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Mana Tohu Mātauranga o Aotearoa
New Zealand Qualifications Authority

Level 1 Chemistry and Biology RAS 2023

92023 Demonstrate understanding of how the properties of chemicals inform their use in a specific context

EXEMPLAR

Excellence

TOTAL 08

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Make sure you have the paper Resource Booklet 92023R.

TASK

Elements in a smartphone

A smartphone is an electronic device that contains a lot of circuitry (electrical components).

The smartphone shown contains the elements copper (Cu), gold (Au), and tin (Sn).

Outside a smartphone	Inside a smartphone
	

(a) Use your knowledge of the physical properties of chemicals to explain why ALL of the three elements are suitable for use as electrical components in a smartphone.

In your answer:

- Identify the ONE type of chemical structure from the list below that copper (Cu), gold (Au), and tin (Sn) all share.
- Identify TWO key physical properties from the list below needed for copper (Cu), gold (Au), and tin (Sn) to be used for electrical components.
- Discuss the structure of the elements and the two physical properties you have chosen, and link these to their use as an electrical component in a smartphone.

Type of chemical structure (choose ONE):

- ○ covalent network
- ○ ionic
- ● metallic
- ○ molecular

Key physical properties (choose TWO):

- ☐ boiling point
- ☐ density
- ☑ electrical conduction
- ☐ heat conduction
- ☑ malleability
- ☐ melting point
- ☐ solubility in water

Discussion:

Copper, gold, and tin are all metallic solids. They are made up of positive metal cations which are held in fixed positions in a 3D lattice, surrounded by a 'sea' of delocalised electrons. The metallic solids are held together by strong metallic bonding, which is the electrostatic attraction between the positive metal cations and the negative delocalised electrons. For a substance to be an electrical conductor, it must have free-moving charged particles. The electrons in the metallic solids, are able to move freely throughout the lattice while staying strongly bonded to the metal cations because the bonding is non-directional. Copper, gold and tin are all suitable for use as electrical components because they can conduct electricity because of their free-moving negatively charged electrons. This makes all three metallic solids ideal for use in the electrical components in a smartphone because they can carry a current throughout the phone to power it.

Copper, gold, and tin share the property of very good malleability. When force is applied a metallic solid, is can be reshaped without breaking. This is because when force is applied to the metallic solid, the metal cations in the 3D lattice slide over each other easily, and the solid remains intact because of the strong electrostatic attraction between the cations and the delocalised electrons. This strong metallic bond is non-directional, and the electrons are able to maintain the bond with the cations because they can move throughout the structure. This ability for cooper, gold and tin to be easily reshaped when force is applied and remain intact, is ideal for the electrical components in a smart phone because they are able to be easily shaped into small intricate parts that are inside the phone, such as wires.

(b) One of the electrical components in a smartphone is a **heat sink**. The heat sink draws heat away from the electrical components in the smartphone to prevent the phone overheating.

Table A: Properties of chemicals

Substance	Melting point °C	Electrical conductivity, σ (1 / ohms m)	Thermal (heat) conductivity, k (W / mK)
Copper	1084	5.96×10^7	413
Gold	1063	4.52×10^7	319

Note: 10^7 = 10 000 000

Use **Table A** to discuss which of the two elements above (copper or gold) would be the most suitable as a **heat sink**.

Most suitable element:

(●) copper ( ) gold

Discussion:

Gold is more suitable as a heat sink because it has a lower thermal conductivity than copper, which means that the positive metal cations are less densely packed in the gold lattice, so when heat is applied and the metal cations start to vibrate, it is harder to transfer the thermal energy to the surrounding cations. This property is makes gold a better choice for a heat sink because it is more of a heat insulator than copper and will stop heat being transferred around the phone by absorbing more of it. Gold has also got a high melting point. This is due to the strong metallic bonds between the positive metal cations and delocalised electrons. These metallic bonds take a lot of heat energy to break which is why gold needs such high temperatures to change from solid to liquid. Gold's high melting point means that it can withstand high temperatures as a heat sink while maintaining solid state.

(c) Solder is a combination of metals, mainly tin (Sn). Solder is used to join the electrical components of the smartphone together. Solder does this by **melting** then **cooling**, forming a **solid** join connecting the electrical components together.

