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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 1 Chemistry and Biology 2025

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 2–15 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.

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Excellence

TOTAL 23

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Make sure you have the paper Resource Booklet 92023R.

QUESTION ONE

Low-density polyethylene (LDPE) is a type of polymer that can be used to make the body of a kayak.

(a) Define the term polymer.

A Polymer is a macromolecule made up of repeating units of monomers that have strong intramolecular bonds. Monomers join together with covalent and form long chains in a process called polymerisation. These long chains stack and group together and form weaker bonds between themselves, creating a 3D strucuture.L

LDPE is widely used due to its versatility, moisture resistance, and low melting point. It is characterised by its low density and flexibility.

A kayak needs to be buoyant and insoluble in water, so it can float on the water with kayakers.

Figure 1: Carbon, C, and hydrogen, H, bonds form long chains and branches in LDPE

Figure 2: Skeleton structure of LDPE (top) compared with the related high-density polyethylene (HDPE) (bottom)

(b) Explain how the structure and bonding of LDPE results in a low-density polymer that is suitable for use in kayaks.

The Polymer LDPE has multiple branches that make the substance relatively flexible and have a low density. These properties arise from the structure and bonding of the polymer. Polymers consist of multiple units of monomers covalently bonded together, however, LDPE has a low density because of its ability to form multiple branches and chains of molecules. This makes the material less dense as the strucutre is not as compact and uniform as HDPE for example and when layered has much more empty space between layers due to the branching. This means there is less mass per metric volume in LDPE compared to HDPE and so the material will be less dense. This is a beneficial trait for kayaks as it makes it more likely for the kayak to float. In order to float, an object must be less dense than water. Having the lowest density material possible will allow more weight to be added into a kayak before the amount fo water displaced is less than the weight of the object. If a kayak is amde of a more dense material, but is the same shape, less weight will be able to be added to it before it begins to sink.

A kayaker is looking for a new kayak made out of stronger and harder carbon fibre sheets.

Figure 3 shows three layers of carbon fibre sheets, with a close-up of the atomic structure of the planes of carbon atoms that make up these layers.

Figure 3: Layers of carbon fibre sheets, with close-up of atomic structure

(c) (i) Select the type of material a carbon fibre sheet is.

- (selected) covalent network
- ionic material
- metallic solid
- molecular substance
- polymer

(ii) Explain why the structure and bonding within a carbon fibre sheet results in a kayak that is hard and strong.

Carbon fibre is a covalent network material with a layered structure. The Carbon atoms in one layer are covelently bonded to 3 others and form a hexagonal and regular network of carbon atoms. Covalent bonds are teh strongest chemcial bonds, and require a lot of energy or a large amount of force to overcome these bonds. Therfore, the sheets of carbon fibre are very resistant to corrosion, heat, and are not soluble in water (as the attraction between water-water molecules and carbon-carbon molecules are much stronger than the carbon-water interactions). These layers of carbon are attracted to each other by weaker bonds, and are not covalently bonded to each other. However, the larger the network, the stornger the force of attraction between two sheets will be. Therefore, due to the size of the cabron sheets required to build a kayak and the sheer number of attractive froces between sheets of carbon fibre, the forces between the sheets are also incredibly strong and resistant to breaking easily. This structure and bonding of carbon fibre sheets make this material incredibly hard and resistant to sratches, dents, and tears as a large amount of force is requried to disrupt the hexagonal lattice and cause damage to the material. This also makes the kayak incredibly strong as the forces that hold teh carbon atoms together are so storng and so numerous that only incredibly large amounts of force or heat energy can overcome these bonds. For these reasons, a cabron fibre kayak has many beneficial qualities that make it suitable for use outdoors. It's hardness and resitance to scratching and dents allow ecploring in rough areas and reefs without fear of damage to the kayaks body. And its strength allows the kayak to persist in rough environments without breaking, such as slapping agaisnt waves with a lot of force.

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QUESTION TWO

The shaft of a kayak paddle is made of aluminium, Al.

(a) (i) Select the type of material aluminium, Al, is.

