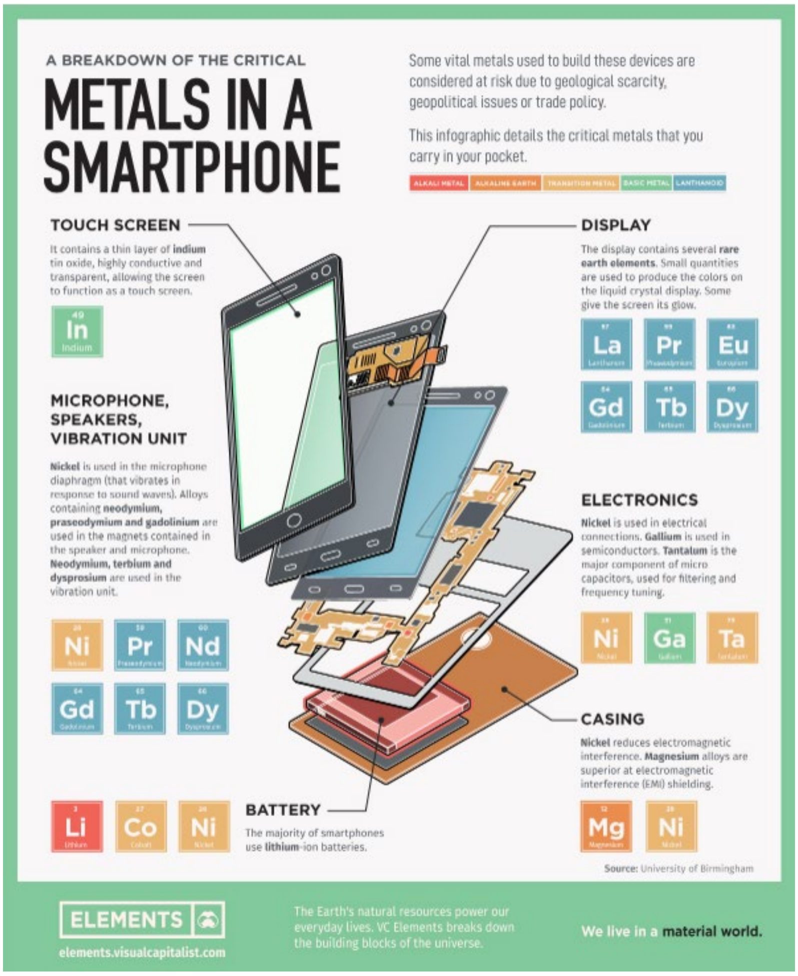
CB1.4 PROPERTIES OF CHEMICAL SUBSTANCES FOR THEIR INTENDED USE CORE NOTES



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2024

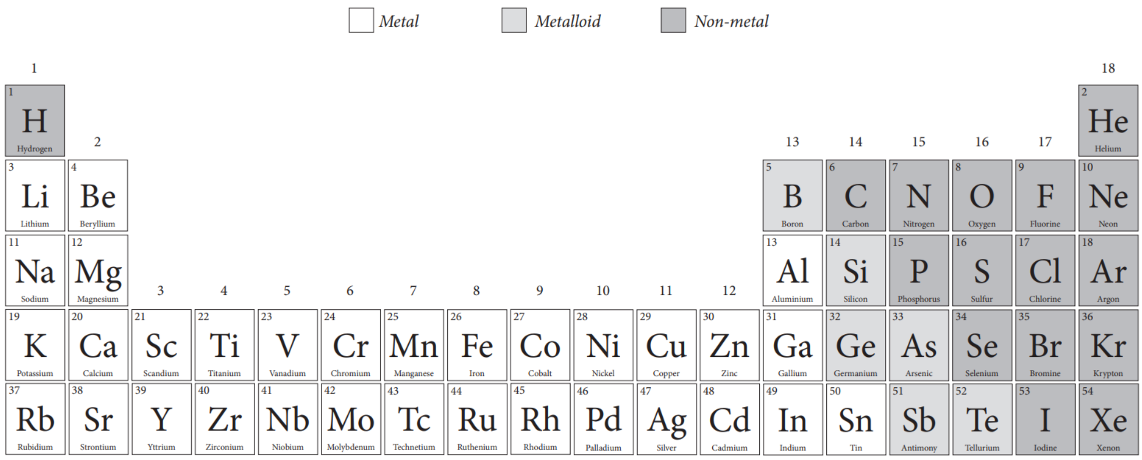
Index

p.2 – 4 metal and non-metals and physical properties of substances.
p.5 – 7 bonding in ionic solids and their properties.
p.8 conductivity practical salt and salt water.
p.9 – 10 ionic solids practice exam question.
p.11 – 12 bonding in metallic solids and their properties.
p.13 – 15 practicals for metallic solids physical properties.
p.15 alloys.
p.16 – 18 metallic solids practice exam question.
p.19 covalent bonding and bonding in molecular substances.
p.20 phase change and molecular bonding linked to melting and boiling point.
p.21 sublimation of iodine practical.
p.22 molecular substances physical properties.
p.23 – 24 molecular substances exam question compared to ionic solids.
p.25 – 27 bonding in 3D covalent extended network solids (diamond, silica and graphite) and their physical properties.
p.28 – 30 3D covalent extended network solid practice exam question compared to molecular substances.
p.31 – 35 bonding in polymers intramolecular forces (covalent bonding) and intermolecular forces of attraction in straight chain and not straight chain polymers linked to their physical properties.
p.36 – 52 summary of the 5 types of substances, a description of their bonding and explanations of their physical properties table.
p.53 – 64 model answer section for the practice exam questions.

Properties of metal and non-metal elements

Metals are placed on the left-hand side of the periodic table, and non-metals on the right.

FIRST 54 ELEMENTS



Physical properties

The table summarises some typical properties of metals and non-metals.

Metals	Non-metals
High melting points	Low melting points
Good conductors of electricity (electrical conductors)	Poor conductors of electricity
Good conductors of heat (thermal conductivity)	Poor conductors of heat
High density	Low density
Malleable	Brittle
Ductile	-
Hardness	-
Sonorous (makes a ringing sound when hit)	Non sonorous
Lustre (shiny appearance)	-

Electrical conductor's means that metals carry delocalised electrons (free moving electrons) this means that electricity can flow through a metal due to the charged electrons. Hence, metals are used in electrical wiring and circuit boards as the electricity can flow through the metals easily.

A good **thermal conductor** means that heat can be passed on from one metal atom to another. Metals have non-directional bonding and delocalised electrons (free moving electrons) this means when heat is applied the metal atoms gain kinetic energy and start to vibrate (due to the free moving delocalised electrons). This kinetic energy is passed onto neighbouring atoms allowing heat energy to pass through the metal. Hence, metals are used to make pots and pans as when heat is applied the metals atoms gain kinetic energy and pass it onto neighbouring atoms and then into the food. Meaning the food will cook quickly as the metal pot or pan is a good thermal conductor.

A substance with a high **density** means it has a high mass for its size (has a greater mass per unit volume). This is true for lead; Lead has a high density. This is why lead is used in fishing sinkers as a small ball of lead has a high mass and will sink down into the water drawing the hook closer to the bottom of the ocean where the fish are feeding. On the other hand, Aluminium has a very low density. It means that a larger piece of metal can be used but the mass isn't too high. This is why aluminium is used in aircrafts or for casing of objects as its mass is not too much and it is considered 'light weight' to carry the object around.

Malleable substances can be bent or hammered into shape without shattering. This can happen due to non-directional metallic bonding between the metal atoms, and they can easily slide past one another without breaking the strong metallic bonds. Hence, why Aluminium can be used as hair foils. The aluminium atoms slide past one another to form a thin sheet which then can easily be bent and used as hair foils.

Ductile means that a substance can be drawn out into a long wire without snapping or breaking. This is also due to the non-directional metallic bonding between the metal atoms, and they can easily slide past one another without breaking the strong metallic bonds. Hence, why copper is used as electrical wiring. The copper atoms can easily slide past one another to form thin wires without breaking the strong metallic bonds.

Hardness/ tensile strength means that a substance can withstand a large amount of force (or energy) without fracturing (breaking). The harder the substance, the more force (or energy) it can take and not be broken or fractured. Metals have hardness due to the strong metallic bonding between the metal atoms (metal cations and surrounding delocalised electrons) which require a large amount of force/ energy to overcome these forces of attraction.

Softness is when a substance can be easily deformed. Due to the very weak intermolecular forces holding the molecules together molecular substances are usually soft as only a small amount of energy/ force is required to deform of break the very weak intermolecular forces between the molecules.

Sonorous means that a metal will making a ringing sound when struck with a force. Metals are sonorous due the non-directional bonding between the metal atoms which allows them to vibrate when hit. Metals with a lower density tend to be more sonorous. Metals that are drawn into wires (ductile) are highly sonorous, such as metal guitar strings.

Lustre means that the metal is shiny. This is a result of metal atoms being tightly packed (close to each other) that the light reflects off the surface making the metal appear shiny. Hence, metals are used as jewellery because it is shiny and has an appealing appearance.

Solubility the ability to break down in water (bonds are broken). The attraction between the water molecules and the metal atoms in metallic substances are not stronger than the electrostatic attractions between metal cations and the pool of loosely held electrons themselves. Hence, the metallic substances will not dissolve in water.

Melting point is the minimum amount of energy required to break the bonds in a substance to change it from a solid to a liquid. Due to the very strong electrostatic attraction between the cations and pool of loosely held electrons that form strong metallic bonds, a very large amount of heat energy is required to break these very strong metallic bonds to change the solid to a liquid. Hence, metallic substances have very high melting points.

Boiling point is the minimum amount of energy required to break the bonds in a substance to change it from a liquid to a gas. Due to the very strong electrostatic attraction between the cations and pool of loosely held electrons that form strong metallic bonds, a very large amount of heat energy is required to break these very strong metallic bonds to change the liquid to a gas. Hence, metallic substances have very high boiling points.

Brittle a hard substance that can break/ shatter easily when force is applied. Due to the very strong electrostatic attraction between the cations and anions forming strong directional ionic bonds when a large enough force is applied the like charges align and repel which causes the ionic lattice to shatter. Hence, ionic solids are brittle.

Ionic bonding and properties of ionic substances

Ionic bonding

Ionic bonding occurs when a positive ion (cation) and a negative ion (anion) form a bond. The bond is formed by **electrostatic attraction** which is kind of like magnets. The north and south poles are attracted to each other which is just like positive ion and negative ion being attracted to one another.

The important thing to remember is that the **smallest particle in ionic bonding will be an ion**. Ionic bonding will always occur when:

METAL + NON-METAL = IONIC BONDING

Ionic bonding in sodium chloride (NaCl)

After sodium (Na) has lost an electron to form sodium ion (Na^+) and chlorine (Cl) has gained an electron from the sodium atom to form chloride ion (Cl^-) the two ions will form an ionic bond by electrostatic attraction.

