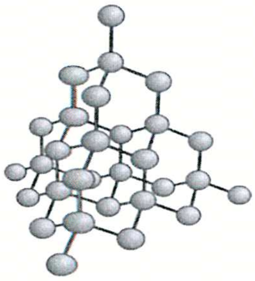
Giant covalent structures

Giant covalent structures are substances where all of the atoms in these structures are linked to other atoms by strong covalent bonds.

Carbon forms different giant covalent structures depending on how the carbon atoms are bonded which gives each form different properties. These different forms of the same carbon are called allotropes of carbon.



Diamond

Bonding/Structure

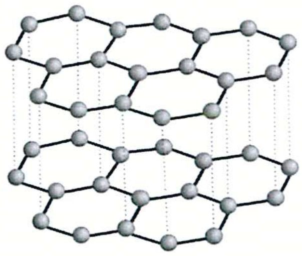
- Each carbon is bonded to four other carbons.
- In a regular 3D structure.
- Very strong covalent bonds between the carbons.

Properties

- **Hard**: Strong forces between the carbon atoms.
- **Transparent/shiny**: Arrangement of the carbon atoms allow it to reflect light.
- **High melting points/boiling points**: Strong forces between each of the bonded carbon atoms.
- **Cannot conduct electricity**: no free electrons (non-metal)

Uses

- Drill Bits: Its hardness makes it very good for drilling through hard substances.
- Jewellery: It's transparent and shiny appearance makes it very attractive and desirable for jewellery



Graphite

Bonding/Structure

- Each carbon bonded to three others.
- Arranged in layers (3D).
- Strong covalent bonds between atoms.
- Weak intermolecular forces between the layers.
- Free electrons (one from each carbon atom) can move through the structure.

Properties

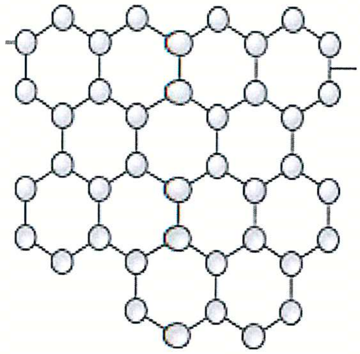
- **Soft**: Weak forces between layers
- **Electrical Conductor**: Free electrons between layers,
- **Slippery**: Made up of layers, these layers can move over each other.
- **High melting/boiling point**: Strong forces between atoms a lot of energy is needed to overcome these bonds.

Uses

- Pencils: its softness makes it suitable for pencils. All pencils are now made out of graphite.
- Electrodes: As graphite is able to conduct electricity and is fairly unreactive it makes it suitable for use as electrodes during electrolysis.
- Lubricant: As graphite is very slippery it makes it ideal for use as a lubricant.

Graphene

Bonding/Structure



- Each carbon bonded to three others.
- One layer of graphite.
- One atom thick (2D structure).
- Strong covalent bonds between atoms.
- Free electrons (one from each carbon atom) can move through the structure.

Properties

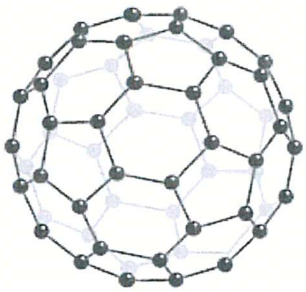
- **Semi-transparent (see through)** – this is because it is so thin.
- **Extremely strong** – due to the giant covalent structure/lattice and the strong covalent bonds.
- **Excellent conductor of heat and electricity** – due to the free electrons that can move around the structure.
- **Low density (lightweight)** – it is only 1 atom thick and 2-dimensional.

Uses

- Electronics – used in circuits due to excellent electrical conductivity (research is being done to produce semi-transparent electrons using graphene).
- Composite materials (e.g. carbon fibres) – used to reinforce other materials to make them stronger and lighter due to its strength and low density.

