Question 1 (11 marks)

Portable heaters need fuel that is both lightweight and that burns without producing a lot of smoke. Butane and ethanol are both commonly used as fuels in portable heaters.

Question 1a (2 marks)

Draw the full structural formulas of butane and ethanol showing all of the bonds.

Question 1b (2 marks)

Identify the class of organic compound that butane and ethanol each belong to.

Butane

Ethanol

Question 1c (5 marks)

The energy released on combustion can be calculated using the equation:

$$q = mc\Delta T$$

where q = energy released, m is the mass of water heated and ΔT is the temperature change.

If the combustion of 1.00 g of ethanol releases 30.0 kJ of energy, **calculate** the mass of ethanol that is required to heat 400 g of water at 10.0°C to 98.0°C. The specific heat capacity of water is 4.19 $Jg^{-1}{}^{o}C^{-1}$. Give your answer to three significant figures.

B I U x_2 x^2 Ω Σ Styles

Question 1d (2 marks)

The molar mass of butane is 58 g mol^{-1} and the combustion of one mole of butane releases 2877 kJ. Use this information and the information from part (c) to **identify** whether ethanol or butane is the best choice of fuel. Use calculations to **justify** your answer.

B I | U x_2 x^2 | Ω Σ Styles

Question 2 (7 marks)

Metallic elements can be combined to form alloys that have different properties from the pure elements. The video below describes the properties needed for alloys used to build mountain bikes.

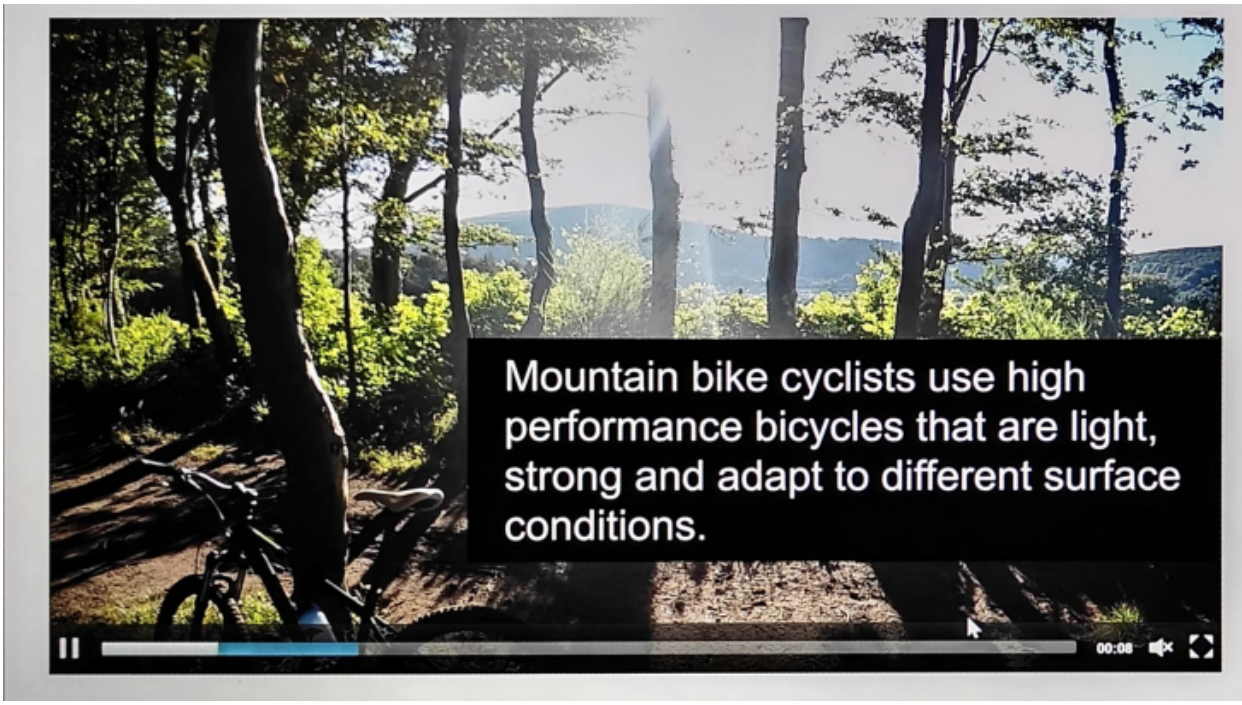
13 Al Aluminium	6 C Carbon	21 Sc Scandium
Atomic number: 13	**Atomic number:** 6	**Atomic number:** 21
Atomic mass: 27	**Atomic mass:** 12	**Atomic mass:** 45
Melting point: 660°C	**Melting point:** 3500°C	**Melting point:** 1539°C
Number of protons/electrons: 13	**Number of protons/electrons:** 6	**Number of protons/electrons:** 21
Number of neutrons: 14	**Number of neutrons:** 6	**Number of neutrons:** 24
Type of bonding: metallic	**Type of bonding:** covalent	**Type of bonding:** metallic
Density: (low) 2.70 g cm^{-3}	**Density:** (low) 2.62 g cm^{-3}	**Density:** (low) 2.99 g cm^{-3}
Characteristics: silvery-white, malleable, ductile, soft, corrosion resistant, good conductor	**Characteristics:** black, rigid, very high strength to weight ratio, high heat tolerance, does not react easily, poor conductor	**Characteristics:** silvery-white, hard, reacts in air and with water, burns easily, good conductor

