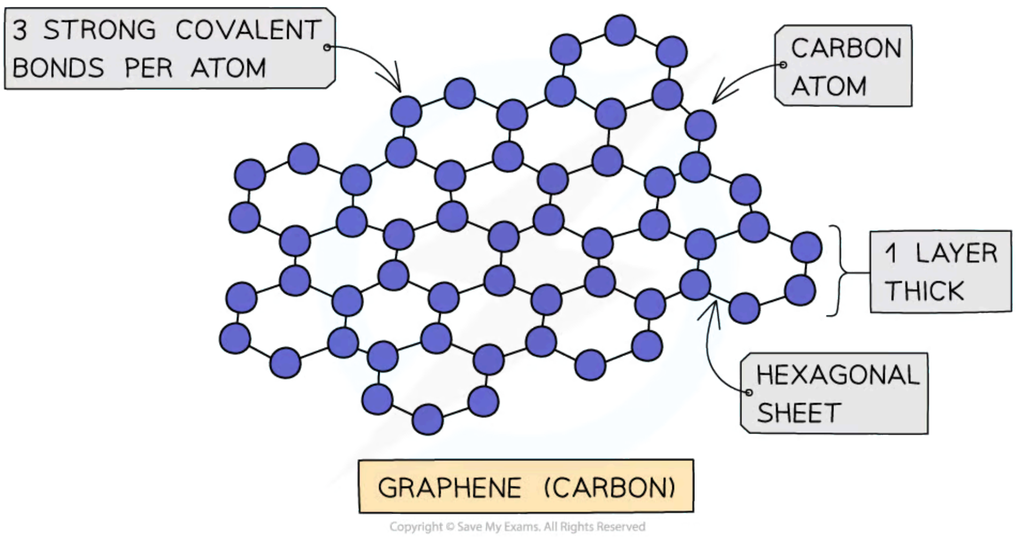


The structure and bonding in C_{60} fullerene – the football shaped molecule

Graphene

Your notes

- Graphene consists of a single layer of graphite which is a sheet of carbon atoms covalently bonded forming a continuous hexagonal layer
- It is essentially a 2D molecule since it is only one atom thick
- It has very unusual properties make it useful in fabricating **composite** materials and in **electronics**



Graphene is a truly remarkable material that has some unexpected properties

- Graphene has the following properties:
  - It is extremely **strong** but also amazingly **light**
  - It **conducts heat and electricity**
  - It is **transparent**
  - It is **flexible**
- Strength: It would take an elephant with excellent balance to break through a sheet of graphene
  - It is very strong due to its unbroken pattern and the strong covalent bonds between the carbon atoms. Even when patches of graphene are stitched together, it remains the strongest material out there
- Conductivity: It has free electrons which can move along its surface allowing it to **conduct electricity**
  - It is known to move electrons 200 times faster than silicon

  - It is also an excellent conductor of heat
- Flexibility: Those strong bonds between graphene's carbon atoms are also very flexible. They can be twisted, pulled and curved to a certain extent without breaking, which means graphene is bendable and stretchable
- Transparent: Graphene absorbs 2.3% of the visible light that hits it, which means you can see through it without having to deal with any glare
  - This gives it the potential to be used for making computer screens of the future

Examiner Tips and Tricks

Questions often ask you to state and explain the use of graphene or fullerenes, so make sure you can state their uses and link them to their bonding arrangements.

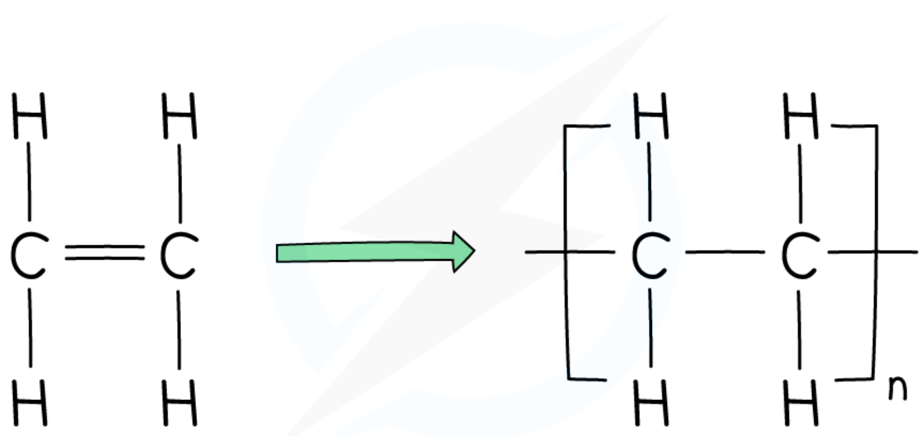
Your notes

Polymers

Your notes

Polymers

- Polymers are very large molecules which are built up by linking together 50 or more smaller molecules called **monomers**
- Each repeat unit is connected to the adjacent units via **covalent bonds**
- Some polymers called **homopolymers** contain just one type of monomer unit
  - Examples of these include **poly(ethene)** and **poly(chloroethene)**, commonly known as PVC
- Others contain two or more different types of monomer units which are called **copolymers** which have interesting and useful properties
  - Examples of these include ABS, a copolymer used in producing water pipes and musical instruments
- **Poly(ethene)** is a very common type of polymer which is formed from the addition of many ethene monomers together
- The intermolecular forces between the molecules in a polymer tend to be strong hence many of these substances are solid at room temperature