Fullerenes

Bonding/Structure



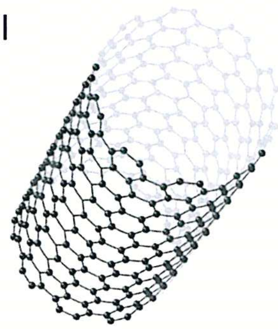
- Each carbon forms 3 covalent bonds to other carbon atoms.
- The fourth electron is delocalised to become a 'free electron'.
- The carbon atoms form pentagonal/hexagonal/heptagonal (5,6,7 sided) rings.
- The rings form an interlocking pattern.
- The rings form a 3-dimensional structure that is hollow.

Properties

- **Very stable** – can withstand high temperatures and pressures due to strong covalent bonds.
- **Hollow centre** – 3-dimensional shape produces a cage like structure.
- **Lubricant** – structures can roll,

Uses

- Drug delivery – the hollow centre of the molecule can carry drugs into specific parts of the body.
- Lubricants – used to reduce friction when metal parts of machines move past each other. The spherical shape of the molecules allows them to roll past each other.



4. A student studied the physical properties of two polymers.

Polymer A was hard and rigid. It could not be stretched.

Polymer B could be stretched a little before breaking.

a Identify the polymer, A or B, which contains covalent cross-links between the polymer chains. ______________ [1 mark]

b Explain the reason for your answer.

____

____

____ [2 marks]

Giant covalent structures

1. Simple molecules and giant covalent structures are both covalently bonded.

Some examples are shown below.

ammonia	diamond	graphite	oxygen	silicon dioxide	water

a Complete **Table 3** but writing the names of the examples into the correct columns. [4 marks]

Table 3

Simple molecules	Giant covalent structure
Water	Diamond

Synoptic **b** State **one** example from **Table 3** that is:

i An element ______________ [1 mark]

ii A gas at room temperature ______________ [1 mark]

iii Made up of carbon atoms only ______________ [1 mark]

2. **Figure 10** shows three examples of giant covalent structures.

Name each one. [3 marks]

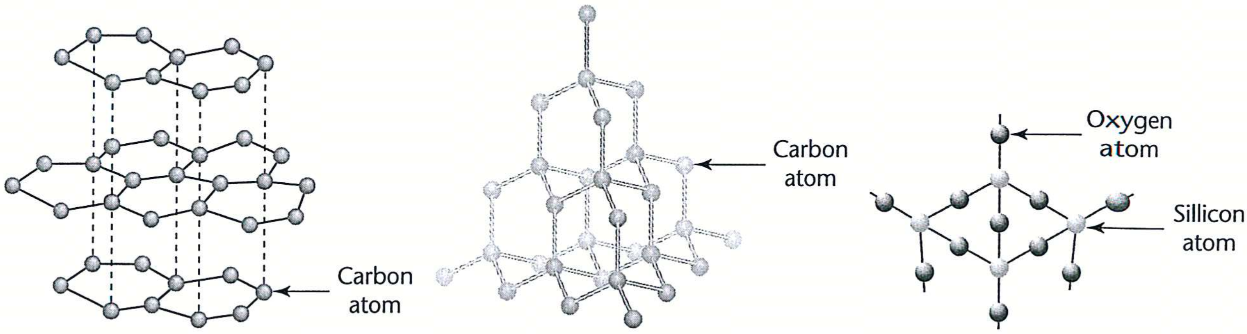


Figure 10

__________________ __________________ __________________

3. Silicon dioxide (SiO_2) and carbon dioxide (CO_2) are both covalent compounds.

Compare their structures.

You should describe the bonding between the atoms in each.

____

____

____

____ [4 marks]

Properties of giant covalent structures

1. Which is a property that **all** giant covalent structures have?

Tick **one** box.

- ☐ Able to conduct electricity
- ☐ High melting and boiling point
- ☐ Hard
- ☐ Strong

[1 mark]

> **Remember**
> All the bonds in a giant covalent structure are very strong.