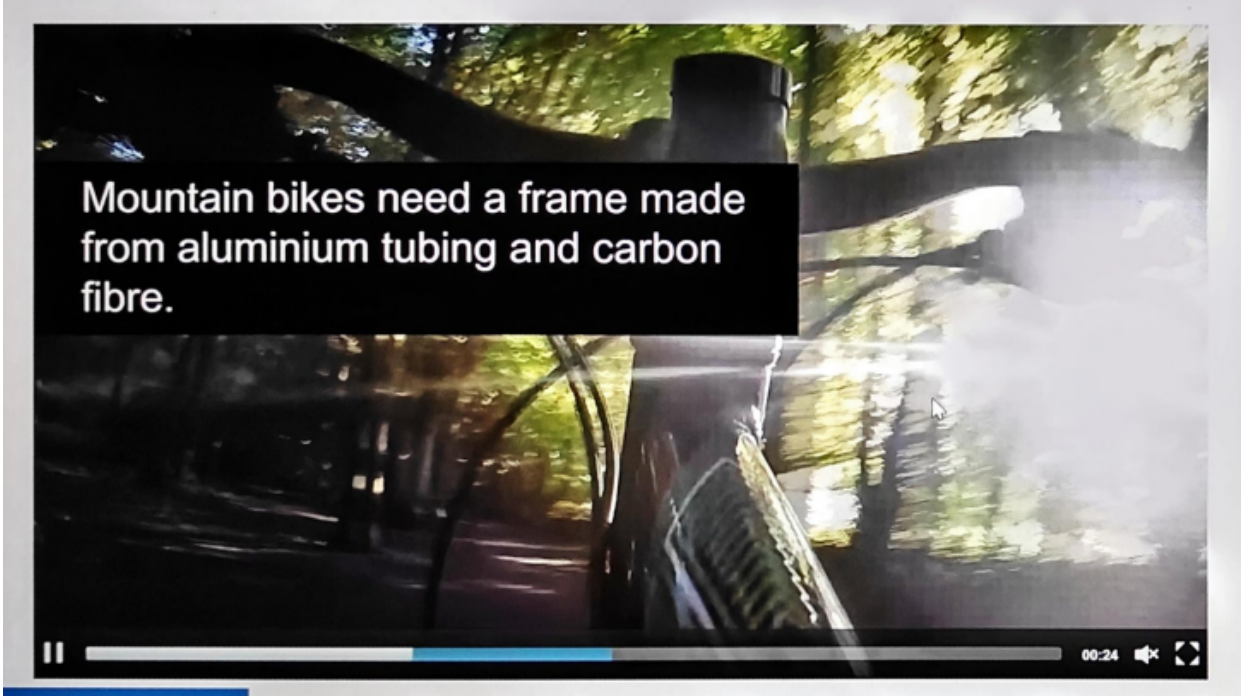
Question 2a (4 marks)

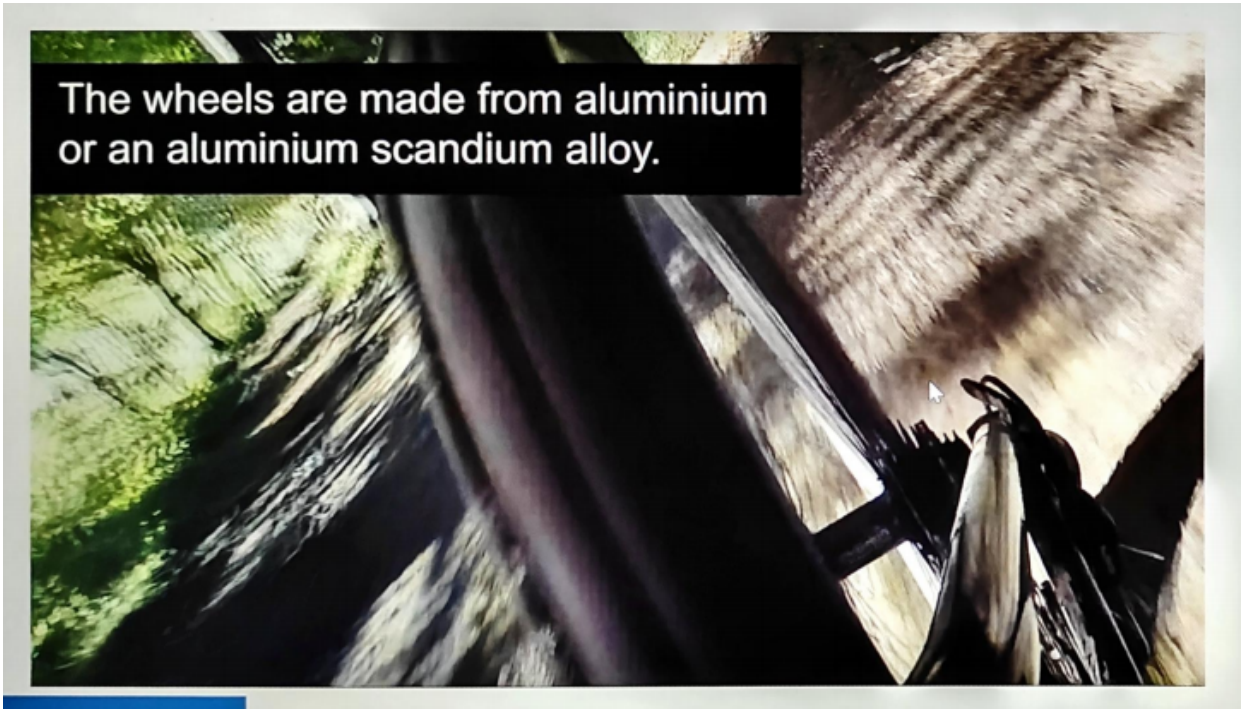
Interpret the data above and **state two** physical properties of both aluminium and carbon that make these elements suitable for building mountain bikes.

	Property 1	Property 2
Aluminium		
Carbon		

Reset




Mountain bikes need a frame made from aluminium tubing and carbon fibre.
00:24


The wheels are made from aluminium or an aluminium scandium alloy.