- ○ covalent network
- ○ ionic material
- ● metallic solid
- ○ molecular substance
- ○ polymer

(ii) How does the structure and bonding of aluminium, Al, allow it to be malleable, forming the long, hollow tube of the shaft of the paddle?

The strucutre of metallic substances consists of metal cations arranged in a tight lattice strcuture, and surrounded by delocalised electrons. The ability for these electrons to be free-moving creates a 'sea' of electrons around a tight strucutre of metal cations. The electrostatic forces of attraction between oppositely charged cations and electrons hold teh metal cations in a tight position as the electrons constantly moving throughout the surface pull the cations closer to each other. Because of this structure and the behaviour of the electorns in a mettallic substance, Aluminium is able to be a malleable substance. A little amount of force is require to bend and move teh cations into a desirable shape (such as the kayak shaft) as the regular aluminium cations can easily slide past each other and then resettle into a new position once force is removed. This is because the bonds between metal cations, and electrons are nondirectional. The bonds do no break once a force is applied, rather shift and manuver themselves into a new position before resettling just as strong as before.

Figure 4 shows aluminium, Al, and the alloying of aluminium and magnesium, Mg.

Figure 4: The alloying process of aluminium and magnesium

(b) (i) Define the term alloy.

B I U

An alloy is a cobination of a metal and another material with different qualities (typically another metal) to form a new substance with better/more useful qualities than the pure substance alone.

(ii) Explain how adding magnesium, Mg, to aluminium, Al, to make an alloy, changes the malleability of the material.

B I U

Alloys have many beneficial traits as they are usually stronger than a pure metal. This is because when two different metals with differing atom sizes are mixed, the regular arrangement of metal cations is disrupted. This creates a material that can resist more force and is usually less dense as atoms are not as tightly arranged. However, alloys will have a negative impact on a substance's malleability. The disruption in the regular arrangement of the cations means it is more difficult for the atoms to slide past each other and be shaped by force. When magnesium is added to Aluminium, the extent of the susbtance's malleability will decrease.

Table 1 shows the physical properties of aluminium, Al, and two different alloys that could be used for a kayak paddle.

The shaft of a kayak paddle is formed of a long, hollow tube. It needs to:

- float if it is dropped into the water
- be hard enough to pull the blades through the water
- be light enough for a kayaker to lift and use.

Table 1: Density and hardness of substances		
Substance	**Density**	**Relative hardness**
Pure aluminium	2.7 g / cm^3	Low
Aluminium and magnesium alloy	2.60–2.7 g / cm^3	Medium
Steel (iron and carbon alloy)	7.75 g / cm^3	High

(c) Using the information in Table 1 and your knowledge of structure and bonding of materials, discuss why an aluminium and magnesium alloy would be preferred over both pure aluminium and steel (iron and carbon alloy) as the material used for kayak paddles.

B I U

The aluminium magnesium alloy is teh best material for use as a kayak paddle shaft due to its low density and relative hardness. For a kayak paddle to float, it must be less dense than water. Pure aluminiuma and the alloy are the least dense substances. The alloy is 2.6 to 2.7 g/cm^3, which is similar to aluminium's density of 2.7 g/cm^3 which are both relatively low and would be able to float on water campared to the density of steel at 7.75 g/cm^3 which is incredibly dense and would likely sink when dropped. Density arises from the structure and bonding within a substance. An aluminium atoms has an atomic mass of 13daltons and magnesium has an atomic mas of 12 daltons whereas iron has an atomic mass of 26 daltons, and carbon has a mass of 6 daltons. Assuming both there are the same number of atoms in all three materials, Steel still has a higher atomic mass than the other materials and will be more dense per metric volume. Pure aluminium will be more dense than the Al and Mg alloy, because Mg has a smaller atomic mass than Al (12 vs 13) and the disruption in atom size will cause larger gaps and therefore less mass per cm^3. Even though Steel is the hardest substance, the alloy is still the best choice for this purpose. Hardness comes from the amount of force required to dent/bend a substance. While a a high relative hardness might be useful when using the kayak paddle, it also directly restricts teh malleability of the metal. The steel alloy is hard because of teh structure of different atoms. The variation is size makes it difficult for metal cations to move past each other, requiring a higher force to bend and deform th paddle but allows means it is incredibly difficult to turn steel into a hollow tube shape as it has very little malleability. Pure aluminium has a regular arrangement of atoms that makes it incredibly malleable and easy to form into a tube shape, but its high malleability also means it has very little hardness, and when force is applied onto the shovel by the pressure of the water, the force will easily deform the paddle shaft as teh atoms can easily slide past each other. The Aluminium Magnesium alloy sits in teh Goldilocks zone, it is hard enough to resist deformation when pressure is applied by the water, but not hard enough to restrcit malleability. The Aluminium and Magnesium alloy has the right ratio of metal cation mixture/disruption that means tha cations cannot easily slip past one another when a small force is applied such as by the pressure of the water, but can still move past each other and be shaped when a large force is applied, such as by industrial machines.
For these reasons, the alloy is the preferred material to use.