2. Diamond is the hardest naturally occurring substance on Earth.

Figure 11 shows its structure.

Explain why diamond is hard.

You should use what you know about its structure and bonding.

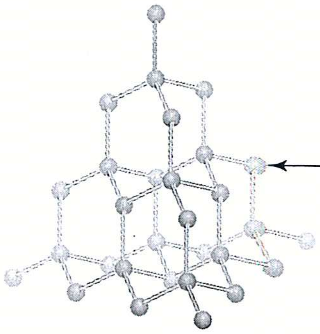


Figure 11

____

______________________________ [2 marks]

3. **Figure 12** shows the structure of graphite.

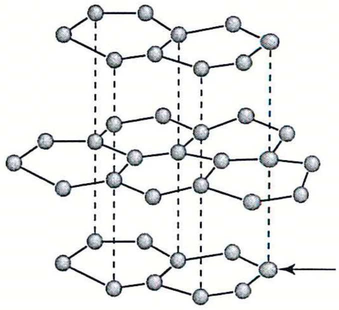


Figure 12

a State one similarity between the structure of diamond and graphite.

______________________________ [1 mark]

[2 marks]

b Graphite is a soft material that can conduct electricity.

What other substance can conduct electricity?

☐ Polymer ☐ Metal ☐ Silicon dioxide ☐ Diamond [1 mark]

c Explain why graphite can conduct electricity.

____

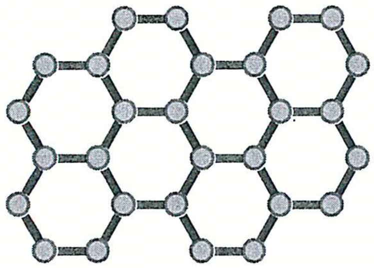
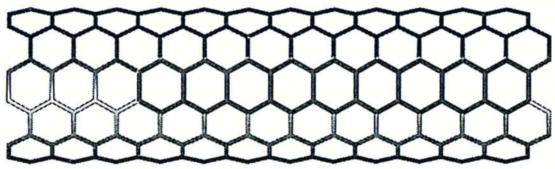
______________________________ [2 marks]

Graphene and fullerenes

1. This question is about carbon structures.

a Select **two** words from the box to name the structures below.

Carbon nanotube	Diamond	Graphite	Graphene

Structure A ____________ Structure B ____________ [2 marks]

b How many carbon atoms are in each ring in structure A? ____________ [1 mark]

c State one use of structure B.

____ [1 mark]

d Explain why its properties make it suitable for this use.

____

____ [2 marks]

2. Carbon nanotubes are a type of fullerene.

> **Remember**
> You need to be able to use prefixes so try and remember what they mean.
> 1 nm = 1×10^{-9} m.

Maths **a** The width of one type of carbon nanotube is 10 nm.

What is this in metres?

Tick **one** box.

☐ 1×10^{-6} m ☐ 1×10^{-7} m ☐ 1×10^{-8} m ☐ 1×10^{-9} m [1 mark]

b It has a width:length ratio of 1:100 000

How long is the carbon nanotube **in mm**?

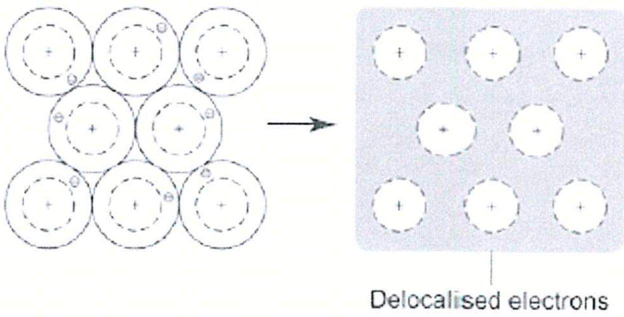
1 nm = 0.000001 mm

____________ mm [3 marks]

Metallic bonding

Metals consist of giant structures of atoms arranged in a regular pattern.
When metals are in their pure element form, they still want a full outer shell.

