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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 1 Chemistry and Biology 2024

92023 Demonstrate understanding of how the physical properties of materials inform their use

Credits: Four

Achievement	Achievement with Merit	Achievement with Excellence
Demonstrate understanding of how the physical properties of materials inform their use.	Explain how the physical properties of materials inform their use.	Evaluate how the physical properties of materials inform their use.

Check that the National Student Number (NSN) on your admission slip is the same as the number at the top of this page.

You should attempt ALL the questions in this booklet.

Pull out Resource Booklet 92023R from the centre of this booklet.

If you need more room for any answer, use the extra space provided at the back of this booklet.

Check that this booklet has pages 2–8 in the correct order and that none of these pages is blank.

Do not write in the margins (////). This area will be cut off when the booklet is marked.

YOU MUST HAND THIS BOOKLET TO THE SUPERVISOR AT THE END OF THE EXAMINATION.

Excellence

TOTAL 24

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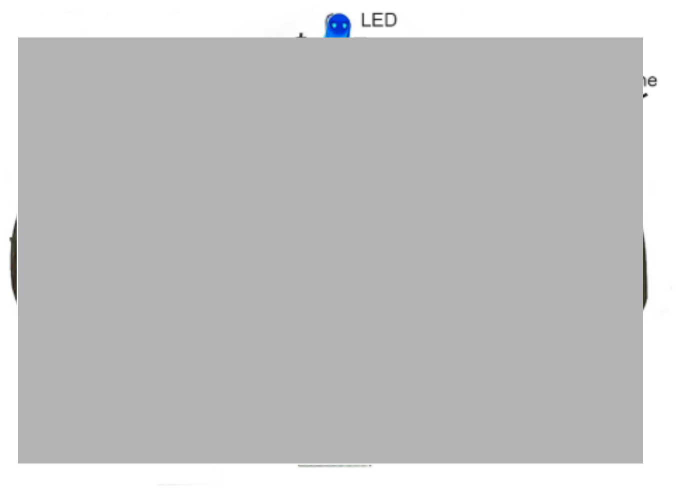
Make sure you have the paper Resource Booklet 92023R.

QUESTION ONE: Paper electrical circuits

A pencil containing graphite (carbon), C, has been used to draw an electrical circuit, which is an outline of a car.
A 9V battery and light-emitting diode (LED) are also part of the circuit.

Table 1: Physical properties of graphite (carbon), C		
Physical property	**Numerical values**	**Comment**
Melting point	3 650 °C	Very high
Solubility in water	-	Insoluble
Electrical conductivity	3×10^5 σ (S / m) at 20 °C	Good
Malleability	4.80 GPa	Brittle
Hardness	1 to 2 Moh	Soft



(a) Describe TWO physical properties of graphite (carbon) and link these two physical properties to their use in drawing and creating an operating electrical circuit.

Graphite is an electrical conductor (it has an electrical conductivity of 3×10^5 σ (S / m) at 20 °C), which means it allows the flow of electricity through its structure. This makes it possible to be used for the pathway for current to flow in a circuit as its delocalised electrons can attract to the positive node of the battery, and generate current.

Furthermore, graphite is soft (it has a low hardness value of 1 to 2 Moh and not able to resist deformation), which means a graphite pencil can be used to draw the circuit on a surface, and spread out the graphite to make the car outline (the circuit) due to its weak intermolecular forces, which I will explain in depth in part b, as well as it's electrical conductivity.

(b) Explain these TWO physical properties with reference to the structure and bonding of graphite (carbon).

Graphite is an allotrope of carbon (a different structure of the same element in the same state), and is a giant covalent network (non-metal atoms covalently bonded together in a giant repeating strcucture). In graphite, carbon covalently bonds to 3 other carbon atoms, leaving 1 electron unbonded, and delocalised per carbon atom. It forms giant 2d graphene layers in a hexagonal carbon-carbon structure, where the carbon atoms are covalently bonded together. These giant graphene sheets are non-polar as there is no electronegativity differences between carbon atoms, so these 2d graphene sheets stacked and held together by weak london/dispersion forces from the temporary dipoles formed by the graphene sheets to form a 3d graphite structure.

Graphite is electrically conductive (it has an electrical conductivity of 3×10^5 σ (S / m) at 20 °C) due to it's 1 delocalised electron per carbon atom, as a requirement for electrical conductivity (the ability for a substance to allow electricity to pass through its structure) is either freely movable electrons, or charged particles. This is why graphite is able to conduct electricity, and be used as a 'wire' in a circuit, like is being done here with the car.