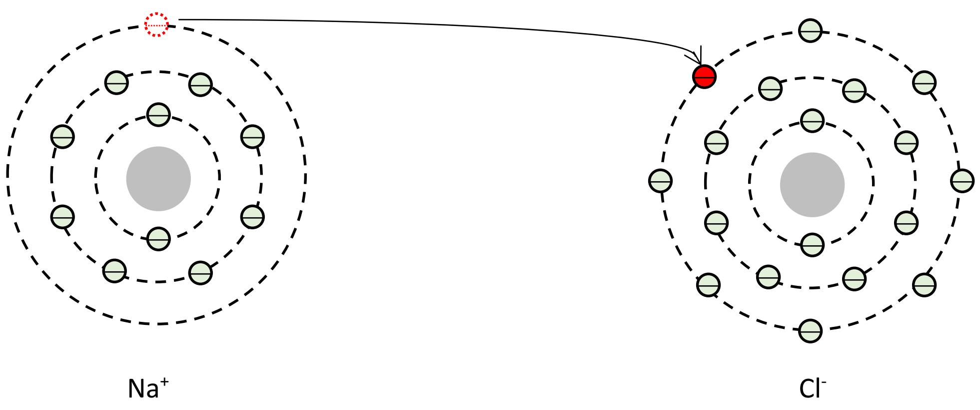


Figure 1.

Salt (NaCl) actually forms a crystal lattice so it is represented as follows:

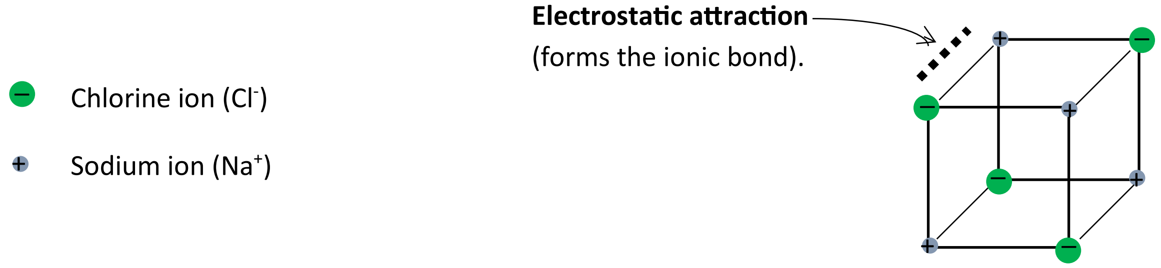


Figure 2.

Ionic solids

An ionic solid forms due to electrostatic attraction between the metal cations and non-metal anions to form directional ionic bonds resulting in a rigid 3D lattice.

METAL + NON-METAL = IONIC SOLID (don't write this in the exam)

e.g. NaCl (sodium chloride – salt)

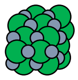


Figure 3.

Sodium chloride is an ionic solid that forms due to electrostatic attraction between the cations (Na^+) and anions (Cl^-) to form directional ionic bonds resulting in a rigid 3D lattice. (see figure 7).

Summary of ionic bonding:

- The smallest particle that makes up an ionic compound is an ion (cations and anions).
- They have directional bonding due to the cations (positive ions) and anions (negative ions) lining up forming very strong ionic bonds due to electrostatic attraction between the oppositely charged ions.

Properties of ionic substances:

It is due to the relatively strong ionic bonding in ionic solids that they have the following properties:

- **Moderately high melting points (mps)** – that is why NaCl has a high mp (801ºC) which is due to the strong electrostatic attraction between the cation and the anion therefore, a lot of energy (heat) is required to break these bonds to change solid NaCl into liquid NaCl.

- **Conduct electricity when in <u>molten</u> (melted) or in <u>solution</u> (dissolved in water)** – this is due to the ions being free to conduct electricity as they are no longer stuck in a rigid lattice (directional bonding).

- **DO NOT conduct electricity when in a <u>solid state</u>** – this is due to the ions being held in a rigid lattice and therefore, they are not free to move or conduct electricity.

- **Brittle and will shatter when hit with a hammer** – this is due to the electrostatic directional bonding between the positive metal ion and the negative non-metal anion so when you hit the rigid ionic lattice it will shatter as the like charges will align and repel.

- **Hard substance** – due to the directional bonding between the metal cations (positive ions) and non-metal anions (negative ions) lining up forming very strong ionic bonds due to electrostatic attraction between the oppositely charged ions.

- **Soluble in water** – this is because ionic solids interactions between the water molecules and the ionic substance is strong enough to overcome the electrostatic attraction between the ions (cations and anions) that make the ionic solid. This causes the solid to dissolve.

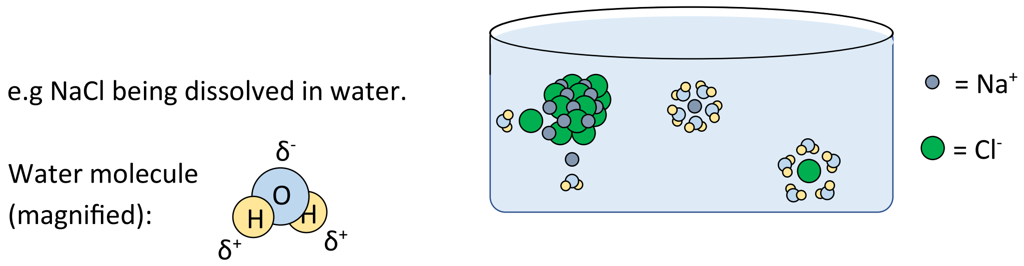


Figure 4.

An example of a useful ionic substance is fluoride in toothpaste. In toothpaste there is sodium fluoride (NaF). When we brush our teeth, we added water to the toothpaste. The attraction between the sodium fluoride ionic solid and water molecules are stronger than the electrostatic attractions between the cation and anion in the ionic solids themselves. Once the fluoride ions have been pulled out of the rigid ionic lattice by the water molecules, they are available to be dissolved to keep our teeth strong and healthy.

Electrical conductivity practical.

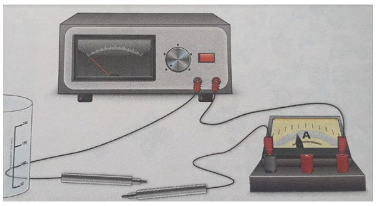
This practical is to look at the electrical conductivity of ionic salts.

Equipment:

- Powerpack.
- An ammeter.
- 3 x electrical wires.
- 2 x alligator clips.
- A 100 mL beaker.
- Distilled water.
- Salt.
- Spatula.

Method:

1. Set up the powerpack ammeter and wires as shown below:



2. Touch the two alligator clips together to watch the ammeter needle move. Thus, this is recording the current as a full conducting electrical pathway has been established (thus, the metal alligator clips are good electrical conductors).
3. Place several spatulas of salt into the bottom of the 100 mL beaker to cover the bottom completely.
4. Place the alligator clips on the solid salt (one alligator clip each side) and record the ammeter reading.
5. Fill the beaker to the 50 mL mark with water. Using the spatula stir until the slat has dissolved.
6. Place the alligator clips in the beaker with saltwater immersing the tips of the alligator clips (one alligator clip each side) and record the ammeter reading.

Observations:

- Solid salt –

- Saltwater –

NCEA exam type question one:

Explain why salt and saltwater has a have different electrical conductivity in terms of the bonding between the particles.

Include:

- The type of bonding and a description of the bonding in salt.
- Link the bonding of solid salt and dissolved salt (saltwater) to their electrical conductivity.
- Explain the solubility of salt by linking the interactions between the solid salt and water due to the type of bonding in salt.

NAME OF SOLID	TYPE OF SOLID	SMALLEST PARTICLE	ATTRACTION BETWEEN THE PARTICLES	TYPE OF BOND
Sodium chloride (NaCl)				

NCEA exam type question two:

Titanium dioxide (TiO_2) is a brittle but hard compound. It is used in lenses for peoples' glasses. Explain why titanium dioxide (TiO_2) is a good material to make lenses in glasses but why glasses must not be dropped as the lenses may shatter on impact with the ground in terms of the bonding between the particles. ***Titanium dioxide is not a 3D covalent substance***.

Include:

- The type of bonding and a description of the bonding in titanium oxide (TiO_2).
- Link the bonding of titanium oxide (TiO_2) to its hardness which makes it suitable to make lenses in glasses.
- Explain why you must not drop glasses by linking the bonding in titanium oxide (TiO_2) to its brittleness.

NAME OF SOLID	TYPE OF SOLID	SMALLEST PARTICLE	ATTRACTION BETWEEN THE PARTICLES	TYPE OF BOND
Titanium dioxide (TiO_2)				

Metallic bonding and the properties of metallic substances

Metallic solids

Metallic solids are made up of tightly packed metal atoms (metal cations) that are held together by the electrostatic attraction between the positive metal cations and the pool of surrounding delocalised (loosely held) electrons forming strong non-directional metallic bonds. The easiest way to classify a metallic solid is to remember that:

METAL + METAL = METALLIC SOLID (don't write this in the exam)

It is due to the relatively strong metallic bonding in ionic solids that they have the following properties:

- **Fairly high melting points (mps)** – this is due to the strong electrostatic attraction between the positive metal cation and the pool of delocalised electrons forming very strong metallic bonds. Therefore, a large amount of energy (heat) is required to break these strong metallic bonds. That is why metals have a high melting point such as copper as it melts at a temperature of 1083ºC.

- **Conduct electricity in solid and liquid (molten) states** – this is due to the free moving (delocalised) electrons that can carry an electrical charge making metals excellent electrical conductors.

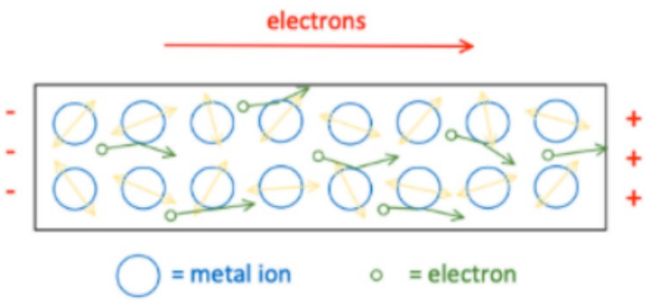


Figure 5.

- **Conduct heat (thermal conductor)** – this is because the atoms have non-directional bonding between the atoms (cations and pool of delocalised (moving) electrons) when the atoms are being directly heated kinetic energy is passed onto neighbouring atoms (and they begin to vibrate) until the whole metal object has heated. It is due to the delocalised electrons that heat (thermal) energy passes through metals making them excellent conductors.

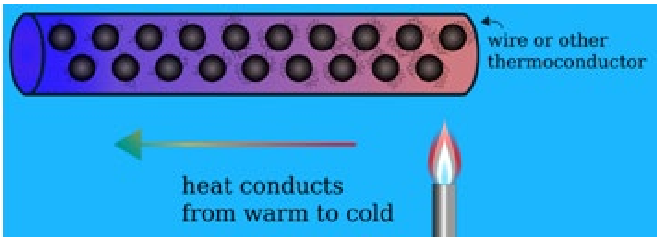


Figure 6.

- **Metals have a high density** – this is due to the metals having their atoms tightly packed together so there are more atoms occupying the space. As density is a measure of mass per volume, there is a high mass of atoms per unit volume.