To do this they 'delocalise' their outer shell electrons to become positive ions. The electrons form a 'sea' of delocalised electrons that move between the positive metal ions.



Strong forces of attraction between the positive metal ions and the delocalised electrons give metals their properties.

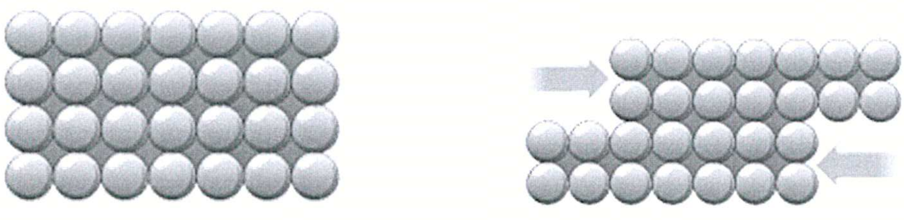
Properties of Metals

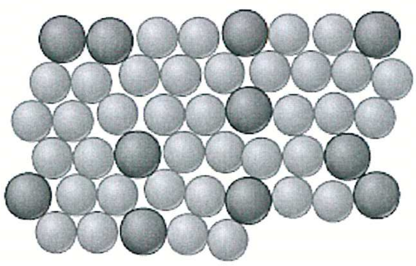
Metals have giant structures of atoms with strong metallic bonding. The structure of metals and the bonding present between the ions and delocalised electrons give metals the properties:

- High melting / boiling point – due to strong electrostatic forces of attraction between the ions and delocalised electrons.
- Good thermal conductor – the delocalised electrons transfer the heat energy more quickly through the structure.
- Good electrical conductor – the delocalised electrons can carry the charge of the current.
- Malleable/ductile – the regular layers of the metal ions can slide over each other, changing its shape.
- High density – the metal ions are arranged in a regular structure that is held closely together by the delocalised electrons.

Alloys

In pure metals, atoms are arranged in layers, which allow metals to be bent and shaped. Pure metals are too soft for many uses and so are mixed with other metals to make alloys which are harder.





In an alloy, the layers cannot slide as easily.

Command word

If you are asked to evaluate something you must use the information in the question plus your own scientific knowledge to consider evidence for and against.

To get maximum marks you should state evidence from both sides of the argument along with your reasoning. This means explain why the evidence supports the argument.

Metallic bonding

1. The atoms in which substances are held together by metallic bonding?

Tick **two** boxes.

☐ Carbon ☐ Carbon dioxide ☐ Cobalt ☐ Copper [2 marks]

2. What is true about metallic bonding?

Tick **one** box.

☐ It is weak ☐ It is strong ☐ It is covalent ☐ It is ionic [1 mark]

3. **Figure 14** shows metallic bonding.

Choose the correct labels from the list below to label it.

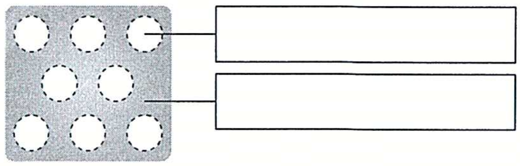


Figure 14

negative ion	positive ion	sea of electrons	sea of protons

[2 marks]

4. The electrons in a metal are delocalised.

What does this mean?

____

____

______________________________ [2 marks]

5. Explain why the atoms in a metal are held tightly together.

____

____

____

______________________________ [3 marks]

Properties of metals and alloys

1. Which substance is an alloy?

Tick **one** box.

☐ aluminium ☐ bronze ☐ copper ☐ zinc [1 mark]

2. Define alloy

____ [2 marks]

3. **Figure 15** shows the structure of an alloy.

Explain why alloys are stronger than pure metals.