Question 2b (1 mark)

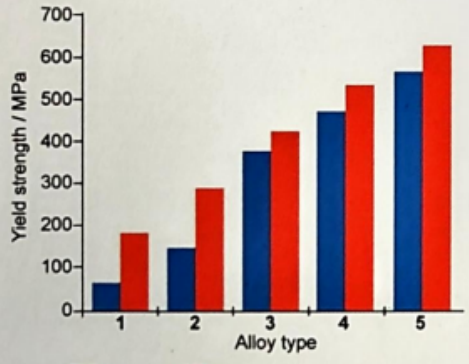
Scandium is added to many different alloys to increase yield strength. The yield strength is the pressure at which the material starts to deform or crack.

Use information about the elements to **suggest** why scandium would not be suitable to use on its own when building mountain bikes.

B I U x_2 x^2 Ω Σ Styles

Question 2c (2 marks)

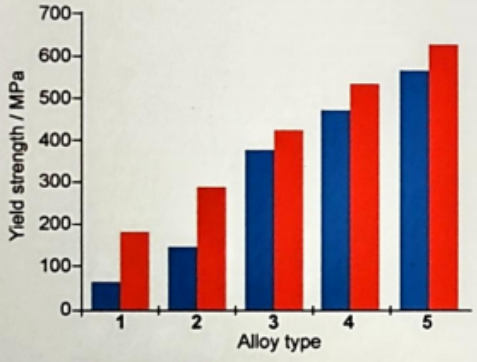
The graph shows the relationship between the yield strength and type of alloy, with and without scandium.



Use the graph to **state** the effect of scandium on the alloys shown.

B I U x_2 x^2 Ω Σ Styles

The graph shows the relationship between the yield strength and type of alloy, with and without scandium.



Key: No Sc Sc

1 Al–1% Mg
2 Al–6% Mg
3 Al–Zn–Mg
4 Al–Zn–Mg–Cu
5 Experimental alloys

Use the graph to **state** the effect of scandium on the alloys shown.

B I U x_2 x^2 Ω Σ

Styles

Question 3 (6 marks)

Fireworks contain different salts which emit a characteristic colour at very high temperatures. The colours are shown in the table.

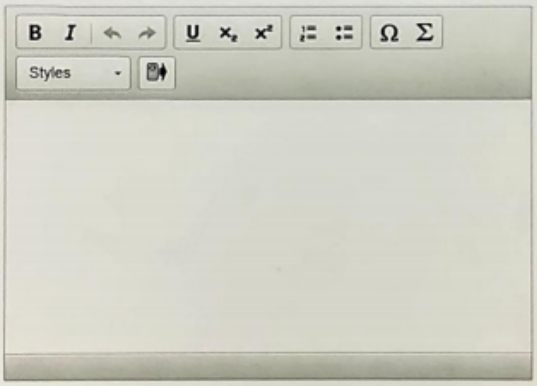
copper chloride	blue-green
calcium chloride	orange-red
iron chloride	red-brown
strontium chloride	bright red
barium chloride	green

Fireworks contain different salts which emit a characteristic colour at very high temperatures. The colours are shown in the table.

copper chloride	blue-green
calcium chloride	orange-red
iron chloride	red-brown
strontium chloride	bright red
barium chloride	green

Question 3a (1 mark)

State all the colours that would appear if only the compounds containing group 2 elements (alkaline earth elements) mentioned in the table on the left were selected for a firework.

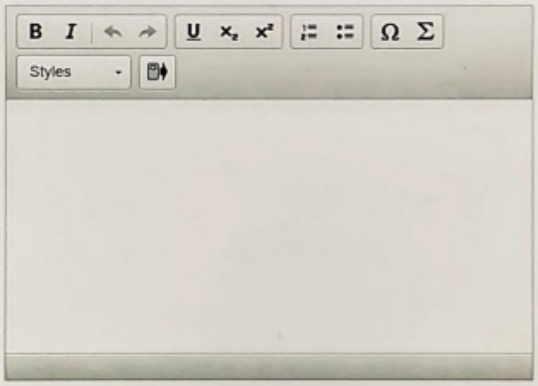


Fireworks contain different salts which emit a characteristic colour at very high temperatures. The colours are shown in the table.

copper chloride	blue-green
calcium chloride	orange-red
iron chloride	red-brown
strontium chloride	bright red
barium chloride	green

Question 3b (2 marks)

State if the reactions happening in fireworks are endothermic or exothermic. **Justify** your answer.



Fireworks contain different salts which emit a characteristic colour at very high temperatures. The colours are shown in the table.

copper chloride	blue-green
calcium chloride	orange-red
iron chloride	red-brown
strontium chloride	bright red
barium chloride	green

Question 3c (1 mark)

Identify one transition metal mentioned in the table on the left.

Question 3d (1 mark)

Magnesium metal can also be added to fireworks to produce white sparks. Magnesium has three stable isotopes with mass number of 24, 25 and 26.

State the meaning of the term *isotope*.

Question 3e (1 mark)

Calculate the number of neutrons contained in an atom of magnesium-24.

Question 4 (9 marks)

Question 4a (3 marks)

Party balloons can either be filled with helium gas or with air. Balloons filled with helium gas float more easily but deflate faster than balloons filled with air.

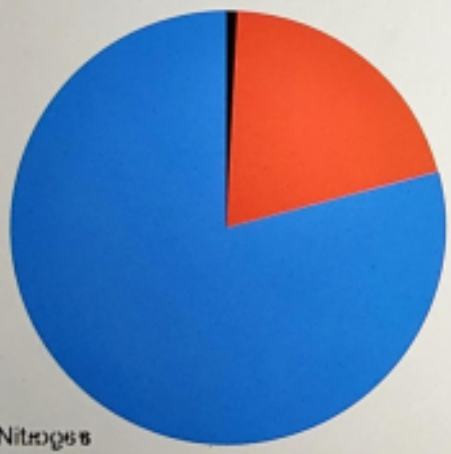
The diagram below shows the composition of air.

