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

Merit

TOTAL 06

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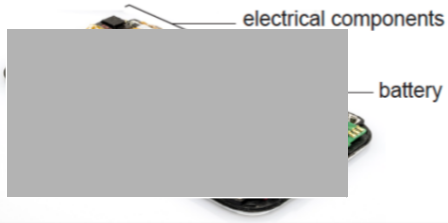
Make sure you have the paper Resource Booklet 92023R.

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 all have a metallic structure. This means that the atoms are all positive ions whose valence electron(s) are delocalised, meaning the electrons are free to move throughout the metal. Attraction between the metal ions and the sea of delocalised electrons is what keeps the metal together. Because of this, the metal ions can be moved without compromising the structure of the metal. In human terms, this means you can bend, squish and stretch the metal, which we call malleability. This is useful for electrical components for a number of reasons. First, it lets you pull the metal into wires, which are a core component of electronics as it lets you easily connect components while using as little space as possible. Second, you can press sheets of metal into very intricate shapes, therefore letting you make the components as small as possible. Smartphones are small, and so have a lot of space constraints, making metal greatly useful for their production. Another useful property of metals for use in electrical components is electrical conductivity. Electricity is the movement of charged particles, and metals contain a sea of delocalised electrons, which are charged particles. For this reason, metals are great conducters of electricity, making them fantastic for use in electrical components in smartphones..

(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:

Copper is more suitable as a heat sink than gold. Heat is conducted when vibrating particles bumb into other vibrating particles, transferring some of that energy to the other particles, making them vibrate. Heat is the vibration of particles. Copper has a heat conductivity of 413 k (W / mK), compared to gold's 319 (W / mK). This means copper conducts heat better than gold. The reason for this is that copper atoms vibrate more relative to the distances between atoms with less heat compared to gold, and so have a higher chance to bumb into each other, transferring heat easier. This makes copper more suitable as a heat sink than gold as it does a better job of taking heat away from components and transferring it somewhere to be dissipated to the environment. Copper and gold both have similar high melting points, meaning they won't melt under load and one isn't significantly more likely to melt under load. Electrical conductivity has nothing to do with usefulness as a heat sink.

(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

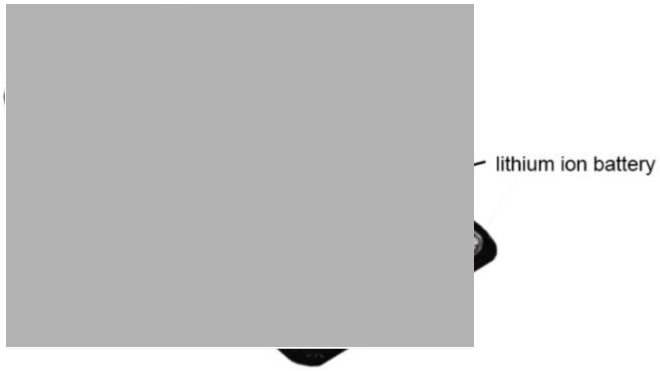
Substance	Melting point °C	Electrical conductivity, σ (1 / ohms m)
Copper	1084	5.96×10^7
Gold	1063	4.52×10^7
Tin	232	9.17×10^6

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 made to be easily meltable yet decently good at conducting electricity. The bonds holding metals together are between the positive metal ions and the negative sea of electrons surrounding them. Melting is when those bonds are weakened to allow the metal atoms to flow past each other with ease. While copper melts at 1084 degrees celcius, tin melts at only 232 degrees. This is because the bonds holding tin together are weaker than in copper, meaning those bonds are more easily weakened to the point of melting. This lets tin be melted with a simple soldering iron, and applied directly to other metals. Also, because tin has a lower melting point than copper or gold, the molten tin can be cold enough to not melt those other metals. Tin is around five times less conductive than copper and gold, which isn't great, but solder is less to bridge gaps, and more so to hold other metals to each other. However, its relatively high conductivity means that it can make up for any accidental gaps. Electricity is the movement of charged particles, and in metals, there is a sea of electrons which are free to move, letting electricity be conducted. In copper and gold, these electrons move with greater ease than in tin. However, tin still conducts reasonably well. All this lets tin be great for use in 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.