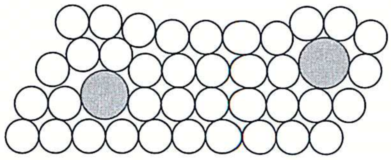


Figure 15

____

____ [2 marks]

4. The data in **Table 4** shows the melting points of metals found in group 1 and 2 of the periodic table.

Synoptic

Table 4

Metal	Melting point in °C
Calcium	842
Magnesium	650
Potassium	63
Sodium	98

a Use the data in **Table 4** to compare the melting point of group 1 and 2 metals.

____

____ [1 mark]

b In general, the more delocalised electrons there are in the metal, the stronger the metallic bonds.

Use the information to suggest an explanation for your answer to part **a**.

Use the electronic structure of the metals in your answer.

____

____

____

____ [4 marks]

Topic 2 – Bonding, Structure and the Properties of Matter Glossary

Key Word	Definition
Ionic bonding	A chemical bond formed by electrons being transferred from a metal atom to a non-metal atom.
Allotrope	Different structure of the same element.
Alloy	A mixture of metal atoms with atoms of different sizes.
Boiling point	The temperature where a substance goes from a liquid to a gas or from a gas to a liquid.
Change of state	When a substance changes from one state to another e.g. solid to liquid.
Chemical property	A characteristic of a substance observed when it undergoes a chemical reaction.
Condensation	The process in which a gas becomes a liquid.
Covalent bonding	A chemical bond formed between non-metal atoms sharing pair(s) of electrons.
Delocalised electrons	Electrons that are not connected to a specific atom.
Diamond	An allotrope of carbon where each atom is covalently bonded to four other carbon atoms.
Dot and Cross diagram	A diagram used to illustrate electron arrangement using dots and crosses to represent electrons.
Electron	A tiny particle with a negative charge. Electrons orbit the nucleus of atom/ion in shells.
Electrostatic force	A strong attractive force that occurs between opposite charges.
Evaporation	The process in which a liquid becomes a gas.
Freezing	The process in which a liquid becomes a solid.
Fullerene	An allotrope of carbon where each atom is covalently bonded to three other carbon atoms to form a 3D hollow cage or tube.
Giant covalent structure	A substance that contains many atoms covalently bonded together.
Graphene	An allotrope of carbon where each atom is covalently bonded to three other carbon atoms in a 2D shape (one layer of graphite).

Graphite	An allotrope of carbon where each atom is covalently bonded to three other carbon atoms in layers.
Intermolecular force	A weak force of attraction between molecules.
Lattice	A regular repeated three-dimensional arrangement of atoms, ions, or molecules in a metal or other crystalline solid.
Melting	The process in which a solid becomes a liquid.
Melting point	The temperature where a substance goes from a solid to a liquid or from a liquid to a solid.
Metallic bonding	Bonding that occurs in metals where each metal atom delocalises electrons to become positive ions with full outer shells.
Negative ion	An atom that has gained electrons to get a negative charge.
Neutral	No overall charge.
Outer shell	The last electron shell of the atom – sometimes called a valence shell.
Physical property	A property that can be observed or measured e.g. appearance, texture, colour, odour, melting point, boiling point, density, solubility
Polymer	A long molecule made from many smaller molecules.
Positive ion	An atom that has lost electrons to get a positive charge.
Simple molecule	A few atoms covalently bonded together.
State symbol	Symbol used to identify the state of substance in a chemical equation.
Sublimation	The process in which a solid becomes a gas or a gas becomes a solid.