This media is interactive

Use the diagram and your knowledge of the characteristics of gases to **explain** why a balloon filled with helium gas will deflate faster than a balloon filled with air.

The diagram below shows the composition of air.

This media is interactive



Nitrogen

Oxygen

Other gases

Note: Other gases include carbon dioxide (0.03 %) and small proportions of other gases including argon and water vapour.

Use the diagram and your knowledge of the characteristics of gases to **explain** why a balloon filled with helium gas will deflate faster than a balloon filled with air.

B I U x_2 x^2 Ω Σ Styles

Question 4b (4 marks)

The hot air balloon was the first successful method of human flight. Hot air balloons are filled with air and have a basket hanging underneath with a gas burner attached to it. The pilot heats the air inside the balloon using the burner and the balloon rises in the sky.

Use kinetic theory to **explain** how warming the air inside a hot air balloon makes it rise in the sky.

B I U x_2 x^2 Ω Σ Styles

Question 4c (2 marks)

Imagine you are on a hot air balloon ride and you have an unopened bag of sweets. As your altitude increases, **predict** what changes will happen to the bag of sweets. **Justify** your answer.

Question 5 (23 marks)

Metals react with acids but they do not all react at the same rate. Some metals are more resistant to acids than others and react more slowly.

You need to design a case for a battery that contains acid. To help you to decide which metal to use for the battery case you will have to carry out an investigation using the following metals: iron, zinc, lead, copper, tin and chromium. You are also provided with standard glassware, other laboratory equipment and sulfuric acid.

This media contains no audio

Question 5a (18 marks)

Design a method to determine which metal is most resistant to acid leaking from the battery. In your answer you should include:

- the independent, dependent and control variables
- details of how you will manipulate the variables
- a list of the equipment you will need
- details of the data you will collect
- how you will use your data to decide which metal is most resistant to the acid
- how you will ensure your method is safe.

B I U x_2 x^2 Ω Σ Styles

Question 5b (5 marks)

Design a table suitable for recording **and** processing your data. You should select the number of rows and columns, add labels and list the metals you will investigate.

Create New Table

Reset

Question 6 (3 marks)

The first ever battery was invented by Alessandro Volta. The video contains information about how Volta's battery worked.

©

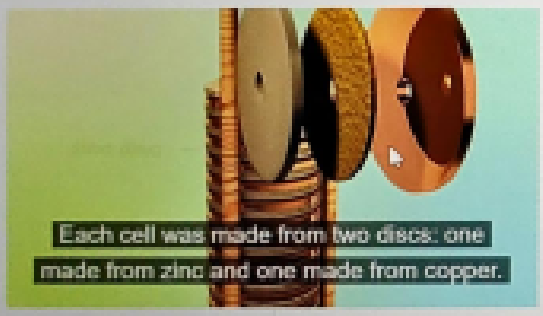
Question 6a (1 mark)

When the circuit is complete, charged particles move through the electrolyte soaked filter paper.

State the type of charged particles that move in the solution.

Question 6 (3 marks)

The first ever battery was invented by Alessandro Volta. The video contains information about how Volta's battery worked.



©

Question 6a (1 mark)

When the circuit is complete, charged particles move through the electrolyte soaked filter paper.

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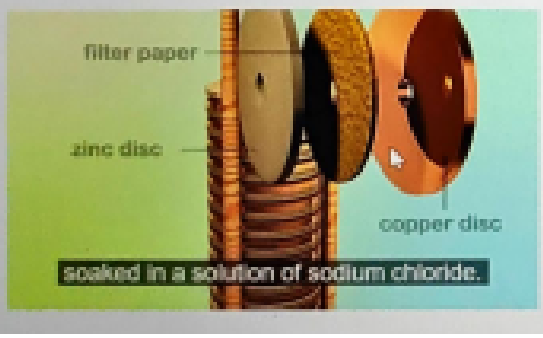


Question 6a (1 mark)

When the circuit is complete, charged particles move through the electrolyte soaked filter paper.

State the type of charged particles that move in the solution.

The first ever battery was invented by Alessandro Volta. The video contains information about how Volta's battery worked.

Question 6b (2 marks)

Describe what would happen to the cell if the filter paper was not soaked in electrolyte.

Question 7 (17 marks)

A group of students used a simulation to model the behaviour of electrochemical cells using different metals. They decided to use the simulation with different combinations of metals and 1 mol dm^{-3} solutions of their ions. The students recorded the voltage. Below is the table for the data they wanted to record:

Question 7a (1 mark)

This media is interactive

Click on an electrode on the right to reveal data.

Electrode on left: Magnesium

Electrode on right:
- Copper
- Lead
- Magnesium
- Silver
- Zinc

Using the simulation, build an electrochemical cell. **Measure** and record the cell voltage.

Electrode on the left	Electrode on the right	Voltage / V
Mg^{2+}/Mg	Zn^{2+}/Zn	
Mg^{2+}/Mg	Ag^{+}/Ag	
Mg^{2+}/Mg	Pb^{2+}/Pb	
Mg^{2+}/Mg	Cu^{2+}/Cu	

Question 7a (1 mark)

This media is interactive

Click on an electrode on the right to reveal data.

Electrode on left: Magnesium

2.707

Electrode on right:
- Copper
- Lead
- Magnesium
- Silver
- Zinc

Using the simulation, build an electrochemical cell. **Measure** and record the cell voltage.