In order to be able to be spread across the surface to form the circuit (car outline on the surface), graphite must be soft because of its low hardness. This is true as although the covalent bonds between carbon atoms inside of the 2d graphene sheets is extremely strong, the weak van der waal london/dispersion forces between graphene sheets is extremely weak. This means that it requires very little force to overcome these forces, and allow the the graphene sheets to slide over one another and essentially break due to being brittle. For these reasons graphene is soft (not hard), as it is not able to resist deformation, as the graphene sheets can slide over one another with very little force required, which is what allows it to be used as a pencil lead and draw on a surface (the 2d graphene sheets get rubbed off as the pencil slides along the surface the circuit is being drawn on due to its physical property of not being hard (soft)). This can be seen from its low hardness value of 1 to 2 Moh.

(c) Evaluate how graphite (carbon) will behave when used to draw and create an operating electrical circuit by linking the TWO physical properties to the structure and bonding.

Graphite is a great choice for use as a draw-able circuit as it electrically conductive (it has an electrical conductivity of 3×10^5 σ (S / m) at 20 °C) due to its delocalised electrons within its structure, from each carbon atom only bonding to 3 out of 4 possible carbon atoms (leaving 1 electron unbonded). This makes it an electrical conductor, as a requirement for electrical conductivity is having freely moveable electrons, to allow the flow of current through its structure. This allows current to flow through the graphite circuit, and take voltage to power the LED light, from the battery pack.

Furthermore, graphite is soft due to its low hardness of 1-2 Moh, which allows it to be spread out in a thin sheet across the surface, to be able to simulate a wire. It is able to be spread out due to the weak london/dispersion forces between 2d graphene sheets, which require very little force to overcome the electrostatic force of attraction, and cause the 2d layers to slide over one another.

So, due to graphite's physical properties of electrical conductivity, and being soft (very low hardness), it is able to be used to draw a complete pathway for current to flow form a 9V battery to power an LED bulb.

Source (adapted)

Car: Steam Powered Family. (2024). *Simple curcuit project* [Image]. steampoweredfamily.com/paper-simple-circuit-project

Arrow: [Vector image]. stock.adobe.com/770919389

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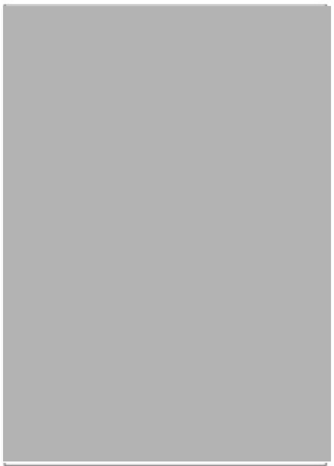
QUESTION TWO: Electrical fire

Carbon dioxide fire extinguishers can be used safely to put out electrical fires. These extinguishers are filled with non-flammable carbon dioxide, CO_2, gas.

Table 2: Physical properties of carbon dioxide and air

Physical property	CO_2	Air
Density at 20°C (kg/m^3)	1.98	1.20
Electrical conductivity	Insulator	Insulator



A carbon dioxide fire extinguisher

(a) Describe TWO physical properties of carbon dioxide and link these two physical properties to the safe use of carbon dioxide to prevent oxygen in the air from fuelling a fire.

Carbon dioxide gas is an electrical insulator (a materials ability to resist the transfer of electricity through itself), which means that it will prevent electricity being transferred from the live wire fire source to the surrounding electrical components, which could cause more over heating and fire, and preventing any people nearby from being electrocuted.

Adittionally, carbon dioxide gas's density is another valuable physical property, as it is more dense than surrounding air (1.98kg/m^3 vs air 1.2kg/m^3) which means it will sink towards to the fire, while the air while rise away from it, due to it being less dense and more bouyant in the dense carbon dioxide gas. By being able to push the air away from the fire to prevent further combustion of oxygen (more fire spreading) due to its high relative density, coupled with its electrical insulation to prevent any further transfer of electricity to surrounding compenents, that could possibly damage them, or any people nearby, carbon dioxide is the perfect choice to use to safely extinguish electrical fires.

(b) Explain these TWO physical properties, with reference to the structure and bonding of carbon dioxide.