- **Malleable (can be shaped) and ductile (can be drawn into wires)** – this is due to non-directional bonding between the metal cations and the pool of loosely held (delocalised) electrons. When pressure is applied the atoms can slide past one another without breaking the strong metallic bonds.

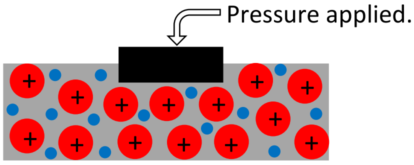


Figure 7.

- **Metals are hard/ have high tensile strength (have hardness)** – this is due to the strong electrostatic attraction between the positive metal cation and the pool of delocalised electrons forming very strong metallic bonds. Therefore, a large amount of force or energy is required to break these strong metallic bonds. Hence, metals do not break or fracture very easily.

- **Metals are sonorous (means that a metal will make a ringing sound when struck with a force.)** – this is due to the non-directional metallic bonding between the metal atoms which allows them to vibrate when hit. Metals with a lower density tend to be more sonorous. Metals that are drawn into wires (ductile) are highly sonorous, such as metal guitar strings. It is due to the delocalised electrons that metals are sonorous.

- **Metals have a lustre (shiny)** – this is due to the metals having their atoms tightly packed together so when the light hits the metal it is deflected which makes the metal appear shiny.

- **DO NOT dissolve in any solvent (insoluble)** – this is because the non-directional metallic bonds are too strong to be overcome by any attractive forces that a solvent such as water may possess. The attraction between the water molecules and the metal atoms are not stronger than the electrostatic attractions between metal cations and the pool of loosely held electrons themselves. Hence, the metallic substances will not dissolve in water.

Properties of metals practical.

This practical is to look at the electrical conductivity of ionic salts.

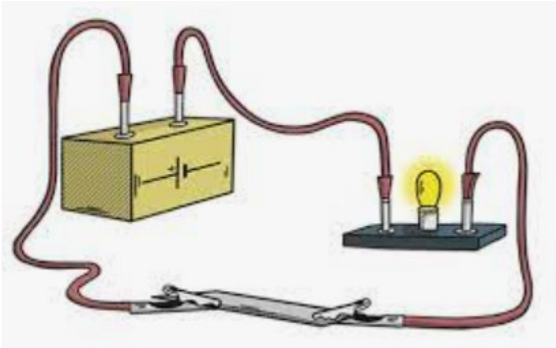
Equipment:

- Powerpack.
- An ammeter.
- 3 x electrical wires.
- 2 x alligator clips.
- Selection of metals (Al, Mg, Pb, Zn, Cu)
- Sandpaper.
- Hot water jug.
- Metal spoon and plastic spoon.
- Spatula.
- 10 mL and 50 mL measuring cylinders.
- Set of metal cubes/ rods to test density of metals.

The ***test for lustre*** of a metal is using sandpapers to remove the oxide coating of the metal to expose the untarnished metal underneath. Then you can record your observations.

Observations:
Inference:

The ***test for electrical conductivity*** is setting up a power pack with wires to a bulb (lamp) and two wires with alligator clips. The metals are clipped between the two alligator clips to complete the circuit (conducting pathway). If the bulb (lamp) glows then that metal allows electrical current to flow through and can be used for anything electrical (e.g. wiring/ contact points etc)



Observations: **Inference:**

The ***test for thermal conductivity*** is boiling water and placing it in a beaker. Then place the metal half in the boiling water and half out of the water. Touch the end of the metal that is not in the water. If it is heating up, then the metal is a good thermal conductor.

Observations: **Inference:**

Testing for density is done by displacement of water. First you must find the mass of the rod by placing them on a scale. You will be given the same sized rods of each metal and 10 mL measuring cylinder. Fill the 10 mL measuring cylinder up to 5 mL. Then drop the metal rod in. check the displacement of the water. The more water displaced the higher density the metal is. You can use these measurements to calculate the density of the metal rod.

Data is:

A) Volume of water in cylinder initially =
B) Volume of water after cube is dropped =
C) Volume of water displaced = B) –A) =
D) Mass of metal rod =

Density = Mass of the metal rod ÷ Volume of water displace by the metal rod

Unit = $g/\ cm^3$

You will be given 5 metal samples you are to carry out the density experiment (displacement of water) and use your data to calculate the density of each type of metal.

Type of metal	Mass of metal rod	Volume of water in cylinder initially	Volume of water after metal rod is dropped	Volume of water displaced	Denisty calculation: $D = m \div V$

To ***test malleability and ductility*** you take strips of sheets of metal and use your hands to see if you can bend and shape the metal. If it bends easily, it is ductile and malleable.

Observations:

Inference:

Metal alloys and their physical properties

A metal alloy is when there is a mixture of 2 or more elements in which one MUST be a metal. A lot of alloys are made of a mixture of metals also. Metal alloys are usually harder and can be less malleable and ductile as it contains different sized atoms which means they cannot slide past each other easily. Hence, the hardness/ tensile strength is increased, and the malleability and ductility are reduced.

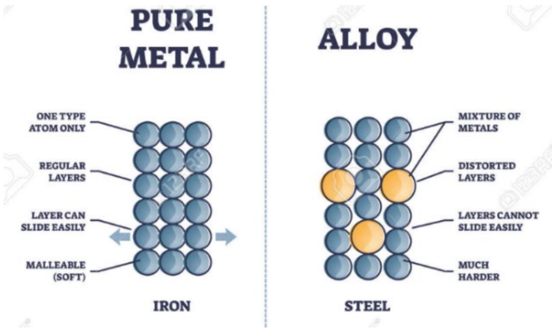


Figure 8. (What Is The Difference Between Alloys And Pure Metals? (whatisdiffer.com))

NCEA exam type question three:

Your cell phone is made of many different chemical substances. Copper is used to make the electrical wires inside your cell phone. An alloy is used to make the case of your cell phone. Answer the following questions using the data provided in the tables below.

Type of substance	Density (g/ cm^3)	Hardness (mohs)
Aluminium (Al)	2.7	2.75
Gold (Au)	19.3	2.5
Magnesium- (Mg)	1.7	3.0

a) The case of a cell phone needs to be strong and lightweight, so it is easy to carry on your person. Discuss which alloy would be better to make the case of a cell phone, aluminium-magnesium, or aluminium-gold?

Include:

- The definition of an alloy and explain how alloys are harder in terms of the size of the atoms.
- The type of bonding and a description of the bonding in aluminium.
- Link the bonding of gold and magnesium to its hardness and density which makes it suitable to use as a cell phone case.
- Explain which alloy you would recommend the manufacturer uses to make the cell phone case by comparing the density and hardness of the two possible metals that would be alloyed with aluminium using the data supplied in the table above.

b) As mentioned above copper is used to make electrical wires in cell phones. Discuss the physical properties of copper and link this to the bonding in copper that make copper a very useful metal for making electrical wires in electronic devices such as a cell phone.

Include:

- Fill in the table below.
- A definition of the type of bonding that occurs in copper.
- Link the bonding of copper to **<u>three</u>** physical properties which makes it suitable to use as electrical wires in a cell phone.

NAME OF SOLID	**TYPE OF SOLID**	**SMALLEST PARTICLE**	**ATTRACTION <u>BETWEEN</u> THE PARTICLES**	**TYPE OF BOND**
Copper (Cu)				

Molecular/ covalent bonding and the properties of molecular substances

Covalent bonding

Covalent bonding (also known as **molecular bonding**) occurs when atoms make bonds by sharing valence electrons to obtain full outer shells (**octets**). When atoms form a covalent bond, they are called **intramolecular** (within the molecule) **forces**. These are the type of forces that hold the molecule together. When the whole molecule interacts with another whole molecule these forces are called **intermolecular** (between neighbouring molecules) **forces** these are very weak forces of attraction as they are long range attraction

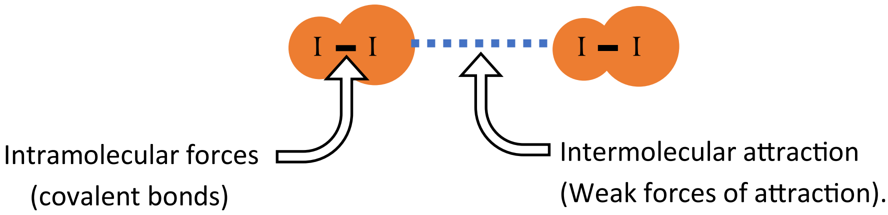


Figure 9.

The important thing to remember is that the **smallest particle in molecular substances will be a molecule**. Molecular bonding will always occur when:

NON-METAL + NON-METAL = MOLECULAR BONDING

Molecular solids

Molecular solids are made up of molecules that are held together by very weak long range **intermolecular forces**. Intermolecular forces are what hold the molecules together. A molecular substance contains very strong covalent bonds (intramolecular) within the molecule but very weak intermolecular attractions between the molecules.

The easiest way to classify a molecular solid is to remember that:

NON-METAL + NON-METAL = MOLECULAR SOLID (don't write this in the exam)

Phase change, intermolecular forces and melting and boiling point.

Phase change is when a substance changes between solid state, liquid state and gaseous state and vice versa (you can also get situations where you can get a direct phase change from solid to gas phase too).

The lowest energy state is solid, then liquid then gas. Take water for example. If we put water into an ice tray and place it in the freezer the molecule will begin to slow down their movement as there is low energy in the freezer. Once the water molecules lose heat energy they slow down, move closer together and then form intermolecular forces of attraction between the water (H_2O) molecules to form solid ice. Every single water molecule is involved in intermolecular forces of attraction between the water molecules when ice forms.

When we take the water molecules out of the freezer the energy in the room (which we call room temperature which is around 25 ℃) will cause the water molecules in the ice to gain heat energy which causes the molecules to move faster and spread out. This causes some of the intermolecular forces of attraction between the solid water molecules to break which results in the ice melting and forming liquid water. Hence, the phase change between solid state and liquid state is called melting. Therefore, melting point (mp) is the minimum amount of heat energy to melt a substance which is changing the substance from a solid to a liquid.

When we fill up the jug to make a cup of tea the water is in liquid state. When we turn on the jug by flicking on the switch the electricity in the jug provides heat energy to the liquid molecules. This causes the liquid water molecules to gain heat energy which causes the molecules to move even faster and spread out even more. This causes all of the intermolecular forces of attraction between the liquid water molecules to break which results in the water evaporating and forming water vapor (water in the gas state) which we call steam. Hence, when we boil water or a substance and the phase change between liquid state and gas state is called boiling/ evaporations. Therefore, boiling point (bp) is the minimum amount of heat energy to boil/ evaporate a substance which is changing the substance from a liquid to a gas.

See the summary diagram below:

		
SOLID	LIQUID	GAS
Particles close together, vibrating with low energy.	Particles spread out, moving faster with medium to high energy.	Particles spread further apart, moving very fast and with very high energy.
Contains 100% weak intermolecular forces of attraction to hold the molecules in a solid form.	Contains some weak intermolecular forces of attraction to hold the molecules in a liquid form.	Contains no (0%) weak intermolecular forces of attraction

Sublimation of Iodine practical (DEMONSTRATION).

Your teacher will do a demonstration of Iodine in a flask in the fume cupboard. One dark purple iodine crystal is placed in a flask and a rubber stopper in secured on the mouth of the flask. Using a Bunsen flame and holding the flask with a test tube holder, the flask is gently heated in the Bunsen flame.