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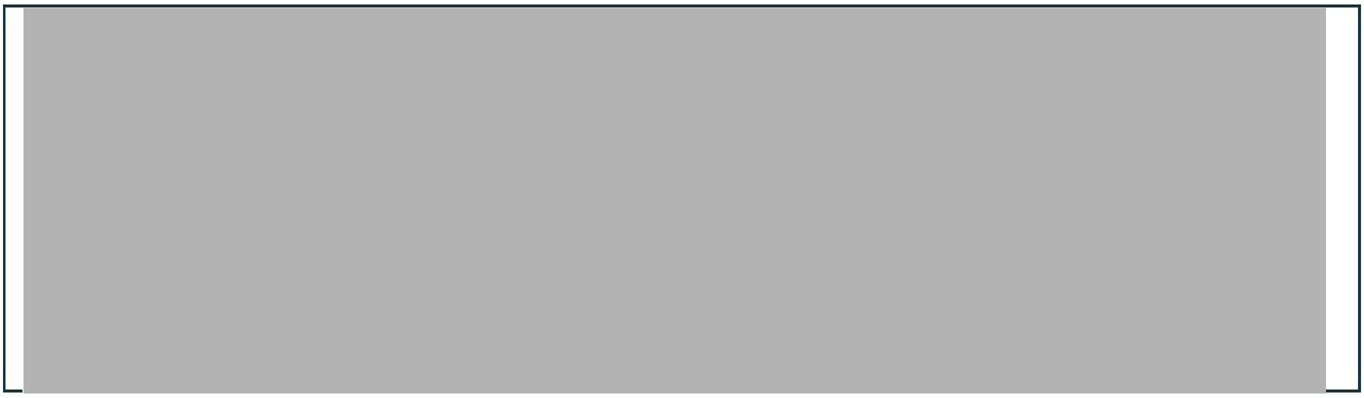
QUESTION THREE

Sea water is made up of water, H_2O, and salt, NaCl. Figure 5 shows the structure and bonding of the individual substances.

Figure 5: Structure and bonding of water, H_2O (left), and salt, NaCl (right)



(a) (i) Select the type of material water, H_2O, is.

( ) covalent network
( ) ionic material
( ) metallic solid
(●) molecular substance
( ) polymer

(ii) Select the type of material salt, NaCl, is.

( ) covalent network
(●) ionic material
( ) metallic solid
( ) molecular substance
( ) polymer

White solid salt, NaCl, is visibly left behind on the surface of the sea kayak. The salt is brittle, and it crumbles easily when touched.

(b) Explain how the arrangement of particles in salt, NaCl, and the attractive forces between these particles leads to this brittleness.

NaCl is an ionic substance made of of positively charge Na ions and negatively charge Cl ions. These ions form bonds as a result fo the strong electrostatic forces between oppositely charged particles and ford a 3D lattice where a positive ion is surrounded by negative ions and a negative ion is surorunded on four sides by positive ions. This result in an alternating pattern of positive and negative charges. When a force is applied that overcomes the electrostatic bonds between layers of alternatiing ions, and the entire row shifts, the positive charged particles align and the negatively charged particles align. Postive charges repel, and this casues the layers to move apart from each other and shatter, creating brittleness and Sodium Chloride's 'crumbly' nautre and crystal-like texture.