Polymerisation of ethene monomers produces poly(ethene). The small n signifies that there is a large number of repeat units

Your notes

Examiner Tips and Tricks

Simply polymers consist of large molecules containing chains of carbon atoms.

Metals

Your notes

Properties of Metals

The link between metallic bonding and the properties of metals

- Metals have **high** melting and boiling points
  - There are many **strong metallic bonds** in giant metallic structures
  - A lot of heat energy is needed to overcome forces and break these bonds
- Metals **conduct** electricity
  - There are **free electrons** available to move and carry charge
  - Electrons entering one end of the metal cause a delocalised electron to displace itself from the other end
  - Hence electrons can flow so electricity is conducted
- Metals are **malleable** and **ductile**
  - Layers of positive ions can **slide** over one another and take up different positions
  - Metallic bonding is not disrupted as the valence electrons do not belong to any particular metal atom so the delocalised electrons will move with them
  - Metallic bonds are thus not broken and as a result metals are strong but **flexible**
  - They can be hammered and bent into different shapes without breaking

Summary Table of the Physical Properties of Metals

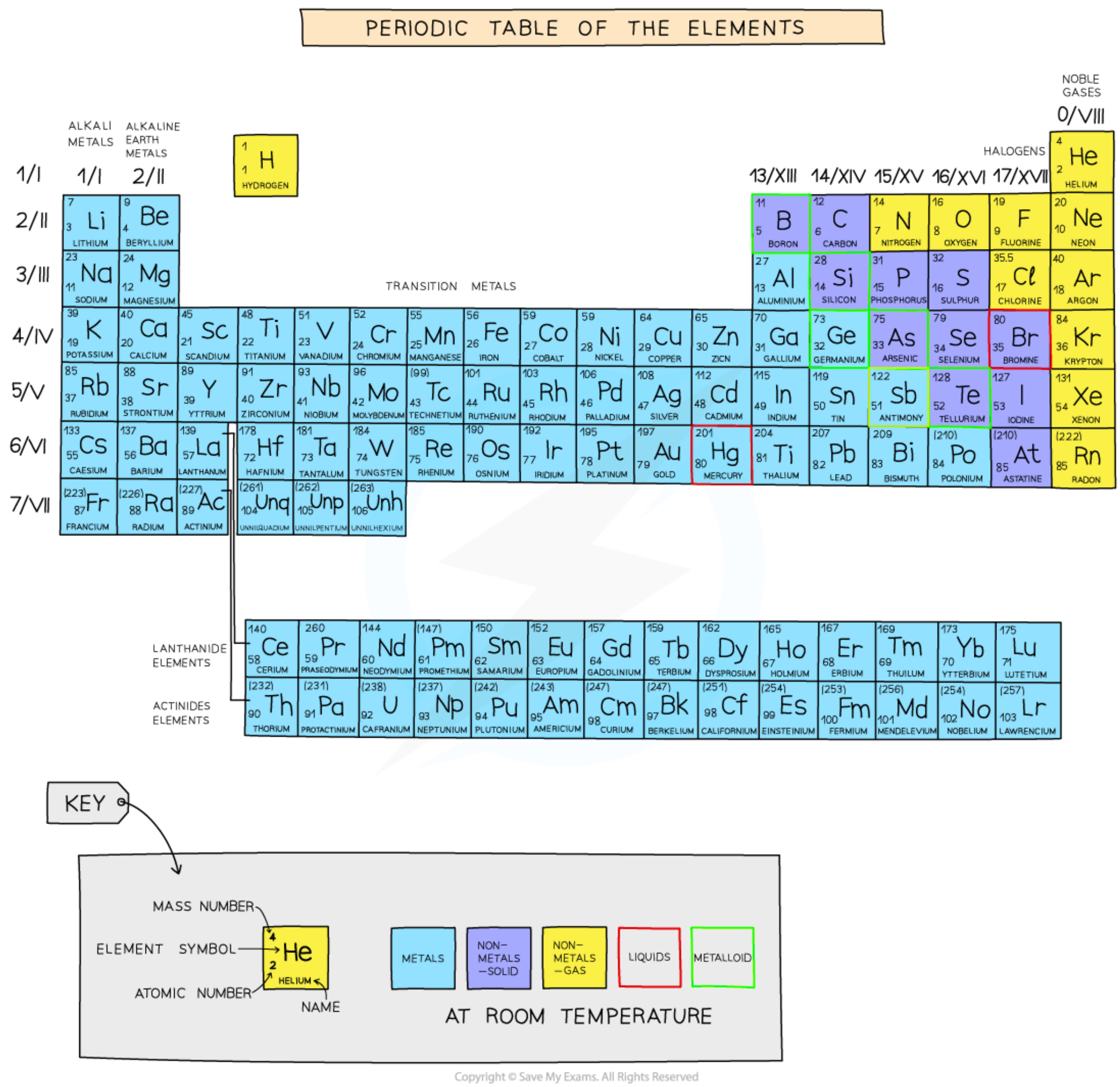
Property	Reason
High melting and boiling point	There are many strong metallic bonds in giant metallic structures so large amounts of heat energy are needed to overcome forces and break these bonds
Good conductors of electricity and heat	Metals are good conductors because of the free electrons that are available to move and carry charge. When a metal is used in an electrical circuit, electrons entering one end of the metal cause a delocalised electron to displace it itself from the other end. Hence electrons can flow so electricity is conducted
Malleable and ductile	Layers of positive ions can easily slide over one another and take up different positions. This does not disrupt the metallic bonding as the valence electrons do not belong to any particular metal atom and so they can move with the layers of positive ions, maintaining the electrostatic forces. The metallic bonds are thus not broken and as a result metallic bonds are strong but flexible. Therefore, they can be hammered into different shapes without breaking.