2. Boiling – C [1 mark], Condensing – D [1 mark], Freezing – A [1 mark], Melting – B [1 mark]
3. **a** Wait until the salol has turned into a liquid. [1 mark] Read the temperature using thermometer. [1 mark]
   b Its melting point is too/very high. [1 mark] So they do not have the equipment to get it hot enough. [1 mark]

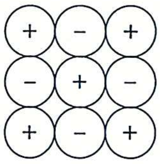
Ionic bonding and ionic compounds

1. sodium chloride (NaCl) [1 mark]
   lithium oxide (Li_2O) [1 mark]
2. **a** Ca^{2+} and O^{2-} [1mark]
   b **i** B [1 mark]
   ii Worked example – full answer given in workbook.
3. K_2S
   K and S [1 mark] in the correct ratio [1 mark]

Dot and cross diagrams for ionic compounds

1. **a** Ionic [1 mark] **b** MgF_2 [1 mark]
2. Electrons transferred from sodium to oxygen. [1 mark] Two sodium atoms each lose one electron. [1 mark] forming Na^+/1+ ions. [1 mark] Oxygen atoms gain 2 electrons [1 mark] forming O^{2-}/2– ions. [1 mark]

Properties of ionic compounds

1. They have high boiling points. [1 mark]
   They are all solids at room temperature. [1 mark]
2. **a** 

   [1 mark]
   b Giant ionic lattice [1 mark]
3. Level 3: Student explains all properties using sound knowledge of the bonding in an ionic compound. [5–6 marks]
   Level 2: Student explains some properties using correct knowledge of the bonding in an ionic compound. [3–4 marks]
   Level 1: Student explains one property correctly [1–2 marks]

   Indicative content

   There are strong forces between the ions.

   This comes about because of the attraction between positive and negative ions.

   The forces act in all directions.

   Large amounts of energy are needed to break the bonds and melt sodium chloride.

   When solid the ions cannot move.

   When melted the ions are free to move and so charge can flow.

Covalent bonding in small molecules

1. Carbon dioxide [1 mark], Water [1 mark]
2. Answers in order: share [1 mark], electrons [1 mark], strong [1 mark]
3. **a** Worked example – full answer given in workbook.
   b The boiling point increases. [1 mark]
4. One line from carbon to each hydrogen [1 mark]

Dot and cross diagrams for covalent compunds

1. Numbering boxes 1 to 4 from top: 1 – 1 [1 mark], 2 – 4 [1 mark], 3 – 3 [1 mark], 4 – 2 [1 mark]
2. **a** Worked example – full answer given in workbook.
   b They do not show the 3D shape of the molecule. [1 mark]
3. 3 shared pairs of electrons [1 mark]
   1 pair remaining on each atom [1 mark]

Properties of small molecules

1. Normally gases or liquids at room temperature. [1 mark] Do not conduct electricity when dissolved in water. [1 mark]
2. carbon [1 mark], hydrogen [1 mark]
3. Covalent [1 mark]
4. The forces between the molecules (intermolecular forces) break. [1 mark]

Polymers

1. Plastic [1 mark]
2. One line drawn joining both chains [1 mark]
3. The intermolecular forces are stronger in poly(ethene) (than ethene). [1 mark] So more heat energy is needed to break the forces [1 mark] and turn poly(ethene) into a gas. [1 mark]
4. **a** A [1 mark]
   b Polymer A cannot be stretched because the polymer chains cannot be moved apart [1 mark] because they are linked by strong cross-links. [1 mark]

Giant covalent structures

1. **a** Simple molecules: ammonia [1 mark], oxygen. [1 mark] Giant covalent structure: graphite [1 mark], silicon dioxide. [1 mark]
   b **i** diamond/graphite/oxygen. [1 mark]
   ii oxygen. [1 mark]
   iii diamond/graphite. [1 mark]
2. Graphite [1 mark], diamond [1 mark], silicon dioxide/silica [1mark]

3. Any 4 from:

Silicon dioxide has a giant covalent structure.

Carbon dioxide is made up of simple molecules.

There are strong covalent bonds between the silicon and oxygen atoms in silicon dioxide.

All bonds in silicon dioxide are strong covalent bonds.

There are strong covalent bonds between the carbon and oxygen atoms in the carbon dioxide.