(c) Explain how the properties and attractive forces of water, H_2O, and salt, NaCl, allow for water to visibly remove the salt from the surface of the sea kayak.

B I U

Water is a molecular substance consisting of water molecules. 2H are covalently bonded to 1O atom and they share electrons to fill the valence shells of both atoms. However, oxygen is more electronegative than hydrogen, so electrons spend the majority of their time closer to the oxygen region of the water molecule. This electronegative creates teh 'V' shape of a water moelcule and also means water is a polar substance. Although a molecule has no charge overall, the oxygen region is negatively charged and the hydrogen region is positively charged. The different charges of the regions of a water moelcuel are attracted to the charges of the ions in sodium chloride. The water-ion attractions are stronger than the water-water and ion-ion attractions. The postive hydrogen regions of a water molecule are attracted to a Cl- ion and it is stripped from the lattice, unable to rejoin as it is completely hydrated by water molecules.Vice versa applies for a positve Na+ ion. The salt on the surface of the kayak will dissolve into the water as the molecules pull individual ions out of the lattice.

A plastic bottle floats on the sea water. The plastic bottle contains both air and fresh water. Table 2 shows the density of each of the materials.

Table 2: Density and arrangement of particles of materials				
	Types of material			
	Sea water	Fresh water	Plastic bottle	Air
Density	1.02–1.03 g / cm^3	~1 g / cm^3	0.94–0.965 g / cm^3	0.0012 g / cm^3
Arrangement of particles	Mixture containing both sodium chloride and water	Pure substance (water molecules)	Pure substance (long chain molecules)	Mixture (gaseous molecules and atoms)

(d) Using the information in Table 2 and your own knowledge of properties of materials, explain why the plastic bottle containing both air and fresh water floats on sea water.

B I U

When sodium chloride is dissolved into pure water, the mixture becomes more dense than pure water alone due to the presence of the solute. Water molecules surround the ions and completely hydrate them. Ordinarily, water molecules would maintain a certain distance from each other as their oppositely charge regions would repel if tehy accidently came too close. However, when attracted to the Na+ and Cl- ions, the water molecules are orientated in a way that allows them to come alot closer to each toher and be packed a lot tighter than pure water. The added mass of the ions and the tighter/more organised arragnement of the water molecuels means salt water is more dense than pure water alone.
For an object to float, it must be less dense than the susbtance it intends to float on. Sea water has a density of 1.02–1.03 g / cm^3 which is more dense than fresh water (~1 g / cm^3), a plastic bottle (0.94–0.965 g / cm^3), and air (0.0012 g / cm^3). A platic bottle filled with fresh water water and air will still float on salt water as the combined mass in the volume of the plastic bottle is less than the mass of the salt water with teh same volume.

Excellence

Subject: Chemistry and Biology

Standard: 92023

Total score: 23

Q	Grade score	Marker commentary
One	E8	The candidate was awarded E8 as they stated that there were strong covalent bonds between the monomers and weak forces of attraction between the chains. The candidate then linked the low density to the branched chains, which accounted for the kayak being light and able to float in water. In part (c), the candidate identified the covalent network, explained the structure, including the hexagonal rings and strong covalent bonding. This was then linked to the large force needed to break the bond making the kayak able to withstand weight.
Two	E8	The candidate was awarded E8 as they identified the metallic solid and explained the structure and non-directional bonding, linked to the ability of cations to move without breaking their bonds when force is applied. This was linked to the paddle shaft being able to be shaped. In part (c), the candidate justified the behaviour of the aluminium alloy when used as a paddle in comparison to pure aluminium and steel by explaining density and hardness of the alloy in terms of structure.
Three	E7	The candidate was awarded E7 as they compared the strength of attractive forces of $Na+$ and Cl^- ions in the solid and H_2O to ions in the solid, which were linked to the salt dissolving or being no longer visible.