Note down your observations:

Include a diagram to show the intramolecular forces in the iodine and the intermolecular forces between the iodine molecules.

Explain the forces of attraction that are holding the solid iodine particles together and then explain what happens to these forces of attraction when the solid iodine is heated.

Properties of molecular substances:

It is due to this weak attraction in between the molecules in molecular solids that they have the following properties:

- **Low melting points (mps) and boiling points (bps)** due to the very weak intermolecular forces that only need a small amount of energy (heat) to break (overcome) these bonds. Room temperature is sufficient energy to break all intermolecular forces. Hence Cl_2 is a gas at room temperature.

  Important note: the larger the molecule (has a larger mass) the more intermolecular forces of attraction that are occurring between the molecules. For example, methane (CH_4) has a small mass. Therefore, a smaller number of intermolecular forces are occurring between the methane molecules. This is why methane is a gas at room temperature -161.5℃ as room temperature (25℃) is more than enough energy to overcome the weak intermolecular forces of attraction between the methane molecules.

  However, bitumen is what we use to make our roads it is made up of a large amount if carbon and hydrogen atoms ($C_{35}H_{72}$) which gives is a much larger mass. This means there is a larger number of intermolecular forces of attraction occurring between these larger molecules. Hence, bitumen is a solid with a melting point of 120 – 150℃. therefore, a large amount of heat energy is required to overcome these forces of attraction.

- **Do not conduct electricity** (lack of available charge to conduct electricity electrons are involved in covalent bonds).

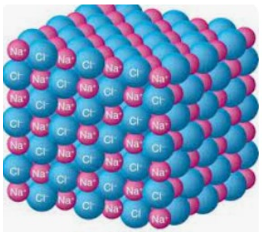
- **Does not dissolve in water molecules** (The attractions between the molecular substance are not strong enough to overcome the attractions between the water molecules themselves. Hence, separate layers will form if they are liquid, so the solid will not dissolve in the water molecules).

- **Solids can easily be cut with a knife** (weak intermolecular forces between the molecules are easily overcome when pressure is applied).

NCEA exam type question four:

Piripi and Mere are cooking a pot of potatoes for dinner and have noticed that the water rises and spills over the edges of the pot. Piripi thinks that if it you put salt on the rim of the pot it will stop the water boiling over. Mere does not agree with Piripi and thinks that rubbing oil around the rim of the pot will stop the water boiling over. In the table below the substances are given. Use the formula of these substances to determine the type of bonding in the solid salt and oil.

A) Fill in the table below:

NAME OF SOLID	SOLUBILITY IN WATER	TYPE OF SUBSTANCE	ATTRACTION <u>BETWEEN</u> THE PARTICLES	TYPE OF BONDING
Cooking oil ($C_{30}H_{50}O$)	Insoluble in water forms separate layers			
Salt (NaCl) 	Soluble in water.			

B) Discuss the bonding in both salt and cooking oil and link this to the interaction both salt and oil have with water.

Include:

- The type of bonding and a description of the bonding in salt **and** cooking oil.
- Link the bonding of salt **and** cooking oil to their interaction with water molecules.
- Explain who is correct (Piripi or Mere) by linking the interaction between water molecules and the salt **and** oil to how they do or do not stop the water boiling over in the pot.

3D covalent network solids bonding and the properties of 3D covalent network substances

Giant 3-D covalent network solids

Giant 3-D covalent network solids are made up of large array (number) of covalently bonded atoms. These bonds are very strong and require a large amount of energy (heat) to break the bonds. There are 3 main types of 3-D covalent network solids to remember:

- Diamond
- Graphite
- Silica (sand)

Diamond

Diamond is made up of **many carbon atoms that are covalently bonded to each other to form a 3D extended network.** This type of **3D covalent bonding is very strong and that is why diamond has a very high melting point (mp) therefore, a very large amount of energy (heat) is required to break the bonds**.

Diamond is a very strong substance and that is why diamond drills are used to drill through very tough materials. As **the bonding in diamond is so strong it cannot be dissolved by any type of solvent (insoluble)** and as it all carbon atoms are covalently bonded to form an extended 3D network **there are no charges available to conduct electricity. Diamond is extremely hard this is due to the very strong directional covalent bonding within the extended 3D network**.

The structure of diamond:
(made up of an array of
Carbon atoms)

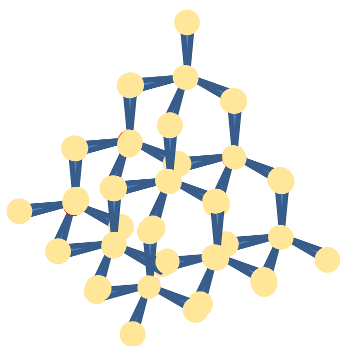


Figure 10.

Silica (sand)

Sand has a very similar structure to diamond and therefore it has very similar properties. Sand (silica) is melted down using very high temperatures to make glass. It is because of the very strong covalent network bonding that a lot of energy (high temperatures) is required to break bonds. Silica is also insoluble (bonds too strong to be broken by any solvent) does not conduct electricity (non-polar and therefore does not have any available charge) and is extremely hard and brittle (very strong directional bonding).

Silica is made up of silicon and oxygen atoms that are covalently bonded to form an extensive 3D covalent network.

The structure of silica (sand):
(made up of an array of SiO_2 molecules)

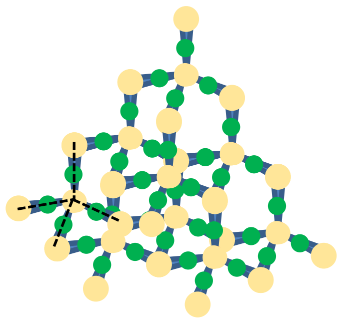


Figure 11.

- **Diamond and silica have very high melting points** (mp) due to the very strong covalent bonding within the network which requires a large amount of heat energy to break the bonds. Hence, the melting point of diamond is nearly 4000 ℃.

- **Diamond and silica are insoluble** (does not dissolve in any solvent) as the covalent network bonds are too strong to be overcome by any forces of attraction a solvent may possess. The very strong covalent intramolecular forces of attraction between the carbon atoms in diamond or silicon and oxygen atoms in silica are too strong to be overcome by the attraction between the solvent (water molecules) may have.

- **Diamond and silica are a very hard substance** this is due to the very strong covalent bonding between the carbon atoms in diamond or the silicon and oxygen atoms in silica. Resulting in an extended 3D lattice of very strong covalent bonds (intramolecular forces).

Graphite

Graphite is **made up of 2D sheets of covalently bonded carbon atoms**. Each carbon atom is **covalently bonded to 3 other carbon atoms. This means that there is one remaining delocalised electron from each carbon atom which is available to move throughout the graphite network**. The result is that **the 2D sheets are held together by weak intermolecular forces of attraction**.

- **Graphite has a very high melting point** (mp) due to the very strong covalent bonding within the network which requires a large amount of energy to break the bonds.

- **Graphite is insoluble** (does not dissolve in any solvent) as the covalent network bonds are too strong to overcome (break) by any attraction that a solvent such as water may have. The attraction between the water molecules and the atoms are not stronger than the very strong network of covalent bonds between the carbon atoms. Hence, graphite will not dissolve in water.

- **Graphite is the only non-metallic substance that conducts electricity**. This is a direct result of the free moving delocalised electrons throughout the extended network meaning that there is available charge to carry an electrical current. Hence, graphite is an excellent electrical conductor.

- **Graphite is used as a lubricant at high temperatures**. Graphite can be used as a lubricant as it is made up of 2D sheets of covalently bonded carbon atoms and they are held together by weak intermolecular forces that require very little energy to break the intermolecular bonds between the 2D sheets of graphite. That is why the sheets can easily glide over each other which makes it a useful lubricant. The reason it **can be used at high temperatures is because there are very strong covalent bonds in between the atoms**. These are also known as very **strong intramolecular forces (in between the atoms) and a lot of energy is required to break these bonds**. Therefore, graphite can withstand high temperatures when being used as a lubricant.

The structure of graphite:

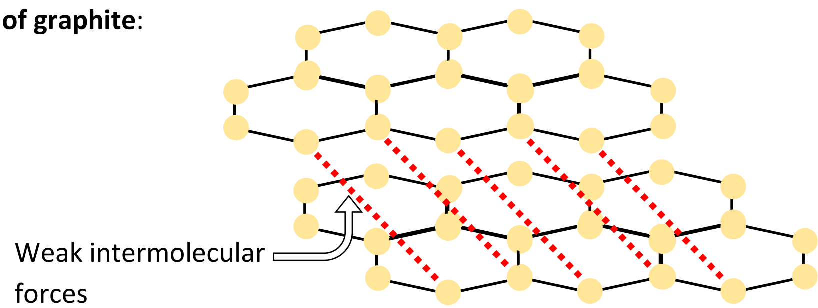


Figure 12.

NCEA exam type question 5

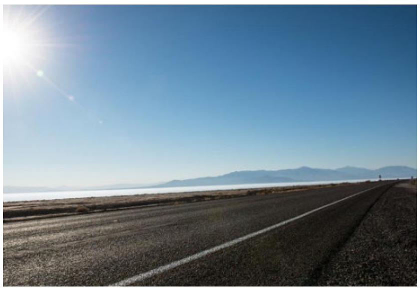
Alkanes are molecules made up of carbon and hydrogen atoms. There are many different length and sized alkanes which have different uses. Alcohols are made up of carbon, hydrogen and oxygen atoms and they are used as disinfectants and antiseptics.

a) Ethanol (alcohol) is used in hand sanitisers due to its volatility. Volatile means that is changes from a liquid to a gas easily and the heat of a person's hand is sufficient to turn liquid hand sanitiser into gas sanitiser and this happen due to evaporation. It is important that the ethanol is evaporated off the persons hand as it is very toxic to humans if ingested (eaten). Explain why ethanol is useful as a hand sanitiser by referring to the physical properties of ethanol.

In your answer include:

- The type of substance ethanol is.
- The bonding **within** the ethanol molecule and the bonding that occurs **between** ethanol the molecules.
- Explain how the bonding in ethanol makes it useful as a hand sanitiser.

b). Bitumen is used to make our roads in NZ. It is a very large alkane molecule made up of many carbon and hydrogen atoms. Using the data in the table below explain how the physical properties of bitumen make it a useful substance for making our roads.



Type of substance	**Hardness (mohr)**	**Melting point point (℃) (mp)**
Sand (SiO_2) *30% in concrete*	6 - 7	1700℃
Bitumen ($C_{35}H_{72}$)	2	120 – 150℃

In your answer include:

- The type of substance bitumen is
- The bonding **within** the bitumen molecule the bonding that occurs **between** the bitumen molecules.
- Explain how the bonding in bitumen makes it useful to use as roads.

c). Concrete is another substance that can be used to make roads. Concrete is a mixture of mostly cement, gravel, and sand, with 30% of concrete having sand (SiO_2) which makes sand a key component of concrete.