There are weak intermolecular forces between the carbon dioxide molecules. [4 marks]

Properties of giant covalent structures

1. High melting and boiling point [1 mark]
2. Strong covalent bonds [1 mark] between all (carbon) atoms [1 mark]
3. a Any one from: Both contain carbon atoms. Both have strong covalent bonds between atoms. [1 mark]
   b Metal [1 mark]
   c There are (delocalised) electrons between the layers [1 mark] which can move/carry charge [1 mark]

Graphene and fullerenes

1. a Graphene [1 mark], Carbon nanotube [1 mark]
   b 6 [1 mark]
   c Any one from: electrical circuits, catalysts, reinforcing materials [1 mark]
   d Property e.g. high electrical conductivity, large surface area, high strength. [1 mark]
   Explanation: e.g. allows electricity to pass through, more chance the reactants will collide, increase the force needed to break the material [1 mark]
2. a 1×10^{-8} m [1 mark]
   b 10 nm × 100 000 [1 mark]
   1 000 000 nm [1 mark]
   1 000 000 × 0.000001 = 1 mm [1 mark]

Nanoparticles

1. a $PM_{2.5}$ – 1000nm [1 mark], Sunscreen particles – 10 nm [1 mark], PM_{10} – 10 000nm [1 mark]
   b sunscreen particles [1 mark] c 1 [1 mark]
2. a 2 × 2 × 2 = 8 [1 mark] cm^3 [1 mark]
   b (2 × 2) × 6 [1 mark] = 24 [1 mark] cm^2 [1 mark]
   c 3:1 (accept 24:8) [1 mark]

Uses of nanoparticles

1. Any one from: Carrying drugs to cells, in cosmetics, sun creams, as deodorants, catalysts [1 mark]
2. a It supports the claim well because the results show that the nanoparticles killed human cells. [1 mark] It does not support the claim well because the experiment was done outside of a human body. [1 mark] so nanoparticles might not have the same effect on a person. [1 mark]
   b It increases the validity [1 mark] because other scientists have checked the research. [1 mark]
   c Level 3: A number of reasons for and against a ban have been discussed with valid reasoning. [5–6 marks]
   Level 2: A number of reasons for and against have been listed. [3–4 marks]
   Level 1: One or two reasons for and against a ban have been stated. [1–2 marks]

Indicative content

Nanoparticles have many uses e.g. applications in medicine, in electronics, in cosmetics and sun creams, as deodorants, and as catalysts.

There are many potential uses of nanoparticles that will not be discovered if they are banned.

There might not be any risk to human health, more research is needed.

Nanoparticles are only a risk to human health if they are inhaled.

Nanoparticles might pose a risk to human health, so a ban would prevent people getting ill.

Because the technology is so new, health problems may become apparent in the future.

Metallic bonding

1. Cobalt [1 mark], Copper [1 mark]
2. It is strong [1 mark]
3. positive ion [1 mark], sea of electrons [1 mark]
4. They are not attached to any particular atom. [1 mark] They are free to move. [1 mark]
5. There is a strong force of attraction [1 mark] between positive metal ions [1 mark] and the 'sea' of negative electrons. [1 mark]

Properties of metals and alloys

1. bronze [1 mark]
2. A mixture [1 mark] of different metals [1 mark]
3. It has atoms of different sizes added [1 mark] which prevents the layers sliding over each other. [1 mark]
4. a The melting points of group 2 metals are higher than the melting points of group 1 metals. [1 mark]
   b Group 2 metals have 2 electrons on their outer shell/ the delocalised electrons in group 2 metals contain 2 electrons from each atom. [1 mark] Group 1 metals have 1 electron on their outer shell/the delocalised electrons in group 1 metals contain 1 electron1 from each atom. [1 mark] There are more delocalised electrons in group 2 metals. [1 mark] So the metallic bonds are stronger in group 2 metals than group 1 metals, so more heat energy is needed to break them. [1 mark]