Carbon dioxide is molecular substance, which means it contains non-metal atoms covalently bonded together to form molecules that are held together by weak intermolecular forces. Each carbon dioxide (CO2) molecule contains one carbon atom covalently bonded to two oxygen atoms in a linear structure. Its linear structure makes any electronegativity differences cancel out, meaning that the CO2 molecules are non-polar, and are held together by weak london/dispersion forces of attraction.

Carbon dioxide is an electrical insulator (A materials ability to resist the transfer of electricity through itself) due to its lack of delocalised electrons which are a requirment for electrical conductivity. All of CO2's electrons are either localised to the covalent bond or to each atom, and are not freely moveable. This lack of delocalised electrons means that electrical energy cannot be transferred through its structure. For these reasons carbon dioxide is an electrical insulator as it does not allow electricity to flow through itself.

Carbon dioxide as a pure gas also has a higher density than air (1.98kg/m^3 vs air 1.2kg/m^3). Density is a measure of how much mass is per unit volume. Therefore, carbon dioxide molecules must be closer together than the molecules in air, in order to increase how much mass is per unit of volume. This makes carbon dioxide gas more dense than air.

(c) Evaluate how carbon dioxide will behave when used as a fire extinguisher by linking the TWO physical properties to the structure and bonding.

Carbon dioxide is an electrical insulator (the ability to resist the transfer of electricity through a material), due to its lack of delocalised electrons. This makes it great to prevent electrical energy from being transferred to surrounding components, which could possibly damage them and help the fire to spread. So, it is a great choice for use as a gas used in electrical fire extinguishers. Another advantage of having no delocalised electrons means that it can be a thermal insulator (the ability for a material to resist the transfer of heat energy through it) too, as no freely moveable electrons, means less collisions between particles, therefore a less efficient transfer of kinetic energy (heat) through carbon dioxide. This could increase the effectivness of CO2 gas for use in a fire extinguisher as it could prevent surrounding components from melting, as heat can not be transferred efficiently through a thermal insulator via conduction. In doing this, damage could be reduced, and the cost for repair as well.

Carbon dioxide gas is also denser than the air around it due to having moelcules that are close together, which means more mass per unit of volume than air (1.98kg/m^3 vs air 1.2kg/m^3). Dense fluids will sink in less dense fluids as the less dense fluids will be more bouyant than the more dense carbon dioxide gas, and therefore rise. This will prevent oxygen gas in the air from reaching the flames which would increase the rate of combustion and make the fire spread more, possibly damaging the environment around the fire and/or hurting the people near it.

Carbon dioxides physical properties of electrical insulation (and thermal insulation), and its high density (1.98kg/m^3 vs air 1.2kg/m^3), make it a great substance to use to extinguish electrical fires safely, and with less damage and cost of repair.

Source

Extinguisher: [Photograph]. stock.adobe.com/204932761

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QUESTION THREE: Harakeke

Harakeke (New Zealand flax) has long upright leaves that can grow up to four metres (4 m) in length. When the green flesh is removed by scraping, a long, white fibre (**polymer**) called **muka** is revealed. This fibre can be spun or plaited.

Muka fibre is a natural polymer material.

The spun muka can be used for many things, including making a kupenga (fishing net). Kupenga could then be weighed down with stones so that the kupenga would sink.

Harakeke leaves (green) and muka fibres (white) Kupenga made by knotting muka fibres together

Table 3: Young's modulus and solubility of various materials		
Material	**Young's modulus* GPa**	**Solubility in water**
Muka	8.6	Insoluble
Hemp	11.8	Insoluble
Wool	2.3	Insoluble
Glass	70–100	Insoluble

* A high value of Young's modulus means that a material is brittle

(a) Describe TWO physical properties of muka and link these two physical properties to their use in making a working kupenga.

Muka is insoluble in water (Not able to dissolve inside of), which means when made into a kupenga (fishing net), it will not dissolve and will stay intact, making it suitable to be used under the water to catch fish.

Additionally, muka has a relative low brittleness of 8.6GPa (in comparison to glass 70-100GPa and hemp 11.8GPa), and is therefore more malleable (the ability for a substance to chamge shape without breaking) and soft (less hard). This makes it possible for Muka to be weaved, twisted, and bent in order to create the shape of a kupenga without breaking apart, and retaining its strength to catch fish.

(b) Explain these TWO physical properties, with reference to the structure and bonding of muka.

Muka is a naturally occurring polymer, which is a long chain of repeating monomers that are non-metal atoms covalently bonded together. Polymers chains twist and tangle to form the polymer material, and these chains are held together by weak van der waal forces.