Type of substance	**Hardness (mohr)**	**Melting point point (℃) (mp)**
Sand (SiO_2) *30% in concrete*	6 - 7	1700℃
Bitumen ($C_{35}H_{72}$)	2	120 – 150℃

Looking at the data in the table and referring to your answer in b) above, explain which substance, concrete or bitumen, would be more suitable to make NZ roads.

In your answer include:

- The type of solid sand (silicon dioxide SiO_2) is and an explanation of the type of bonding that occurs in sand which is a major component of concrete used in roading.
- Link the data of bitumen and sand/ silicon dioxide to the bonding in each substance.
- Make a recommendation to Waka Kotahi (NZ transport agency) as to which substance concrete or bitumen would be more suitable for building NZ roads in the future.

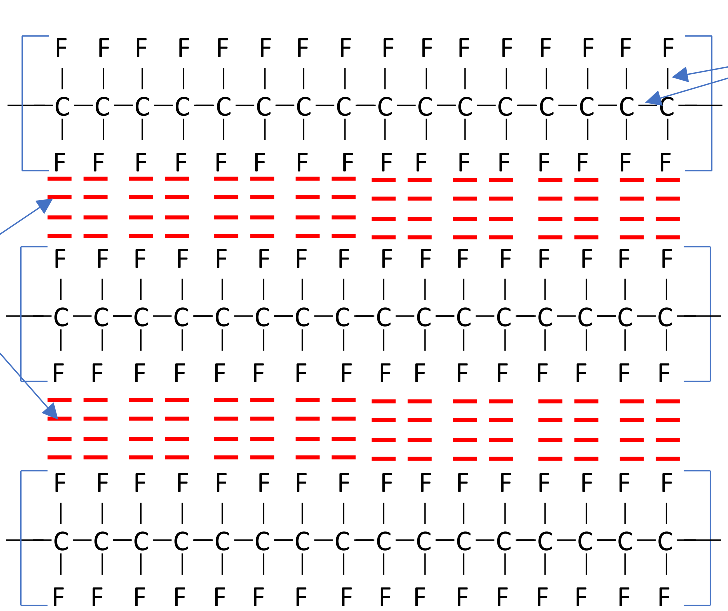
Bonding in polymers and the properties of polymers.

<u>The two types of forces of attraction in polymers:</u>

In polymers there are two forces of attraction occurring. These are intramolecular forces (covalent bonds) of attractions within the long-chained polymer and intermolecular forces of attraction between the layers/ sheets of long-chained polymer.

The intramolecular forces of attraction (covalent bonds) are very strong. These are the bonds that form the long-chained polymer. As these intramolecular forces of attraction are so strong a very large amount of heat energy is required to overcome these forces of attraction.

The intermolecular forces of attraction are very weak. These are the forces of attraction between the layers of the polymer. They are weak because they are long range attractions. So very little heat energy id required to overcome these forces of attraction.



Intramolecular forces of attraction (very strong).

Intermolecular forces of attraction (very weak).

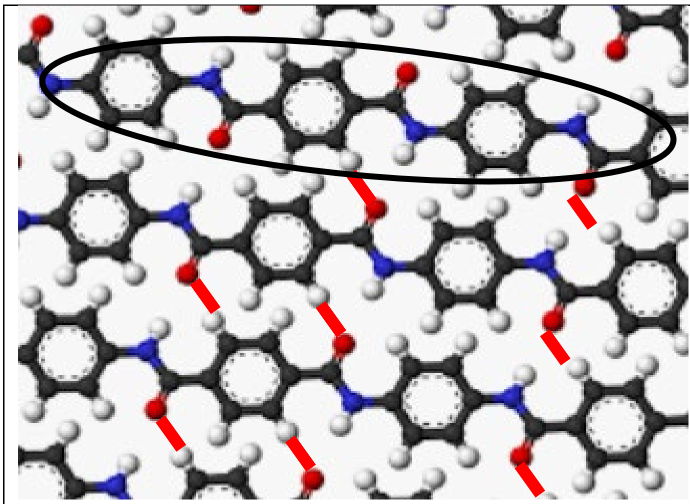
Long-chained polymers can be arranged in layers to form substance such as a plastic shopping bag. Depending on how the long-chained polymers are arranged would determine the polymers physical properties such as hardness, melting point, or solubility.

When the long-chained molecules are nicely overlapped there are more weak intermolecular forces of attraction between layers of a polymer. This means the melting point and hardness would be higher than if the long-chained polymer is not nicely overlapped.

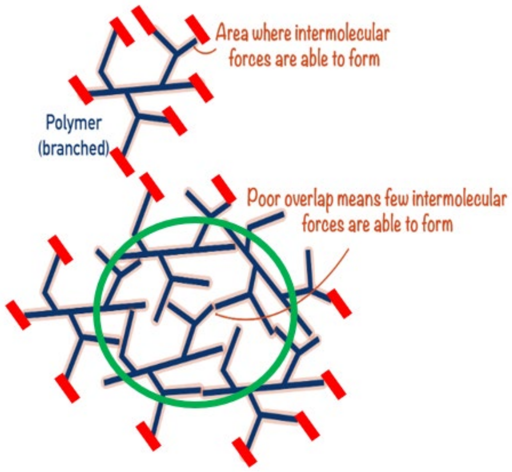
If the long-chained molecule is not nicely overlapped there will be less weak intermolecular forces of attraction between layers of a polymer. This means the melting point and hardness would be lower when the layers of the polymer aren't nicely overlapped.

Polymers do not dissolve in water as the weak intermolecular attractive forces between the polymer layers are too weak to overcome the attractive forces between the water molecules themselves.

Below is a diagram of the polymer Kevlar which shows both very strong intramolecular forces of attraction within the long-chained polymers and very weak intermolecular forces of attraction between the layers of polymer.

<table>
<tr>
<td>


= the polymer chain with very strong Intramolecular forces of attraction.

= long range very weak intermolecular forces of attraction.
</td>
<td>


= areas where long range Intermolecular forces of attraction Can occur.

= areas where intermolecular forces can’t occur due to poor overlap.
</td>
</tr>
<tr>
<td>
Aligning Kevlar polymer chains allows a very large quantity of intermolecular forces of attraction to act between the polymer chained molecules. Even though the intermolecular forces of attraction themselves are long range attractions and they are weak. Having a large quantity of weak intermolecular forces of attraction means more energy is required to overcome these forces of attraction. Hence, Kevlar is a very hard material with a hardness of 7.5 – 8.0 mohs and a melting point of 1250 ℃.

These physical properties are what make the polymer Kevlar a very good material for making armour especially since Kevlar has a low density of 1.4 g cm^{-1}. Having a low density means that Kevlar has a low mass per volume which will not cause too much energy loss when wearing it. The police and the army use Kevlar as bullet proof armour to protect their officers due to their hardness, high melting point and low density.
</td>
<td>
The left top diagram shows that the polymer has less branches which means the polymers can overlap better which results in a larger quantity (more) long range, very weak intermolecular forces. The more of these very weak intermolecular forces of attraction between the polymer molecules, the higher the melting points (mp), and the harder the material is. Thus, more energy would be required to overcome these forces of attraction which results in a higher melting point.

The right top diagram shows that the bottom polymer has many branches which means the polymers do not overlap well which results in less long range, very weak intermolecular forces. As there are less of these very weak intermolecular forces of attraction between the polymer molecules, the lower the melting points (mp), and the softer the material is. Thus, less energy would be required to overcome these forces of attraction which results in a lower melting point.
</td>
</tr>
</table>

NCEA exam type question 6

You are employed to help the product engineers make the strongest plastic shopping bags. Plastic bags are made of a polymer called polyethylene which is many ethene units/ monomers added together. These polymer chains are stacked in rows to create a plastic shopping bag. Below are the results of a test conducted when the polymer chains are positioned in the horizontal and vertical positions.

When the plastic bag has the polymer chains in the horizontal position and they a pulled apart from the top and bottom of the plastic bag, the bag stretches and begins to tear.

When the plastic bag has the polymer chains in the vertical position and they a pulled apart from the top and bottom of the plastic bag, **does not** stretch or tear.

a) Name the **forces of attraction that are been broken** when the bag is pulled apart from top to bottom.

____

b) Name the **forces of attraction that can withstand the force** when the bag is pulled apart from top to bottom.

____

c) Explain which forces of attraction are stronger and why?

____

____

____

____

____

____

d) Below are two diagrams showing the polymer chains in a horizontal position (A) and in the vertical position (B). Use these diagrams and your knowledge of the forces of attraction in polyethylene to decide which position (horizontal or vertical) should the plastic bags be made to ensure they are strong enough to carry groceries without tearing.

A - Horizontal position	B – Vertical position
	

In your answer include:

- An explanation of the type and strength of bonding that occurs **within** the polyethylene chains.
- An explanation of the type and strength of bonding that occurs **between** the polyethylene chains.
- Make a recommendation to the product engineers who are making the plastic bags as to which way the plastic bags should be made (horizontal and vertical) by linking to both the forces of attraction **within** and **between** the molecules so that the strongest plastic bag can be made without it stretching and tearing. Hence, the customer can carry their groceries items without the possibility of them falling onto the ground.

General physical properties linked to the 5 types of substances.

Physical property definition.	**Ionic substance definition linked to the physical property.**	**Metallic substance definition linked to the physical property.**	**Molecular substance definition linked to the physical property.**	**3D covalent network solid definition linked to the physical property.**	**Polymer substance definition linked to the physical property.**
Electrical conductivity is the ability for a substance to allow electrical current to pass through.	___ is an ionic solid that forms due to electrostatic attraction between the cation and anion to form directional ionic bonds resulting in a rigid 3D lattice. Ionic solids do not conduct electricity as the ions are trapped in the rigid 3D lattice due to electrostatic attraction between the cation and anions forming strong directional ionic bonds. In molten state or dissolved in water the electrostatic attraction between the ions has	___ is a metallic solid that forms due to tightly packed metal atoms. The electrostatic attraction between the cation and the pool of loosely held electrons form very strong non-directional metallic bonds. Metallic substances conduct electricity due to the free moving delocalised electrons that can move throughout the network to carry an electrical current. Hence, metals are excellent electrical conductors.	___ is a molecular substance that contains very strong covalent bonds (intramolecular) within the molecule but very weak intermolecular attractions between the molecules. Molecular substances are poor electrical conductors but very good insulators. As molecular substances are made up of covalently bonded molecules that are held together by very weak intermolecular forces of attraction, there is no available charge (ions or electrons) to carry an electrical current. Hence, an electrical	Silicon dioxide (SiO_2) and diamond are 3D covalent network solids that are made up of very strong covalent bonds. Graphite is made up of 2D carbon sheets that are covalently bonded. These sheets are held together by very weak intermolecular forces of attraction. Diamond and silicon dioxide (SiO_2) as all atoms are covalently bonded to form extended 3D covalent network solids there is no available charge	___ polymers are made up of chains of covalently bonded atoms. These polymer chains are held together by very weak intermolecular forces. Polymers are large molecular substances that are poor electrical conductors but very good insulators. As polymers are made up of covalently bonded molecules that are held together by very weak intermolecular forces of attraction, there is no available charge (ions or electrons) to carry an electrical current. Hence, an