Table B: Properties of chemicals

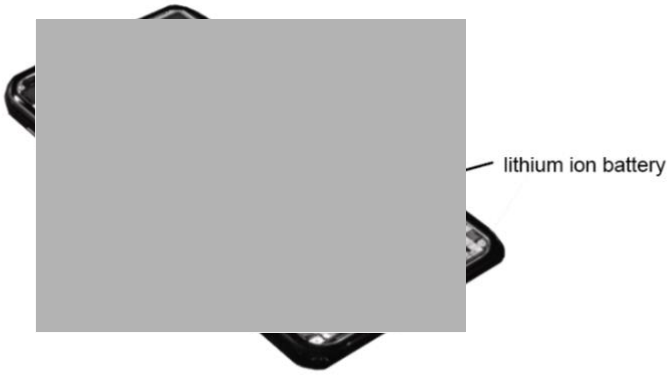
Substance	Melting point °C	Electrical conductivity, σ (1 / ohms m)
Copper	1084	5.96×10^7
Gold	1063	4.52×10^7
Tin	232	9.17×10^6

Note: 10^7 = 10 000 000 and 10^6 = 1 000 000

Use your analysis of the information in **Table B** to discuss why solder is mainly made of tin.

Solder is mainly made out of tin because of its lower melting point, and ability to conduct electricity as shown on Table B. Tin is a metallic solid so it is made up of positive metal cations and delocalised electrons in a 3D lattice. Tin's melting point is lower than the other metallic solids because its metallic bonds - the electrostatic attraction betwene the postive cations and negative electrons, don't take as much heat energy to break as the others. This low melting point is ideal for soldering because the solder must be able to melt easily to join the electrical components. Tin is used for soldering because as it is a metallic solid, it can conduct electricity. The free-moving delocalised electrons can carry a current throughout the lattice, which is ideal for soldering because it connects electrical components, so the current must be able to carry on through the solder.

The battery of a smartphone



Interior view of smartphone showing the lithium ion battery

For electricity to flow, substances need charged particles, either electrons or ions. The electrons or ions require two terminals (+ and –) for the battery to work.

(d) Both graphite and diamond are forms of carbon (allotropes).

Discuss why graphite is used as part of a smartphone battery (terminal) to conduct electricity rather than diamond.

In your answer refer to the:

- type of chemicals graphite and diamond are
- structure of the graphite and diamond
- relevant physical properties of graphite and diamond.

Graphite is a covalent network solid. Graphite has the structure of 2D lattice with layers of bonded carbon atoms held together by weak inter-molecular bonds. Each carbon atom is bonded to 3 others. These carbon atoms are held together by strong covalent bonds, which is the sharing of electrons between atoms. A carbon atom has four electrons in it's valence shell, so because each carbon atom is only bonded to three other carbon atoms, there is one delocalised electron for every carbon atom.
Diamond is also a covalent network solid. It is made up of carbon atoms which are bonded by strong covalent bonds. The structure of diamond is a tetrahedral arrangement, because the carbon in diamond is bonded to four other carbons instead of three. As mentioned before, carbon has four electrons in it's valence shell, and in diamond all four electrons are being shared with other carbons, leaving no delocalised electrons in the structure.
To conduct electricity, a substance must have free-moving charged particles. Graphite's delocalised electrons can move freely throughout the lattice, whereas in diamond, there are no free-moving charged particles as the electrons are all being shared between carbon atoms. This makes graphite more suitable to be used as a part of a smartphone battery because it can carry an electrical current to charge the battery compared to diamond which cannot.

In a smartphone's lithium ion battery, ions can be used to carry a charge (conduct) between the battery terminals.

A salt is a metal ion joined to a non-metal ion (e.g. sodium chloride).

(e) Use your knowledge of the physical properties of chemicals to discuss why a **lithium salt solution** is a more suitable source of lithium ions than a **solid** lithium salt.

In your answer include the:

- type of chemical that lithium salt is
- physical property that a solid salt must have to be able to dissolve into a liquid to form a solution.

