Types of Substance (Structure and Bonding) Notes

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There are many ways that we could be asked questions about structure and bonding in the exams. These questions generally ask **how** the structure and bonding of a compound gives that substance its properties. For example, a question could ask "Explain how graphite conducts electricity." First, let's define these terms, **structure** and **bonding**.

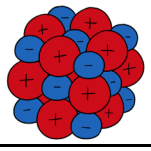
Structure: describes how the atoms, ions or molecules are arranged in a solid.

Bonding: describes how the electrons are distributed to make chemical bonds.

There are separate sections that deal with Ionic and Covalent bonding. So, these will only be mentioned here and not fully explained in this section. In this section we will look at and explain the properties of ionic, covalent and metallic compounds. Let's start with the first, Ionic compounds.

Ionic Compounds

An ionic compound: a compound formed when a metal ion and a non-metal ion react with each other. They are held together by strong electrostatic forces of attraction.

Structure:	The structure of an ionic compound is known as a giant lattice. The figure shows the giant ionic lattice found in ionic compounds. 
Do they conduct electricity?	Yes 😊
How do ionic compounds conduct electricity?	Ionic compounds only conduct when molten (melted) or aqueous (dissolved in solution). When ionic compounds are in these states the **ions** can move and so carry charge. Solid ionic compounds do not conduct electricity.
Melting and boiling point:	Ionic compounds tend to have high melting and boiling points and all are solids at room temperature. The stronger the bonds, the higher the melting point and boiling point. This is because more energy must be put in to break the bonds.

Covalent Compounds

Covalent compounds come in two different forms: simple molecular and giant molecular.

A simple molecular compound: two or more non-metal atoms covalently bonded to form a distinct unit.

A giant molecular compound: a three-dimensional lattice linked by covalent bonds.

Simple Covalent Compounds

Structure:	Simple molecules are just that. They exist as single molecules.
Do they conduct electricity?	No. They don't conduct electricity. 😊
Why don't they conduct electricity?	Simple molecular compounds have no delocalised electrons to move and carry charge.
Melting and boiling point:	Simple molecules have low melting and boiling points are usually gases at room temperature because there are only weak forces holding the molecules together. These are known as intermolecular forces. These require little energy to break or overcome.

Exam note: Intermolecular means in between molecules. Like an intercity bus, which travels between two cities for example. Intermolecular forces are weak, so only a small amount of energy is needed to overcome them. That's why substances with these forces usually have low boiling points.

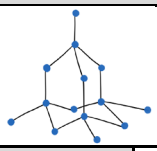
Exam hint: Students regularly lose marks here by saying that the covalent bond breaks when actually they mean the intermolecular forces are overcome. Covalent bonds are very strong so it would take a lot of energy to break those.

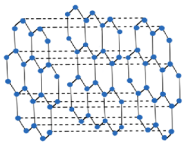
Giant Molecular Compounds

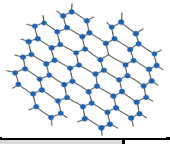
Some non-metals, like carbon, also form covalent bonds but exist as giant structures. Carbon exists in different forms called allotropes; diamond, graphite, graphene and carbon nanotubes. These are giant structures.

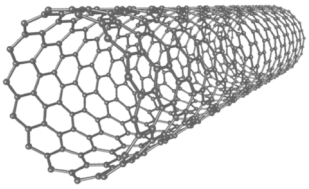
Allotrope: a different structural form of an element.

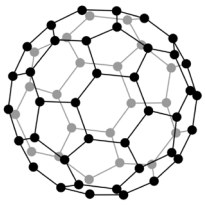
Let's start by looking at the first allotrope of carbon, diamond.

Diamond	
	**Exam note**: the figure to the left shows the general structure of a diamond. You will not be asked to draw it but you could be asked to identify it by matching the box of its name with the image of its structure.
Structure:	The structure of diamond is a giant covalent structure. In diamond, each carbon atom is **covalently bonded to four other carbon atoms.**
Does it conduct electricity?	No.
Why does diamond not conduct electricity?	As each carbon is **covalently bonded to four other carbon atoms** there are no delocalised electrons left over to move and carry charge.
Melting and boiling point:	**To break a diamond would require a very large number of strong covalent bonds to be broken, which requires a lot of energy to be put in**. As a result, diamonds are very strong, hard and have a very high melting point.
Uses	Diamonds are used in jewellery and to make cutting tools.

Graphite	
	**Exam note**: the figure to the left shows the general stucture of graphite. You will not be asked to draw it but you could be asked to identify it by matching the box of its name with the image of its structure.
Structure:	The structure of graphite is a **giant layer lattice**. In graphite, each carbon atom is **covalently bonded to three other carbon atoms.**
Does it conduct electricity?	Yes.
How does graphite conduct electricity?	As each carbon is **covalently bonded to three other carbon atoms** there is **one** delocalised electron left over **from each atom** to move through the layers and carry charge.
Melting and boiling point:	**To break graphite would require a very large number of strong covalent bonds to be broken, which requires a lot of energy to be put in**. As a result, graphite is very strong, hard and has a very high melting point.
Uses	Graphite is used as a lubricant and in pencils.
Why is graphite a good lubricant?	There are only weak intermolecular forces between the layers, meaning the layers can easily slide over each other.