	been overcome which allows the ions to move freely. Thus, the ions can carry an electrical current making molten and dissolved ionic substance good electrical conductors.		current cannot pass through making molecular substance poor electrical conductors but excellent insulators.	ions or electrons) to carry an electrical current. Hence, an electrical current cannot pass through making molecular substance poor electrical conductors but excellent insulators. As each C atom in graphite is covalently bonded to three other C atoms this leaves 1 electron per C atom available to move throughout the 3D network. Thus, there is an available charge (electrons) to carry an electrical current. Thus, graphite is an excellent electrical conductor.	electrical current cannot pass through making polymers poor electrical conductors but excellent insulators.
Melting point is the minimum amount of energy required to break the bonds in a	___ is an ionic solid that forms due to electrostatic attraction between the cation	___ is a metallic solid that forms due to tightly packed metal atoms. The	___ is a molecular substance that contains very strong covalent bonds	Silicon dioxide (SiO_2) and diamond are 3D covalent network solids that are made	___ polymers are made up of chains of covalently bonded atoms. These

substance to change it from a solid to a liquid.	and anion to form directional ionic bonds resulting in a rigid 3D lattice. Due to the very strong electrostatic attraction between the cations and anions forming strong directional ionic bonds a large amount of energy is required to overcome these forces of attraction in the solid to form a liquid. Hence, ionic solids have high melting points.	electrostatic attraction between the cation and the pool of loosely held electrons form very strong non-directional metallic bonds. Due to the very strong electrostatic attraction between the cations and pool of loosely held electrons that form strong metallic bonds, a very large amount of heat energy is required to break these very strong metallic bonds to change the solid to a liquid. Hence, metallic substances have very high melting points.	(intramolecular) within the molecule but very weak intermolecular attractions between the molecules. Due to the strong covalent bonds within the molecules and the very weak intermolecular forces of attraction between the molecules that are holding them in the solid phase. As intermolecular forces of attraction are very weak only a small amount of energy is required to break these forces of attraction to change the solid into a liquid. Hence, melting points of solid molecular substances are low.	up of very strong covalent bonds. Graphite is made up of 2D carbon sheets that are covalently bonded. These sheets are held together by very weak intermolecular forces of attraction. Due to the 3D network of very strong covalent bonds a very large amount of energy is required to break the very strong covalent bonds in the solid to form a liquid. Hence, diamond, silica and graphite have very high melting points.	polymer chains are held together by very weak intermolecular forces. Due to the strong covalent bonds within the molecules and the very weak intermolecular forces of attraction between the molecules that are holding them in the solid phase. As intermolecular forces of attraction are very weak only a small amount of energy is required to break these forces of attraction to change the solid into a liquid. Hence, melting points of solid molecular substances are low. Note if there are many straight

					polymer chains lined up they will have a higher melting point than polymers chains that are not straight and do not overlap well. This is because there will be more very weak intermolecular forces of attraction to overcome that polymer that the chains do not overlap well. Thus, more energy will be required to break the larger quantity of the very weak intermolecular forces of attraction. Hence, straight chain polymers that overlap well will have higher melting points than polymers that don't have straight chains and that do not overlap well.

Boiling point is the minimum amount of energy required to break the bonds in a substance to change it from a solid to a liquid.	___ is an ionic solid that forms due to electrostatic attraction between the cation and anion to form directional ionic bonds resulting in a rigid 3D lattice. Due to the very strong electrostatic attraction between the cations and anions forming strong directional ionic bonds a large amount of energy is required to overcome these forces of attraction in the liquid to form a gas. Hence, ionic substances have high boiling points.	___ is a metallic solid that forms due to tightly packed metal atoms. The electrostatic attraction between the cation and the pool of loosely held electrons form very strong non-directional metallic bonds. Due to the very strong electrostatic attraction between the cations and pool of loosely held electrons that form strong metallic bonds, a very large amount of heat energy is required to break these very strong metallic bonds to change the liquid to a gas. Hence, metallic substances have very high melting points.	___ is a molecular substance that contains very strong covalent bonds (intramolecular) within the molecule but very weak intermolecular attractions between the molecules. Due to the strong covalent bonds within the molecules and the very weak intermolecular forces of attraction between the molecules that are holding them in the liquid phase. As intermolecular forces of attraction are very weak only a small amount of energy is required to break these forces of attraction to change the liquid into a gas. Hence, boiling points	Silicon dioxide (SiO_2) and diamond are 3D covalent network solids that are made up of very strong covalent bonds. Graphite is made up of 2D carbon sheets that are covalently bonded. These sheets are held together by very weak intermolecular forces of attraction. Due to the 3D network of very strong covalent bonds a very large amount of energy is required to break the very strong covalent bonds in the liquid to form a gas. Hence, diamond, silica and graphite have very high boiling points.	___ polymers are made up of chains of covalently bonded atoms. These polymer chains are held together by very weak intermolecular forces. Due to the strong covalent bonds within the molecules and the very weak intermolecular forces of attraction between the molecules that are holding them in the solid phase. As intermolecular forces of attraction are very weak only a small amount of energy is required to break these forces of attraction to change the liquid into a gas. Hence, boiling points of solid molecular substances are low.

			of liquid molecular substances are low.		Note if there are many straight polymer chains lined up, they will have a higher boiling point than polymers chains that are not straight and do not overlap well. This is because there will be more very weak intermolecular forces of attraction to overcome that polymer that the chains do not overlap well. Thus, more energy will be required to break the larger quantity of the very weak intermolecular forces of attraction. Hence, straight chain polymers that overlap well will have higher boiling points than polymers that don’t have straight chains

					and that do not overlap well.
Malleability is the ability to shape a substance into sheets	N/A	___ is a metallic solid that forms due to tightly packed metal atoms. The electrostatic attraction between the cation and the pool of loosely held electrons form very strong non-directional metallic bonds. Due to the very strong non-directional metallic bonds between the metal cations and loosely held electrons that allow the atoms to slide past each other without breaking the strong metallic bonds. Hence, metals are malleable and can be shaped into sheets and other shapes.	N/A	N/A	N/A

Ductility is the ability to draw a substance into thin wires	N/A	___ is a metallic solid that forms due to tightly packed metal atoms. The electrostatic attraction between the cation and the pool of loosely held electrons form very strong non-directional metallic bonds. Due to the very strong non-directional metallic bonds between the metal cations and loosely held electrons that allow the atoms to slide past each other without breaking the strong metallic bonds. Hence, metals are malleable and can be drawn into thin wires.	N/A	N/A	N/A
Density is the amount of volume a mass occupies. The higher	___ is an ionic solid that forms due to electrostatic attraction between the cation	___ is a metallic solid that forms due to tightly packed metal atoms. The	___ is a molecular substance that contains very strong covalent bonds	Silicon dioxide (SiO_2) and diamond are 3D covalent network solids that are made	___ polymers are made up of chains of covalently bonded atoms. These

the density the more mass per unit volume	and anion to form directional ionic bonds resulting in a rigid 3D lattice. Ionic substances are made up of many cations and anions that are held together by electrostatic attraction to form relatively high-density solids as there is a high mass of ions per unit volume.	electrostatic attraction between the cation and the pool of loosely held electrons form very strong non-directional metallic bonds. Due to the tightly packed metal atoms in metallic substances, metals have relatively high density as there is a high mass of atoms per unit volume.	(intramolecular) within the molecule but very weak intermolecular attractions between the molecules. Molecular solids have low density as the molecules are not tightly packed together. There is a low mass of atoms per unit volume.	up of very strong covalent bonds. Graphite is made up of 2D carbon sheets that are covalently bonded. These sheets are held together by very weak intermolecular forces of attraction. 3D covalent solids have low density as the atoms are not tightly packed together. There is a low mass of atoms per unit volume.	polymer chains are held together by very weak intermolecular forces. polymer solids have low density as the molecules are not tightly packed together. There is a low mass of atoms per unit volume.
Hardness the ability for a substance to withstand being deformed/ fractured.	___ is an ionic solid that forms due to electrostatic attraction between the cation and anion to form directional ionic bonds resulting in a rigid 3D lattice.	___ is a metallic solid that forms due to tightly packed metal atoms. The electrostatic attraction between the cation and the pool of loosely held electrons form very strong non-	N/A	Silicon dioxide (SiO_2) and diamond are 3D covalent network solids that are made up of very strong covalent bonds.	___ polymers are made up of chains of covalently bonded atoms. These polymer chains are held together by very weak intermolecular forces.

	Due to the very strong electrostatic attraction between the cations and anions forming strong directional ionic bonds a large amount of energy is required to overcome these forces of attraction in the solid. Hence, ionic solids are hard and requires a large amount of energy to deform or break the strong ionic bonds.	directional metallic bonds. Due to the very strong electrostatic attraction between the cations and the pool of loosely held electrons that form strong metallic bonds a large amount of energy is required to overcome these forces of attraction in the solid. Hence, metallic solids are hard and requires a large amount of energy to deform or break the strong metallic bonds.			Due to the strong covalent bonds within the molecules and the very weak intermolecular forces of attraction between the molecules that are holding them in the solid phase. As intermolecular forces of attraction are very weak only a small amount of energy is required to break these forces of attraction to deform or break the substance. Hence, polymers are generally soft. Note if there are many straight polymer chains lined up, they will have a greater hardness than polymers chains that are not straight and do not overlap well.

					This is because there will be more very weak intermolecular forces of attraction to overcome that polymer that the chains do not overlap well. Thus, more energy will be required to break the larger quantity of the very weak intermolecular forces of attraction. Hence, straight chain polymers that overlap well will have a higher hardness than polymers that don’t have straight chains and that do not.
Softness is when a substance can be easily deformed.	N/A	N/A	___ is a molecular substance that contains very strong covalent bonds (intramolecular) within the molecule but very weak intermolecular	Graphite is made up of 2D carbon sheets that are covalently bonded. These sheets are held together by very weak	___ polymers are made up of chains of covalently bonded atoms. These polymer chains are held together by very

			attractions between the molecules. Due to the very weak intermolecular forces holding the molecules together molecular substances are usually soft as only a small amount of energy/ force is required to deform of break the very weak intermolecular forces between the molecules.	intermolecular forces of attraction. Due to each C only being covalently bonded to 3 other C atoms leaving a delocalize electron per carbon atom to move throughout the network graphite has 2D covalently bonded sheets. These sheets are held together by very weak intermolecular forces of attraction. As these attractions are very weak only a small amount of energy/ force is required to break the intermolecular forces so the 2D sheets can slide over one another. Hence, graphite is a very soft substance.	weak intermolecular forces. Due to the strong covalent bonds within the molecules and the very weak intermolecular forces of attraction between the molecules that are holding them in the solid phase. As intermolecular forces of attraction are very weak, only a small amount of energy is required to break these forces of attraction to deform or break the substance. Hence, polymers are generally soft. Note if there are many straight polymer chains lined up, they will have a greater hardness than

					polymers chains that are not straight and do not overlap well. This is because there will be more very weak intermolecular forces of attraction to overcome that polymer that the chains do not overlap well. Thus, more energy will be required to break the larger quantity of the very weak intermolecular forces of attraction. Hence, straight chain polymers that overlap well will have a higher hardness than polymers that don’t have straight chains and that do not.
Brittle a hard substance that can break easily when force is applied.	___ is an ionic solid that forms due to electrostatic attraction between the cation	N/A	N/A	N/A	N/A

	and anion to form directional ionic bonds resulting in a rigid 3D lattice. Due to the very strong electrostatic attraction between the cations and anions forming strong directional ionic bonds when a large enough force is applied the like charges align and repel which causes the ionic lattice to shatter. Hence, ionic solids are brittle.				
Thermal conductors the ability for heat energy to pass through a substance	N/A	___ is a metallic solid that forms due to tightly packed metal atoms. The electrostatic attraction between the cation and the pool of loosely held electrons form very strong non-	N/A	N/A	N/A

		directional metallic bonds. Metallic substances are good thermal conductors due to the non-directional metallic bonds, the free moving delocalised electrons that can move throughout the network to allow heat to pass through the metal. Hence, metals are excellent thermal conductors.			
Sonorous when a substance vibrates when struck.	N/A	___ is a metallic solid that forms due to tightly packed metal atoms. The electrostatic attraction between the cation and the pool of loosely held electrons form very strong non-directional metallic bonds.	N/A	N/A	N/A