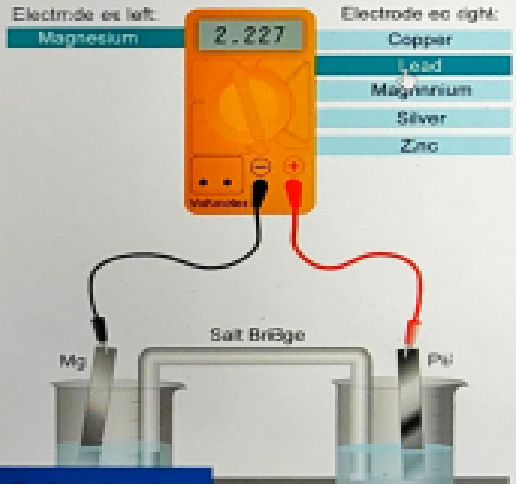
Electrode on the left	Electrode on the right	Voltage / V
Mg^{2+}/Mg	Zn^{2+}/Zn	
Mg^{2+}/Mg	Ag^{+}/Ag	
Mg^{2+}/Mg	Pb^{2+}/Pb	
Mg^{2+}/Mg	Cu^{2+}/Cu	
Mg^{2+}/Mg	Mg^{2+}/Mg	

Reset

Question 7a (1 mark)

This media is interactive

Click on an electrode on the right to reveal data.



Using the simulation, build an electrochemical cell. **Measure** and record the cell voltage.

Electrode on the left	Electrode on the right	Voltage / V
Mg^{2+}/Mg	Zn^{2+}/Zn	
Mg^{2+}/Mg	Ag^{+}/Ag	
Mg^{2+}/Mg	Pb^{2+}/Pb	
Mg^{2+}/Mg	Cu^{2+}/Cu	
Mg^{2+}/Mg	Mg^{2+}/Mg	

Reset

Question 7a (1 mark)

This media is interactive

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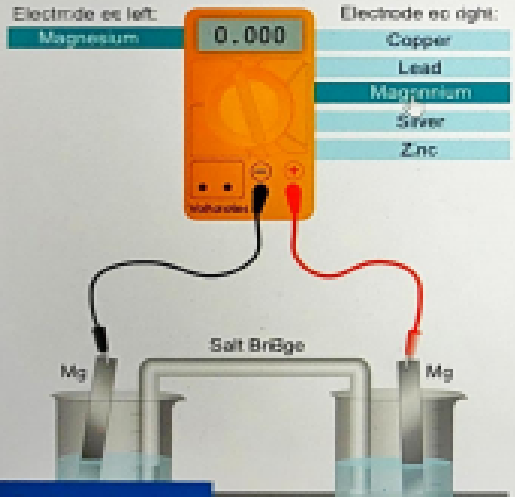


Using the simulation, build an electrochemical cell. **Measure** and record the cell voltage.

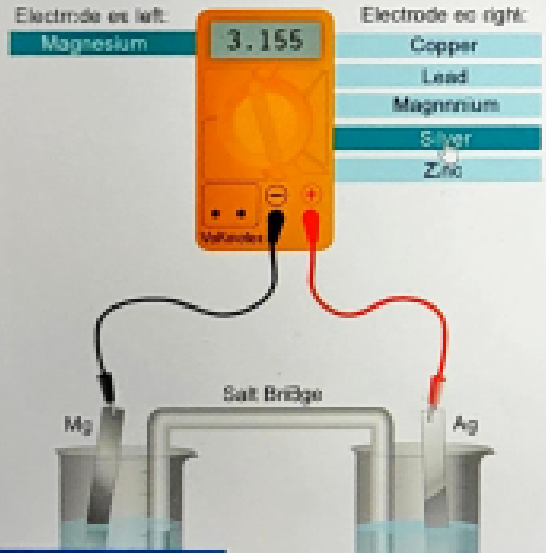
Electrode on the left	Electrode on the right	Voltage / V
Mg^{2+}/Mg	Zn^{2+}/Zn	
Mg^{2+}/Mg	Ag^{+}/Ag	
Mg^{2+}/Mg	Pb^{2+}/Pb	
Mg^{2+}/Mg	Cu^{2+}/Cu	
Mg^{2+}/Mg	Mg^{2+}/Mg	

Reset

Question 7a (1 mark)

This media is interactive

Click on an electrode on the right to reveal data.



Using the simulation, build an electrochemical cell. **Measure** and record the cell voltage.

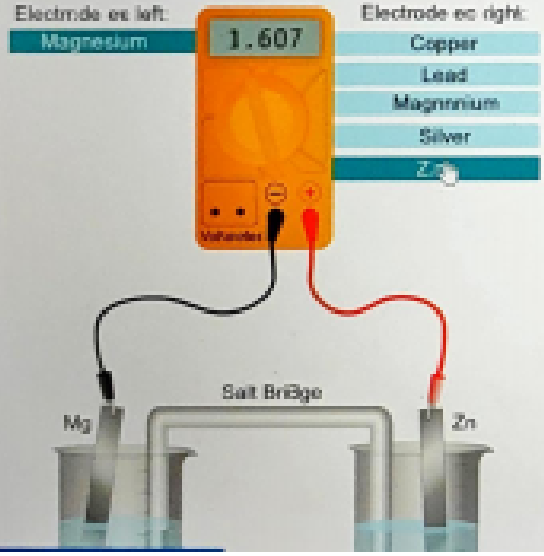
Electrode on the left	Electrode on the right	Voltage / V
Mg^{2+}/Mg	Zn^{2+}/Zn	
Mg^{2+}/Mg	Ag^{+}/Ag	
Mg^{2+}/Mg	Pb^{2+}/Pb	
Mg^{2+}/Mg	Cu^{2+}/Cu	
Mg^{2+}/Mg	Mg^{2+}/Mg	