Lithium salt is an ionic substance. It is made up of positive metal cations and negative non-metal anions, which are held in fixed positions in a 3D lattice when in a solid state. As a solid, the positive metal cations and negative non-metal anions are held together by strong ionic bonding which is the electrostatic attraction between the positive and negative charges of the ions. Lithium salt can be dissolved in a solution of water. Water is made up of polar molecules, meaning that a molecule of H2O has a slightly positive end and a slightly negative end. This is because the shared electrons between the hydrogen and oxygen atoms, spend slightly more time near the oxygen because of its higher electronegativity. When Lithium salt is added to water, the ions are ripped from the 3D lattice by the H2O molecules, because the positive end of the molecules attracts negative ions, and the negative end attracts the positive ions. The ions are now able to move freely throughout the solution because the attraction between the water molecules and the ions is stronger than the attraction between the negative and positive ions.
A lithium salt solution is a more suitable source of lithium ions than in a solid state, because in solution form they are free in move, thus can successfully carry a charge between battery terminals.

(f) Analyse the information provided in Table C.

Table C: Properties of aluminium alloys

Substance	Melting point °C	Density kg / m3	Malleability (GPa)
Alloy 1	635	2810	70
Alloy 2	649	2640	68

Note: A more malleable metal / alloy has a lower GPa value.

Use the information to discuss which alloy would be most appropriate as a battery cover for a smartphone.

In your answer:

- state what an alloy is
- compare the physical properties of the alloys and link these to their suitability as a battery cover in a smartphone.

Alloy 2 would be most appropriate as a battery cover for a smartphone because of its higher melting point, lower density, and more malleability. An alloy is the mixture of two of more elements, one of which is a metal. This makes Alloy 2 a metallic solid. Alloy 2 has a higher melting point because the strong metallic bonds between the positive metal cations and delocalised electrons take more heat energy to break than Alloy 1. This makes Alloy 2 more suitable to be a battery cover because if the battery heats up it is able to withstand higher temperatures than Alloy 1 without changing from solid form. Alloy 2 would also be the better choice for a battery cover because of it lower density. The more dense a substance is, the better it is at conducting heat. This is because when particles are closer together, and heat is applied, the vibrating particles are able to collide with more neighbouring particles and transfer the thermal energy much easier through the structure. Alloy 2 has a lower density than Alloy 2, which means it has worse heat conductivity. This makes Alloy 2 more suitable as a battery cover because if the battery heats up, Alloy 2 will insulate the heat better than Alloy 1, and will not transfer as much heat into the rest of the smartphone, which could cause damage. The third property that makes Alloy 2 more suitable than Alloy 1, is its better malleability. Alloy 2 is made up of positive metal cations and delocalised electrons. The strong metallic bonding means that when force is applied to the structure the cations can slide over each other and the alloy will not break because the strong electrostatic attraction between the electrons and cations is not broken. The metallic bonding in Alloy 2 is stronger than Alloy 1 because Alloy 2's malleability is better. This property of better malleability makes Alloy 2 a better choice as a battery cover because it can be shaped to better fit the battery in the smart phone.

Source:

Outside a smartphone: www.noelleeming.co.nz/p/samsung-galaxy-a54-5g---awesome-graphite/N218021.html

Inside a smartphone (adapted): www.counterpointresearch.com/odms-contributed-23-global-smartphones-shipped-cy2017/

Lithium ion battery (adapted): www.reliancedigital.in/solutionbox/better-understanding-of-batteries-li-ion-vs-li-po/

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Excellence

Subject: Chemistry and Biology

Standard: 92023

Total score: 08

Q	Marker commentary
(a)	Complete discussion of the two key physical properties required for a smartphone.
(b)	Copper selected but gold discussed as why it is a good heat sink. The purpose of a heat sink in a smartphone has been misunderstood.
(c)	The candidate explains why tin has a low melting point to join electrical components and tin can conduct electricity allowing electric to pass through the solder joins connecting components. A statement that the low melting point resulted in other electrical components not being damaged by heat was omitted.
(d)	Complete discussion of diamond and graphite linked to use.
(e)	Complete discussion of ionic solid and solution linked to use.
(f)	Complete discussion of three physical properties of alloy 2 linked to use. Only two physical properties required for excellence criteria.