		Metallic substances are sonorous due to the non-directional metallic bonds the free moving delocalised electrons that can move throughout the network to allow the metal atoms to vibrate and make a ringing sound when struck. Hence, metals are sonorous.			
Solubility the ability to break down in water (bonds are broken)	___ is an ionic solid that forms due to electrostatic attraction between the cation and anion to form directional ionic bonds resulting in a rigid 3D lattice. The attraction between the ___ ionic solid and water	___ is a metallic solid that forms due to tightly packed metal atoms. The electrostatic attraction between the cation and the pool of loosely held electrons form very strong non-directional metallic bonds.	___ is a molecular substance that contains very strong covalent bonds (intramolecular) within the molecule but very weak intermolecular attractions between the molecules. The attraction between the	Silicon dioxide (SiO_2) and diamond are 3D covalent network solids that are made up of very strong covalent bonds. Graphite is made up of 2D carbon sheets that are covalently bonded. These sheets are held	___ polymers are made up of chains of covalently bonded atoms. These polymer chains are held together by very weak intermolecular forces. The attraction between the polymer substance and water

	molecules are stronger than the electrostatic attractions between the cation and anion in the ionic solids themselves. Hence, the ions have been pulled out of the rigid ionic lattice by the water molecules.	The attraction between the water molecules and the metal atoms are not stronger than the electrostatic attractions between metal cations and the pool of loosely held electrons themselves. Hence, the metallic substances will not dissolve in water.	molecular substance and water molecules are not stronger than the attractions between water molecules themselves. Hence, the molecular substance will not dissolve in water and will form separate layers.	together by very weak intermolecular forces of attraction. The attraction between the water molecules and the atoms are not stronger than the very strong network of covalent bonds themselves. Hence, diamond and silica (SiO_2) substances will not dissolve in water.	molecules are not stronger than the attractions between water molecules themselves. Hence, the polymer substance will not dissolve in water and will form separate layers.

MODEL ANSWER SECTION

NCEA exam type question one:

Explain why salt and saltwater has different electrical conductivity in terms of the bonding between the particles.

Include:

- The type of bonding and a description of the bonding in salt.
- Link the bonding of solid salt and dissolved salt (saltwater) to their electrical conductivity.
- Explain the solubility of salt by linking the interactions between the solid salt and water due to the type of bonding in salt.

NAME OF SOLID	TYPE OF SOLID	SMALLEST PARTICLE	ATTRACTION BETWEEN THE PARTICLES	TYPE OF BOND
Sodium chloride (NaCl)	**Ionic**	**Ions (Na^+ and Cl^- ions)**	**Electrostatic attraction between the Na^+ cation and the Cl^- anion**	**Ionic bond**

Solid sodium chloride is made up of sodium metal cations (Na^+) and chloride non-metal anions (Cl^-) that are electrostatically attracted to one another. This electrostatic attraction forms very strong ionic bonds between the cation and anion to form a rigid 3D lattice.

As these ions are held in the rigid 3D lattice there are no available ions to conduct an electrical current. Thus, solid sodium chloride salt does not conduct an electrical current.

When solid sodium chloride is placed in water the salt dissolves because the attraction between the water molecules and the ions in the 3D ionic lattice are strong enough to overcome the electrostatic attraction between the ions (cations and anions) in the ionic lattice. Hence, the ions get pulled out of the ionic lattice. In dissolved form the ions (cation and anions) are available to carry an electrical current. Thus, dissolved salt in water can conduct electricity.

NCEA exam type question two:

Titanium dioxide (TiO_2) is a brittle but hard compound. It is used in lenses for peoples' glasses. Explain why titanium dioxide (TiO_2) is a good material to make lenses in glasses but why glasses must not be dropped as the lenses may shatter on impact with the ground in terms of the bonding between the particles. ***Titanium dioxide is not a 3D covalent substance***.

Include:

- The type of bonding and a description of the bonding in titanium oxide (TiO_2).
- Link the bonding of titanium oxide (TiO_2) to its hardness which makes it suitable to make lenses in glasses.
- Explain why you must not drop glasses by linking the bonding in titanium oxide (TiO_2) to its brittleness.

NAME OF SOLID	TYPE OF SOLID	SMALLEST PARTICLE	ATTRACTION BETWEEN THE PARTICLES	TYPE OF BOND
Titanium dioxide (TiO_2)	**Ionic solid**	**Ions (cations and anions)**	**Electrostatic attraction**	**Ionic bond**

Solid titanium dioxide is an ionic substance = A made up of titanium metal cations and oxide non-metal anions that are electrostatically attracted to one another. This electrostatic attraction forms very strong ionic bonds between the cation and anion to form a rigid 3D lattice = M.

Hardness means that a substance can withstand a large amount of force without being deformed = A. Titanium dioxide is made up of very strong ionic bonds which makes the substance very hard. This is why titanium dioxide is a good material to make lenses as the lenses will not easily be scratched due to the very strong ionic bonds due to the electrostatic attraction between the metal cations and the non-metal anion = M.

Brittle means that the substance will shatter if hit with enough force. Titanium dioxide is hard but also brittle = A. If the lenses are dropped from a height the impact with the ground provides enough force to cause the lenses to break. This is because the force will cause the same charged ions to align and repel. This cause the titanium dioxide lenses to shatter when dropped = M.

A = ____ M = ____

NCEA exam type question three:

Your cell phone is made of many different chemical substances. Copper is used to make the electrical wires inside your cell phone. An alloy is used to make the case of your cell phone. Answer the following questions using the data provided in the tables below.

Type of substance	Density (g cm^{-1})	Hardness (mohs)
Aluminium (Al)	2.7	2.75
Gold (Au)	19.3	2.5
Magnesium- (Mg)	1.7	3.0

a) The case of a cell phone needs to be strong and lightweight, so it is easy to carry on your person. Discuss which alloy would be better to make the case of a cell phone, aluminium-magnesium, or aluminium-gold?

Include:

- The definition of an alloy and explain how alloys are harder in terms of the size of the atoms.
- The type of bonding and a description of the bonding in aluminium.
- Link the bonding of aluminium, gold and magnesium to its hardness and density which makes it suitable to use as a cell phone case.
- Explain which alloy you would recommend the manufacturer uses to make the cell phone case by comparing the density and hardness of the two possible metals that would be alloyed with aluminium using the data supplied in the table above.

  An alloy is formed when there is a mixture of elements with one being a metal = A. As alloys have a mixture of elements there are different sized atoms which means the atoms cannot easily slide past one another which makes the metal harder = M.

  Aluminium is a metallic solid = A which are made up metal cations (Aluminium ions, Al^{3+}) that are electrostatically attracted to a pool of delocalised (loosely held) electrons to form very strong non-directional metallic bonds = M.

  Hardness means that a substance can withstand a large amount of force without being deformed and density is the number of atoms occupying a certain volume. The higher the density the more atoms that occupy a particular volume = A.

  The best metal to use as an alloy with aluminium will be magnesium as it has a greater hardness (3.0) than gold (2.5) and it also has a lower density (1.7) than gold (19.3). As aluminium has a higher hardness on the mohs scale this means that it can withstand more force before deforming or denting this is due to the very strong non-directional metallic bonds = M. Thus, the case will less likely become dented = A. As aluminium has a much lower density value than gold there are less atoms occupying a certain volume = M which will make the case not as heavy to carry around = A.
  I suggest an alloy of aluminium-magnesium will be more suitable than aluminium-gold due to magnesium being a harder metal and being less dense.

  A = ____ M = ____ E = ____ (which is all of it really).

b) As mentioned above copper is used to make electrical wires in cell phones. Discuss the physical properties of copper and link this to the bonding in copper that make copper a very useful metal for making electrical wires in electronic devices such as a cell phone.

Include: **Ductile = wire. Electrical conductor = electrical wires. High melting point = stay solid**

- Fill in the table below.
- A definition of the type of bonding that occurs in copper.
- Link the bonding of copper to **three** physical properties which makes it suitable to use as electrical wires in a cell phone.

NAME OF SOLID	TYPE OF SOLID	SMALLEST PARTICLE	ATTRACTION BETWEEN THE PARTICLES	TYPE OF BOND
Copper (Cu)	Metallic solid.	Atoms (metal cations and electrons)	Electrostatic attraction.	Metallic bond.

Copper is a metallic solid that forms very strong non-directional metallic bonds due to the electrostatic attraction between the metal cations (Cu^{2+}) and the pool of delocalised (loosely held) electrons forming strong metallic bonds = M.

The three physical properties that make copper a good metal to form electrical wires are ductility, electrical conductor and hardness = A. Ductile means that copper metal can be drawn into thin wires. electrical conductor means that copper allows and electrical current to flow through it and hardness means that a force can be applied without breaking the copper = A.

Copper is ductile and can be drawn into thin electrical wires due to the non-directional bonding due to the electrostatic attraction between the metal cations (copper ions, Cu^{2+}) and the pool of delocalised (loosely held) electrons. This allows the metal atoms to slide past on another to form thin wires without breaking the strong metallic bonds = M. Hence, coppers ductility makes it a good substance to make electrical wires = A.

Copper is an excellent electrical conductor due to the non-directional bonding due to the electrostatic attraction between the metal cations (copper ions, Cu^{2+}) and the pool of delocalised (loosely held) electrons. This means there is available charge (delocalised electrons) to carry an electrical current = M. Hence, coppers electrical conductivity makes copper a good substance to make electrical wires = A.

Due to the very strong electrostatic attraction between the cations and pool of loosely held electrons that form strong metallic bonds, a very large amount of heat energy is required to break these very strong metallic bonds to change the solid to a liquid. Hence, metallic substances have very high melting points = M. Hence, coppers high melting point makes copper a good substance to make electrical wires as they will not melt when the current causes heat in the electrical wires in the circuit = A.

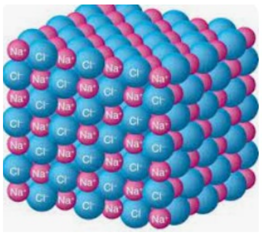
The three properties of copper, high ductility, high electrical conductivity and high melting point makes copper a very suitable substance to make electrical wires that will last = E

A = ___ M = ___ E = ___ (which is all of it really).