Reset

Question 7a (1 mark)

This media is interactive

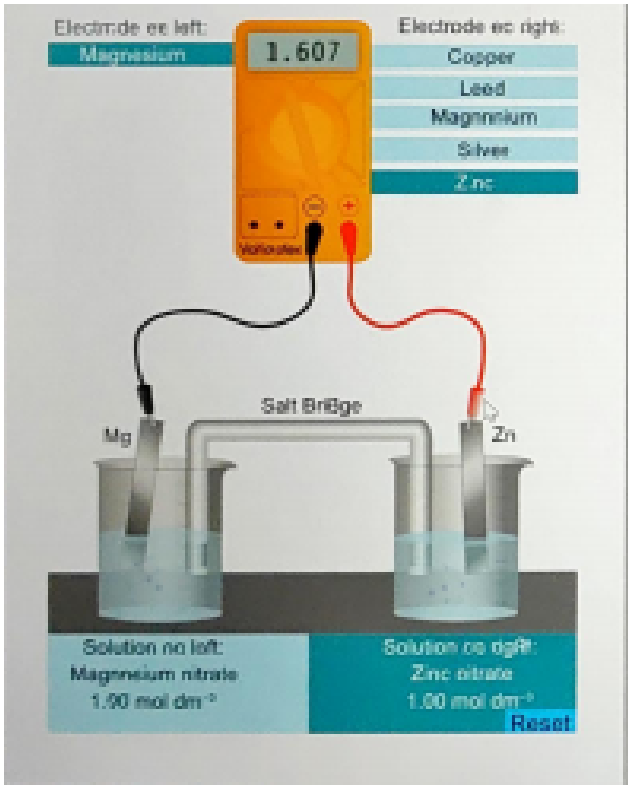
Click on an electrode on the right to reveal data.



Using the simulation, build an electrochemical cell. **Measure** and record the cell voltage.

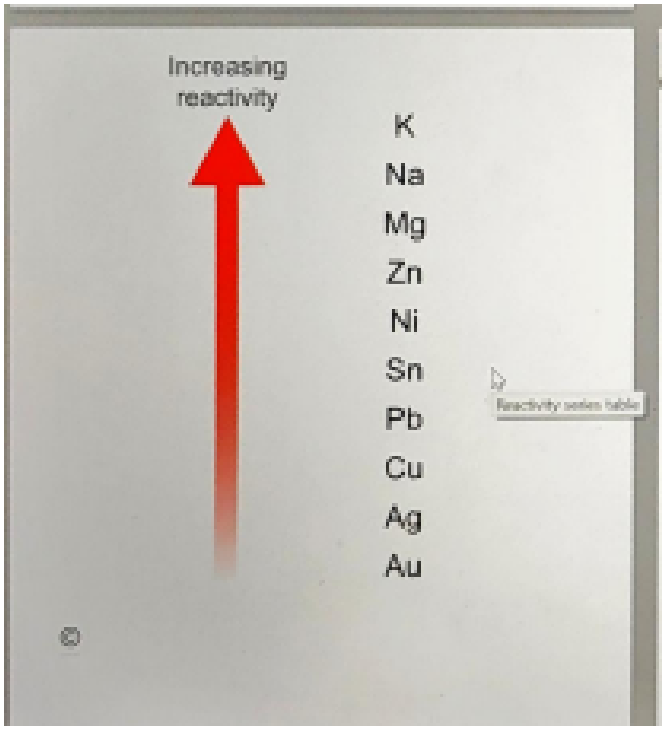
Electrode on the left	Electrode on the right	Voltage / V
Mg^{2+}/Mg	Zn^{2+}/Zn	
Mg^{2+}/Mg	Ag^{+}/Ag	
Mg^{2+}/Mg	Pb^{2+}/Pb	
Mg^{2+}/Mg	Cu^{2+}/Cu	
Mg^{2+}/Mg	Mg^{2+}/Mg	

Reset



Electrode on the left	Electrode on the right	Voltage / V
Mg^{2+}/Mg	Zn^{2+}/Zn	
Mg^{2+}/Mg	Ag^{+}/Ag	
Mg^{2+}/Mg	Pb^{2+}/Pb	
Mg^{2+}/Mg	Cu^{2+}/Cu	
Mg^{2+}/Mg	Mg^{2+}/Mg	

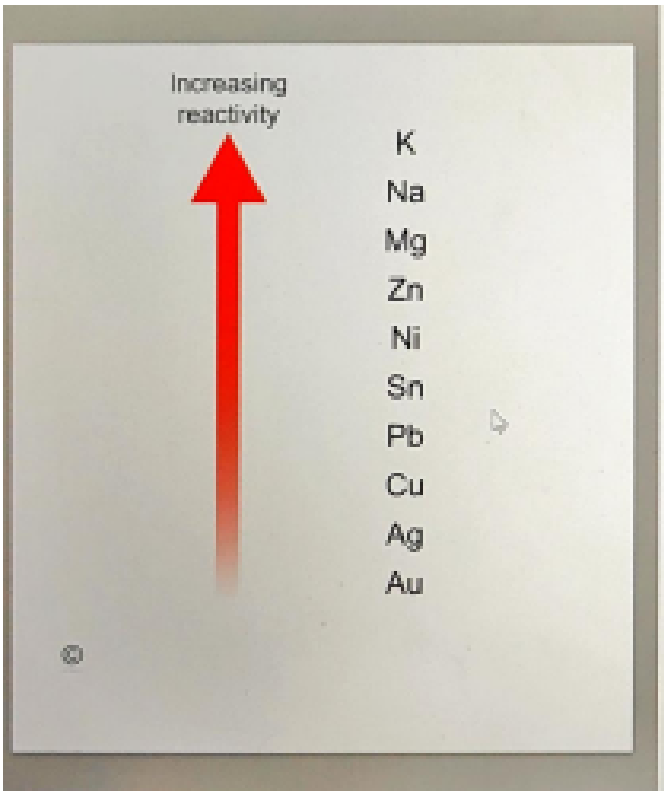
Reset



Question 7b (1 mark)

Using the reactivity series on the left, **state** a suitable hypothesis that could be tested using the data in the table in part (a).