Graphene	
	**Exam note**: the figure to the left shows the general stucture of graphene. You will not be asked to draw it but you could be asked to identify it by matching the box of its name with the image of its structure.
Structure:	In graphene, each carbon atom is **covalently bonded to three other carbon atoms.**
Does it conduct electricity?	Yes.
How does graphene conduct electricity?	As each carbon is **covalently bonded to three other carbon atoms** there is one delocalised electron left over from each atom to move through the structure and carry charge.
Melting and boiling point:	**To break graphene would require a very large number of strong covalent bonds to be broken, which requires a lot of energy to be put in**. As a result, graphene is very strong, hard and has a very high melting point.
Uses	Graphene doesn't really have many uses at the moment but there is a lot of interest in it for future materials.

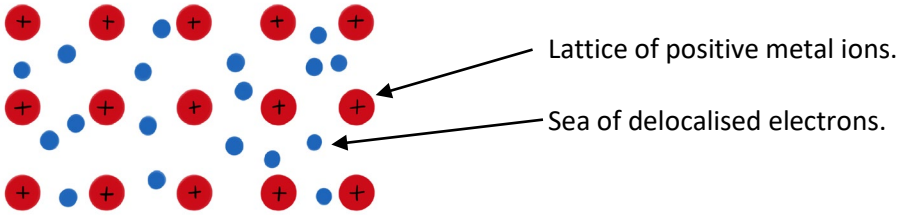
Carbon Nanotubes	
 **Carbon nanotube**	
Structure:	In carbon nanotubes and in Buckminster fullerenes, each carbon atom is **covalently bonded to three other carbon atoms.**
Does it conduct electricity?	Yes.
How do they conduct electricity?	As each carbon is **covalently bonded to three other carbon atoms** there is one delocalised electron left over from each atom to move through the material and carry charge.
Melting and boiling point:	**To break** carbon nanotubes **would require a very large number of strong covalent bonds to be broken, which requires a lot of energy to be put in**. As a result, they are both very strong, hard and have a very high melting point.
Uses	Carbon nanotubes are incredible materials that are used in electronics as they are really good conductors and in medicine as a treatment for cancer.

Buckminster Fullerenes	
 **Buckminster fullerene**	
Structure:	The structure is a simple molecular structure. Each carbon atom is covalently bonded to three other carbon atoms to form a discrete, hollow sphere of 60 carbon atoms.
Does it conduct electricity?	**No**, it's a poor conductor.
Why doesn't it conduct electricity?	Buckminster fullerenes do have are delocalised electrons! So, shouldn't it conduct electricity? **BUT**! And it's a big BUT 😊 the delocalised electrons cannot move between the separate molecules. This means they can't carry a charge through the whole material.
Melting and boiling point:	To melt it, you only need to overcome the weak intermolecular forces between the molecules. We are not breaking the strong covalent bonds. These intermolecular forces require little energy, so it has a much lower melting point than diamond, graphite, or nanotubes.
Uses	Used for drug delivery into the body, as catalysts (due to a large surface area to volume ratio), and as lubricants (the spherical molecules can roll past each other easily).

Metallic Compounds

Metal atoms need to lose electrons to become stable. They do this by losing their outer shell electrons into a sea of delocalised electrons.

Metallic bonding: the attraction between a lattice of positive ions and a sea of delocalised electrons.

Metallic Compounds	
 **Exam note**: we could be asked to label or draw a diagram of the structure of a metal.	
Structure:	The structure of metal is known as a giant lattice.
Does it conduct electricity?	Yes.
How do metals conduct electricity?	The electrons are free to move throughout the metal. This is why all metals conduct electricity.
Melting and boiling point:	Metallic bonding is quite strong, so metals are all solids at room temperature (except mercury) and generally have high melting points. The strong bonds make metals strong materials.

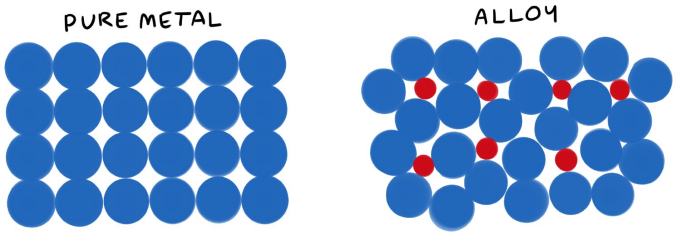
Metals are often called malleable and ductile. But what do these terms mean?

Malleable: means it can be hammered into shape.

Ductile: means it can be drawn out into wire shape.

Alloys

An alloy is a mixture of two or more elements, where at least one element is a metal. Many alloys are mixtures of two or more metals.



Alloys are usually harder and stronger than the pure metals they contain.

This is because the different sized atoms make it harder for the layers of atoms to slide over each other. Alloys are useful because they allow the best properties of metals to be combined.

Steel is an alloy, it is a mixture of iron and carbon, (mostly iron though). 😊