Your notes

Metals and non-metals

- The Periodic Table contains over 100 different elements
- They can be divided into two broad types: **metals** and **non-metals**
- Most of the elements are metals and a small number of elements display properties of both types. These elements are called **metalloids** or **semi-metals**

Your notes



The metallic character diminishes moving left to right across the Periodic Table

- The typical properties of metals and non-metals can be compared side-by-side:

Comparison Table of Metals and Non-metals

Metals	**Non-metals**
Solids at room temperature (except mercury)	Different states at room temperature

Shiny	Dull (when solid)
High density	Low density
Good conductors of electricity	Poor conductors of electricity
Good conductors of heat	Poor conductors of heat
High melting points	Low melting points
Malleable (can be bent and shaped) Ductile (can be drawn into wires)	Brittle (when solid)

Your notes

Examiner Tips and Tricks

Most metals are shiny solids which have high melting points, high density and are good conductors of electricity whereas most non-metals have low boiling points and are poor conductors of electricity

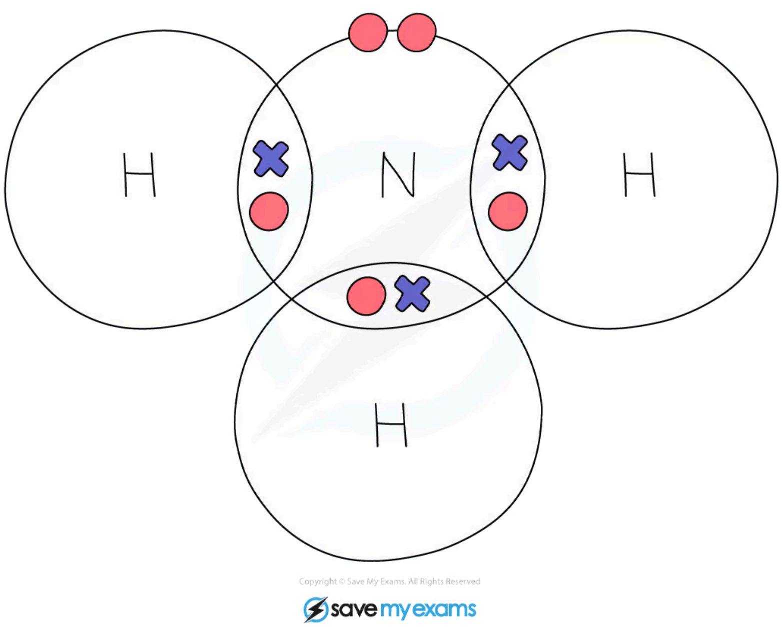
Representing Structures

Your notes

Limitations of Models

Dot and Cross Diagrams

- Advantages:
  - Useful for illustrating the transfer of electrons
  - Indicates from which atom the bonding electrons come from
- Disadvantages:
  - Fails to illustrate the **3D arrangements** of the atoms and electron shells
  - Doesn't indicate the **relative sizes** of the atoms