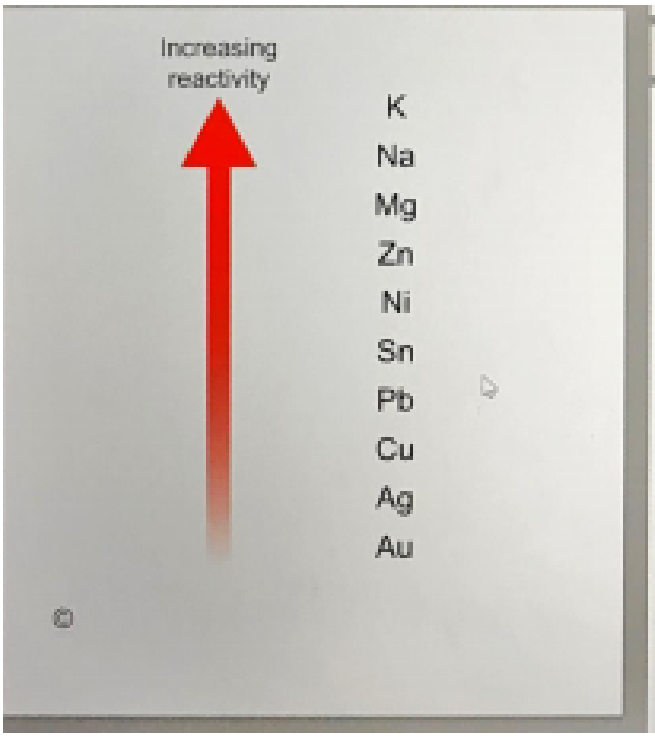
Styles



Identify the variables.

Independent variable

Dependent variable



Question 7d (4 marks)

None of the values recorded from the simulation agreed with published data values. Refer to the validity of the method to **discuss** possible reasons for the different values.

Question 7e (1 mark)

A group of students wanted to repeat this experiment in their own school laboratory. These students wanted to check the data given in the simulation so they needed to set up the same method.

Identify one safety precaution for this experiment.

Question 7f (2 marks)

Using ideas about redox reactions and transfer of electrons, **outline** the processes taking place at each electrode.

Anode

Cathode

Question 7g (4 marks)

A change in mass for both electrodes was observed. The change in mass was expected and was not an experimental error.

Predict the change of mass observed at each electrode. Use scientific reasoning to **justify** your answer.

	Change of mass observed	Justification
Anode		
Cathode		

Reset

Question 8 (9 marks)

Another group of students studied the effect of changing the concentration of the electrolyte on the cell voltage. The electrochemical cell was constructed using copper in aqueous copper sulphate and zinc in aqueous zinc sulphate.

The following data was recorded:

Concentration of Ag^+ in $AgNO_3$ solution / mol dm^{-3}	Concentration of Cu^{2+} in $Cu(NO_3)_2$ solution / mol dm^{-3}	Cell voltage /V
1.00	1.00	+0.448
1.00	0.50	+0.458
1.00	0.10	+0.477
1.00	0.05	+0.484
0.50	1.00	+0.436
0.10	1.00	+0.403
0.05	1.00	+0.387

Question 8a (1 mark)

State how the cell voltage changes as the copper ion solution becomes less concentrated.

Another group of students studied the effect of changing the concentration of the electrolyte on the cell voltage. The electrochemical cell was constructed using copper in aqueous copper sulphate and zinc in aqueous zinc sulphate.

The following data was recorded:

Concentration of Ag^+ in $AgNO_3$ solution / mol dm^{-3}	Concentration of Cu^{2+} in $Cu(NO_3)_2$ solution / mol dm^{-3}	Cell voltage /V
1.00	1.00	+0.448
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1.00	0.05	+0.484
0.50	1.00	+0.436
0.10	1.00	+0.403
0.05	1.00	+0.387

Question 8b (3 marks)

Predict how you would expect the colour of the copper solution to change as the solution becomes less concentrated.
Justify your answer.

B I U Ω Σ

Styles

Another group of students studied the effect of changing the concentration of the electrolyte on the cell voltage. The electrochemical cell was constructed using copper in aqueous copper sulphate and zinc in aqueous zinc sulphate.

The following data was recorded:

Concentration of Ag^+ in $AgNO_3$ solution / mol dm^{-3}	Concentration of Cu^{2+} in $Cu(NO_3)_2$ solution / mol dm^{-3}	Cell voltage /V
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1.00	0.10	+0.477
1.00	0.05	+0.484
0.50	1.00	+0.436
0.10	1.00	+0.403
0.05	1.00	+0.387

Question 8c (1 mark)

State how the cell voltage changes as the silver ion solution becomes less concentrated.

B I U Ω Σ

Styles

Question 8d (4 marks)

The equilibriums in each half-cell are shown below.

$$Ag^+(aq) + e^- \rightleftharpoons Ag(s)$$

$$Cu(s) \rightleftharpoons Cu^{2+}(aq) + 2e^-$$

Combine these two half equations to **formulate** the overall reaction when the half-cells are connected. Include state symbols in your answer.

Question 9 (6 marks)

Many portable computers are powered by lithium ion batteries. Lithium ion batteries are small, rechargeable and have a long life. To reduce the loss of charge when not in use, it is recommended that they are stored in a fridge.