NCEA exam type question four:

Piripi and Mere are cooking a pot of potatoes for dinner and have noticed that the water rises and spills over the edges of the pot. Piripi thinks that if it you put salt on the rim of the pot it will stop the water boiling over. Mere does not agree with Piripi and thinks that rubbing oil around the rim of the pot will stop the water boiling over. In the table below the substances are given. Use the formula of these substances to determine the type of bonding in the solid salt and oil.

c) Fill in the table below:

NAME OF SOLID	SOLUBILITY IN WATER	TYPE OF SUBSTANCE	ATTRACTION BETWEEN THE PARTICLES	TYPE OF BONDING
Cooking oil ($C_{30}H_{50}O$)	Insoluble in water forms separate layers	**Molecular substance**	**Strong covalent bonds (intramolecular forces) within the molecule AND very weak intermolecular force between the molecules.**	**Molecular bonding (intermolecular forces)**
Salt ($NaCl$) 	Soluble in water.	**Ionic solid**	**Electrostatic attraction (between the metal cation (Na^+) and the non-metal anion (Cl^-).**	**Ionic bonding.**

d) Discuss the bonding in both salt and cooking oil and link this to the interaction both salt and oil have with water.

Include:

- The type of bonding and a description of the bonding in salt **and** cooking oil.
- Link the bonding of salt **and** cooking oil to their interaction with water molecules.
- Explain who is correct (Piripi or Mere) by linking the interaction between water molecules and the salt **and** oil to how they do or do not stop the water boiling over in the pot.

Cooking oil is a molecular substance = A made up of molecules that contain strong covalent bonds (intramolecular forces) within the molecules. The molecules are held together by very weak intermolecular forces of attraction.

The attraction between the cooking oil (molecular substance) and water molecules are not stronger than the attractions between water molecules themselves. Hence, the cooking oil (molecular substance) will not dissolve in water and will form separate layers = M. Thus, Mere is correct that putting oil around the rim of the pot should stop the water boiling over as it creates a barrier between the oil and water = E.

Salt (sodium chloride) is an ionic solid = A that forms due to electrostatic attraction between the cation (Na^+) and anion (Cl^-) to form directional ionic bonds resulting in a 3D lattice = M. The attraction between the ions in the salt and water molecules are stronger than the electrostatic attractions between the cation and anion in the ionic solids themselves. Hence, the ions have been pulled out of the rigid ionic lattice by the water molecules = M. Therefore, Piripi is incorrect if the water in the pot starts to boil over the water will dissolve the solid salt which will not create a barrier. Thus, the water will continue to boil over = E.

In conclusion, Mere is correct because cooking oil and water create separate layers which creates a barrier to stop the water boiling over whereas, Piripi is incorrect because the salt dissolves as the water boils over which will not stop the water to continue to boil over = E.

A = ___ M = ___ E = ___ (which is all of it really).

NCEA exam type question 5

Alkanes are molecules made up of carbon and hydrogen atoms. There are many different length and sized alkanes which have different uses. Alcohols are made up of carbon, hydrogen and oxygen atoms and they are used as disinfectants and antiseptics. Below is a table that shows the data of ethanol and bitumen. Use this data to answer the questions below.

Ethanol made up of non-metal atoms = molecular substance

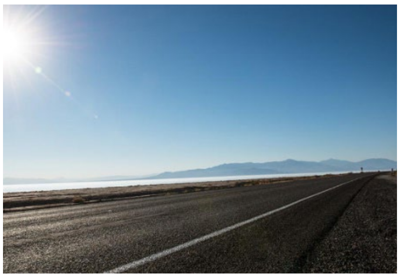
a) Ethanol (alcohol) is used in hand sanitisers due to its volatility. Volatile means that is changes from a liquid to a gas easily and the heat of a persons hand had is sufficient to turn liquid hand sanitiser into gas sanitiser and this happen due to evaporation. It is important that the ethanol is evaporated off the persons hand as it is very toxic to humans if ingested (eaten). Explain why ethanol is useful as a hand sanitiser by referring to the physical properties of ethanol.

In your answer include:

- The type of substance ethanol is.
- The bonding **within** the ethanol molecule and the bonding that occurs **between** ethanol the molecules.
- Explain how the bonding in ethanol makes it useful as a hand sanitiser.

Hand sanitiser (ethanol) is a molecular substance = A made up of molecules that contain covalent bonds (intramolecular forces) within the molecules. The molecules are held together by very weak intermolecular forces of attraction = M. Due to the very weak intermolecular forces of attraction between the molecules that are holding them in the liquid phase (even though they contain strong covalent bonds within the molecules) the intermolecular forces of attraction are very weak only a small amount of energy is required to break these forces of attraction to change the liquid into a gas = M. Hence, boiling point of the liquid hand sanitiser is low, and the temperature of a person's hand is sufficient energy to break these weak intermolecular forces of attraction. Hence, the hand sanitiser will evaporate that way the toxic hand sanitiser will not be ingested (eaten) = E

b). Bitumen is used to make our roads in NZ. It is a very large alkane molecule made up of many carbon and hydrogen atoms. Using the data in the table above explain how the physical properties of bitumen make it a useful substance for making our roads.



Type of substance	Hardness (mohr)	Melting point point (℃) (mp)
Sand (SiO_2) *30% in concrete*	6 - 7	1700℃
Bitumen ($C_{35}H_{72}$)	2	120 – 150℃

Bitumen is made up of non-metal atoms = a molecular substance.

In your answer include:

- The type of substance bitumen is.
- The bonding **within** the bitumen molecule the bonding that occurs **between** the bitumen molecules.
- Explain how the bonding in bitumen makes it useful to use as roads.

Bitumen is a molecular substance = A that contains very strong covalent bonds (intramolecular) within the molecule but very weak intermolecular attractions between the molecules = M. Due to the very weak intermolecular forces of attraction between the molecules that are holding them in the solid phase (even though there are strong covalent bonds within the molecules) the intermolecular forces of attraction are very weak only a small amount of energy is required to break these forces of attraction to change the solid into a liquid. However, as bitumen is a very large molecule there is a very large quantity of intermolecular forces occurring in bitumen which makes the melting point increase. Hence, melting points of bitumen is around 120 – 150 °C. It is also to the large quantity of very weak intermolecular forces of attraction occurring in bitumen that has a hardness of 2 on the mohs scale = M.

c). Concrete is another substance that can be used to make roads. Concrete is a mixture of mostly cement, gravel, and sand, with 30% of concrete having sand (SiO_2) which makes sand a key component of concrete.

Type of substance	**Hardness (mohr)**	**Melting point point (℃) (mp)**
Sand (SiO_2) *30% in concrete*	6 - 7	1700 ℃
Bitumen ($C_{35}H_{72}$)	2	120 – 150 ℃

Looking at the data in the table and referring to your answer in b) above, explain which substance, concrete or bitumen, would be more suitable to make NZ roads.

In your answer include:

- The type of solid sand (silicon dioxide SIO_2) is and an explanation of the type of bonding that occurs in sand which is a major component of concrete used in roading.
- Link the data of bitumen and sand/ silicon dioxide to the bonding in each substance.
- Make a recommendation to Waka Kotahi (NZ transport agency) as to which substance concrete or bitumen would be more suitable for building NZ roads in the future.

Concrete contains silicon dioxide (SiO_2) which is a 3D covalent network solid that are made up of very strong covalent bonds = A Due to the 3D network of very strong covalent bonds in concrete a very large amount of energy is required to break the very strong covalent bonds in the solid to form a liquid. Hence, concrete (silica) has a very high melting point of 1700 °C. It is also due to the 3D network of very strong covalent bonds that concrete (silicon dioxide) that concrete is a very hard substance and has a hardness of 6 – 7 mohr

= M

Comparing concrete and bitumen, concrete would be a more suitable substance for Waka Kotahi (NZ transport agency) to make NZ roads. This is because it is a much harder substance (6 – 7 mohr) than bitumen (2 mohr). Concrete also has a much higher melting point (1700 °C) compared to bitumen (120 – 150 °C) = E

A = ____ M = ____ E = ____ (which is all of it really).

NCEA exam type question 6

You are employed to help the product engineers make the strongest plastic shopping bags. Plastic bags are made of a polymer called polyethylene which is many ethene units/ monomers added together. These polymer chains are stacked in rows to create a plastic shopping bag. Below are the results of a test conducted when the polymer chains are positioned in the horizontal and vertical positions.

When the plastic bag has the polymer chains in the horizontal position and they a pulled apart from the top and bottom of the plastic bag, the bag stretches and begins to tear.

When the plastic bag has the polymer chains in the vertical position and they a pulled apart from the top and bottom of the plastic bag, **does not** stretch or tear.

a) Name the **forces of attraction that are been broken** when the bag is pulled apart from top to bottom.

   Very weak intermolecular forces of attraction because the bag stretches and breaks = A.

b) Name the **forces of attraction that can withstand the force** when the bag is pulled apart from top to bottom.

   Strong covalent bonds (intramolecular forces of attraction) as the bag withstands the force applied = A.

c) Explain which forces of attraction are stronger and why?

   The covalent bonds (intramolecular forces of attraction) are such stronger that the very weak intermolecular forces of attraction. Because when the polymer is in the horizontal position the bag tears so that must be breaking the weak intermolecular forces and when it is pulled by the sides it must be the strong covalent bonds being pulled which are strong so it withstands this force applied = M.

d) Below are two diagrams showing the polymer chains in a horizontal position (A) and in the vertical position (B). Use these diagrams and your knowledge of the forces of attraction in polyethylene to decide which position (horizontal or vertical) should the plastic bags be made to ensure they are strong enough to carry groceries without tearing.

A - Horizontal position	B – Vertical position
	

In your answer include:

- An explanation of the type and strength of bonding that occurs **within** the polyethylene chains.
- An explanation of the type and strength of bonding that occurs **between** the polyethylene chains.
- Make a recommendation to the product engineers who are making the plastic bags as to which way the plastic bags should be made (horizontal and vertical) by linking to both the forces of attraction **within** and **between** the molecules so that the strongest plastic bag can be made without it stretching and tearing. Hence, the customer can carry their groceries items without the possibility of them falling onto the ground.

Polythene is a straight chain polymer made up of polymer chains that are held together by strong covalent bonds (intramolecular forces). These polymer chains are held together by very weak intermolecular forces of attraction = M. I would recommend that the plastic bag be made in the vertical position because when you place groceries in the bag and gravity applies weight force to the plastic bag in a downwards direction, the bag is pulling against

the strong covalent bonds (intramolecular forces of attraction) as they are lined up to align the vertical position = E

The covalent bonds are much stronger than intermolecular forces. Hence, the plastic bag will withstand the weight force and will not stretch or tear. If the plastic bag is made in the horizontal position the very weak intermolecular forces are aligned with the horizontal position. Which means the weight force will pull on the very weak intermolecular forces. Thus, the bag is more likely to stretch and tear = M.

Thus, I recommend making the plastic bag in the vertical position as the covalent bonds are stronger than the weak intermolecular forces so the plastic bag will not stretch and tear= E.