Both graphite and diamond are examples of covelent networks. This means that the carbon atoms which make up graphite and diamond are sharing electrons between them, causing a very strong bond. In diamond, every possible bond is made, meaning every atom and electron are locked in place. However, in graphite, some bonds aren't made and the atoms are quite aligned as they should. This means there are enough bonds to hold the material together as a solid, however, some electrons are delocalised like in a metal. As electricity is the movement of charged particles, and graphite has moveable charged particles, it can conduct electricity.

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 salts are ionic compounds, where one element has given one or more electrons to the other, causing complete valence shells and stability. An ionic compound is held together by the electrostatic forces between positive and negative ions. When solid, these ions are locked in place and can't move. Because electricity is the movement of charged particles, and solid lithium salts have no moveable ions, and so is not a suitable source of lithium ions. However, when a lithium salt is dissolved in solution, the ions are sticking the the particles in the liquid they're dissolved in and aren't attracted to the other ions. This means those ions can move freely as if liquid. Therefore, dissolved lithium salts are a great source of lithium ions, as those ions can be taken from the liquid.

(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.

An alloy is a compound containing at least one metal. An alloy would be more suitable for a smartphone battery cover if it were: more malleable, as that lets it be formed easier; less dense, as that makes the phone lighter. Alloy 1 is more dense than alloy 2. This means that either the atoms are closer together, or whatever was added to alluminium to form the alloys had more particles in each atom for alloy 1 than 2. This makes alloy 2 more suitable. Alloy 1 is less malleable than alloy 2. This means that the attraction between the metal ions and the sea of electrons is stronger in alloy 1, making it harder to move the ions past each other. This makes alloy 2 more suitable. Overall, alloy 2 is more suitable than alloy 1 as it was more malleable and less dense.

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/

Merit

Subject: Chemistry and Biology

Standard: 92023

Total score: 06

Q	Marker commentary
(a)	The response about the structure of metals and particles is well explained and is linked to the conductivity of metals. The response about the malleability of metals mentions "without compromise" but does not explain what this means in terms of, for example, electrons – positive nuclei / atoms / cations attractions being non-directional, allowing the atoms to roll over each other without breaking the electrostatic forces. Malleability and electrical conductivity are linked to use.
(b)	The candidate recognises copper as a better thermal (heat) conductor compared to gold and links the heat sink to smartphone use. Melting point is not linked to the heat energy that metals can absorb due to the large amount of energy required to break metallic bonds. The candidate states "electrical conductivity has nothing to do with usefulness as a heat sink". Heat sink is an electrical component, so a requirement is to conduct electricity. Copper is a better conductor of electricity than gold.
(c)	The candidate recognises that tin's electrical conductivity is low but is still able to conduct reasonably well. Candidate links use of joining other metals rather than components of the smartphone, and the low melting point of tin is related to not being able to melt gold and copper. The link to use in smartphones is missing (i.e. components in smartphones can be damaged by high heat).
(d)	The type of chemical is identified. The candidate discusses the structure of diamond ("atoms and electrons locked into place") but provides no link between the structure allowing (or not) electrical conduction. Graphite structure misses where the delocalised electrons come from for electrical conduction. No link to use, nor that graphite is a solid.
(e)	Statement for dissolved ions could be strengthened by deleting comment that "[dissolved ions] aren't attracted to other ions" as this is incorrect.
(f)	The definition of an alloy incomplete. Malleability and density of alloy 2 are identified as properties that are desirable as easier to form and are lighter. To gain excellence, both points need to be linked to use (e.g. lighter means easier to carry).