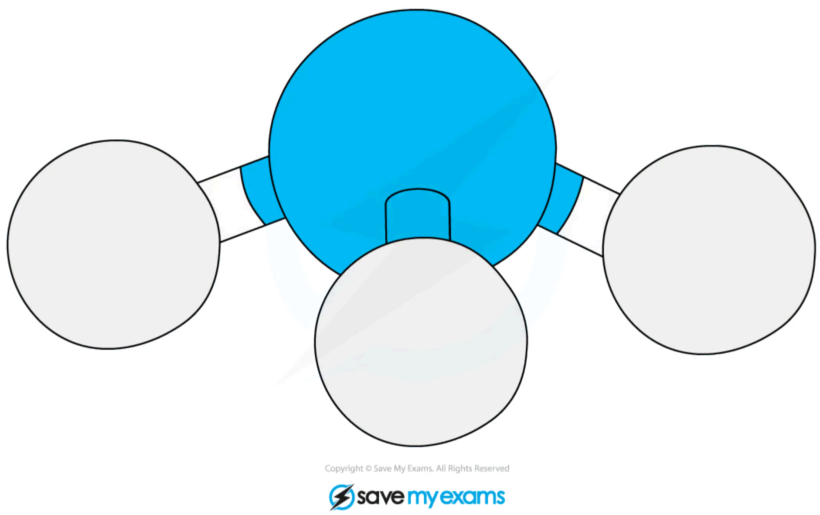


A dot & cross diagram of ammonia

Ball and Stick Model

- Advantages:
  - Useful for illustrating the arrangement of atoms in **3D space**

- Especially useful for visualizing the **shape** of a molecule
- Disadvantages:
  - Fails at indicating the **movement** of electrons
  - The atoms are placed far apart from each other, which in reality is not the case as the gaps between atoms are much smaller

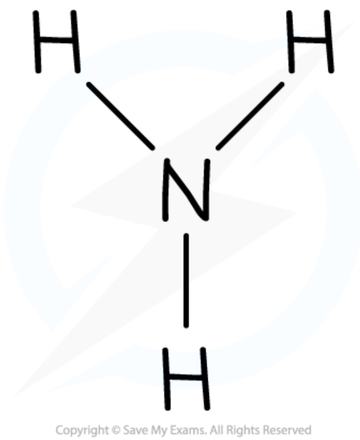


Ball and stick model of ammonia which illustrates the 3D arrangement of the atoms in space and the shape of the molecule

2D Representations of Molecules

- Advantages:
  - Displayed formulae are 2D representations and are basically simpler versions of the ball and stick model
  - Adequately indicate what atoms are in a molecule and how they are connected
- Disadvantages:
  - Fail to illustrate the relative sizes of the atoms and bonds
  - Cannot give you an idea of the shape of a molecule and what it looks like in 3D space

Your notes



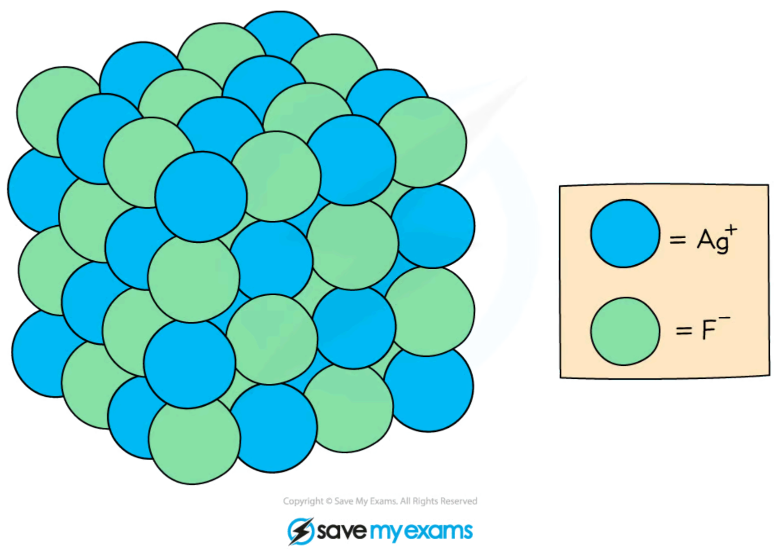
Displayed formula of ammonia

3D Representations of Ionic Solids

- Advantages:
  - 3D drawings and models depict the arrangement in space of the ions
  - Also show the repeating pattern in giant lattice structures
- Disadvantages:
  - Only illustrate the outermost layer of the compound
  - Are difficult and time-consuming to draw

Your notes

Your notes



3D representation of the ionic lattice structure of silver fluoride. The silver atoms are in blue/grey and the fluorine atoms in green

Examiner Tips and Tricks

You should be able to confidently describe the limitations of particular representations and models, including dot and cross, ball and stick models and two- and three-dimensional representations.