When in contact with water, muka is insoluble, this is due to the amount of van der waal forces between polymer chains. Water is a polar molecule, which means one side is partially negative, while the other is partially positive. The amount of forces between polymer chains means that waters polarity is not strong enough to electrostatically attract and detangle the polymer. Furthermore the polymer is long chains of non-metal atoms covalently bonded together, which means that even if water molecules could untangle it, it would not able to separate the individual atoms from the polymer, as they are held in fixed positions with strong covalent bonds. For these reasons muka is insoluble in water.

Muka also has a low brittleness at 8.6GPa compared to glass which has a GPa of 70-100, which makes it more malleable, and les prone to breaking. This is because polymer chains are held together through non-directional bonds. This means that polymer chains can shift around with little effort as the van der waal forces are very weak, however the van der waal forces will continue to be there to hold the polymer together. So, even if the muka polymer is bent and twisted, there will still remain van der waal forces, between the polymer chains to hold it together due to its high plastic deformity (the ability to bend before breaking).

(c) Evaluate how muka will behave when used as a kupenga by linking the TWO physical properties to the structure and bonding.

When used as a net, muka will be able to work well due to its physical properties of not being soluble in water, and its malleability (the ability to change shape without breaking due to its low brittleness of 8.6GPa compared to something like glass which has a GPa of 70-100).

Muka is malleable due to its low brittleness (It does not break when bent out of shape) that arises from its high plastic deformity (ability to bend before breaking). This is due to the flexibility inside of the polymer chains from weak van der waal that require very little force to overcome, and their non-directional nature, which means they will still be there holding the molecule together even when the polymer chains shift over each other. This makes it possible for muka to be weaved, twisted, and bent in order to create the shape of a kupenga without breaking apart, and retaining its strength to catch fish.

Muka is also insoluble in water (not able to dissolve) because the amount of forces between polymer chains means that waters polarity is not strong enough to electrostatically attract and de-tangle the polymer, and will instead just stay attracted to its self through the hydrogen bonds between water molecules. This makes it possible for muka to be used as a net to catch fish, as when it is under the water it will remain intact and not dissolve, meaning it will maintain the strength to hold the fish in the net.

Source (adapted)

Harakeke: Naepflin, W. *Extracting the muka from the flax blades* [Photograph]. All Flax. allflax.nz/what-is-flax-weaving

Kupenga: Brown, A. (2006). *Fishing nets made by knotting strips of flax together* [Photograph]. Ali Brown Weaving. alibrown.nz/the-history-of-flax

Excellence

Subject: Chemistry and Biology

Standard: 92023

Total score: 24

Q	Grade score	Marker commentary
One	E8	Explained that graphite has good electrical conductivity and is soft, which makes it ideal for the use. Described graphite as a giant covalent network and explained the arrangement of atoms (structure) and presence of strong intra-molecular and weak intermolecular forces of attraction (bonding). Discussed the good electrical conductivity linked to the arrangement and force of attraction between carbon atoms and the presence of delocalised electrons, which allows the circuit to operate. Comprehensively discussed how softness is linked to the layered arrangement of carbon atoms with weak intermolecular forces of attraction between them. This means that the graphene sheets require little force to overcome the forces of attraction, allowing the sheets to slide over one another and be suitable to draw the circuit.
Two	E8	Explained that carbon dioxide has poor electrical conductivity and is denser than air, which makes it ideal for the use. Described carbon dioxide as a molecular substance and explained the arrangement of atoms (structure) and presence of strong intra-molecular and weak intermolecular forces of attraction (bonding). Discussed the poor electrical conductivity due to the covalent bond between carbon and oxygen, which results in a lack of delocalised electrons, and inability for electricity to flow. Discussed that carbon dioxide is denser than air due to molecules being closer together and having more mass per unit volume, which causes it to sink. This pushes air away from the fire and prevents further combustion of oxygen.
Three	E8	Defined a polymer and described the arrangement of monomers (structure) and the presence of intramolecular and weak intermolecular forces of attraction (bonding). Discussed the insolubility of muka due to the strong covalent bonds within the polymer and the Van der Waal forces between the chains. These forces are too strong for polar water to overcome and will not dissolve the kupenga. Comprehensively discusses how the malleability of muka is linked to the weak intermolecular forces of attraction between the polymer chains. These attractions require little force to overcome them and allow them to shift over each other, which enables muka to be weaved without breaking apart.