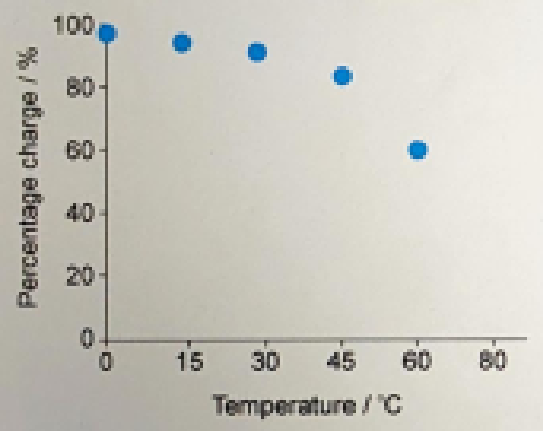
Question 9a (1 mark)

State a hypothesis to test the validity of the storage advice.

A lithium ion battery will maintain 98 % of its charge for an entire year at a temperature of 0°C, 96 % at 15°C, 94 % at 30°C, 82 % at 45°C and 75 % at 60°C.

Temperature / °C	Percentage charge / %
0	98
15	96
30	94
45	82
60	60

Scatter graph | Bar chart | Pie chart



Question 9b (1 mark)

Select a suitable graph to display the data of percentage charge against temperature.

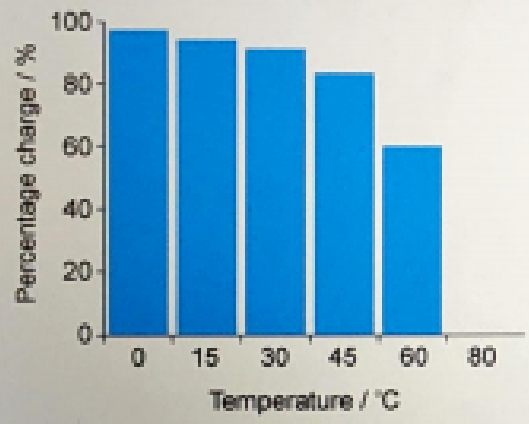
- Scatter graph
- Bar chart
- Pie chart

Question 9c (1 mark)

Use the graph to **estimate** the percentage of the charge maintained at a temperature of 50°C.

50°C

Scatter graph | Bar chart | Pie chart



Question 9b (1 mark)

Select a suitable graph to display the data of percentage charge against temperature.

- Scatter graph
- Bar chart
- Pie chart

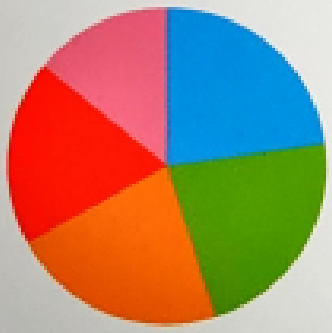
Question 9c (1 mark)

Use the graph to **estimate** the percentage of the charge maintained at a temperature of 50°C.

50°C

Scatter graph | Bar chart | Pie chart

Percentage charge / %



Key:

0°C 15°C 30°C 45°C 60°C

Question 9b (1 mark)

Select a suitable graph to display the data of percentage charge against temperature.

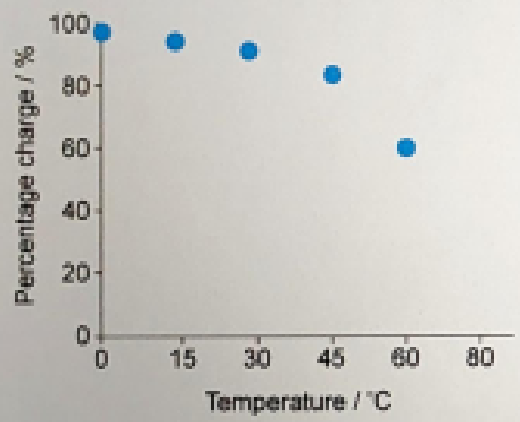
- Scatter graph
- Bar chart
- Pie chart

Question 9c (1 mark)

Use the graph to **estimate** the percentage of the charge maintained at a temperature of 50°C.

50°C

Scatter graph | Bar chart | Pie chart



Question 9c (1 mark)

Use the graph to **estimate** the percentage of the charge maintained at a temperature of 50°C.

50°C

Question 9d (1 mark)

Use the graph to **estimate** the percentage of the charge maintained at a temperature of 80°C.

80°C

Scatter graph | Bar chart | Pie chart

Percentage charge / %
100
80
60
40
20
0
0
15
30
45
60
80
Temperature / °C

Question 9d (1 mark)

Use the graph to **estimate** the percentage of the charge maintained at a temperature of 80°C.

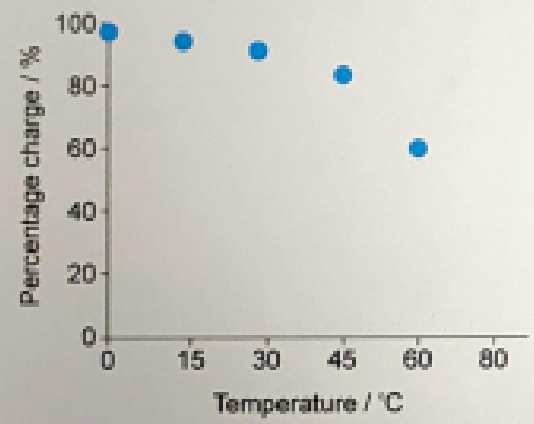
80°C

Question 9e (2 marks)

Compare the validity of the estimations in your answers to parts (c) and (d).

B I Ω Σ

Scatter graph Bar chart Pie chart



Question 9e (2 marks)

Compare the validity of the estimations in your answers to parts (c) and (d).

Styles

Question 10 (8 marks)

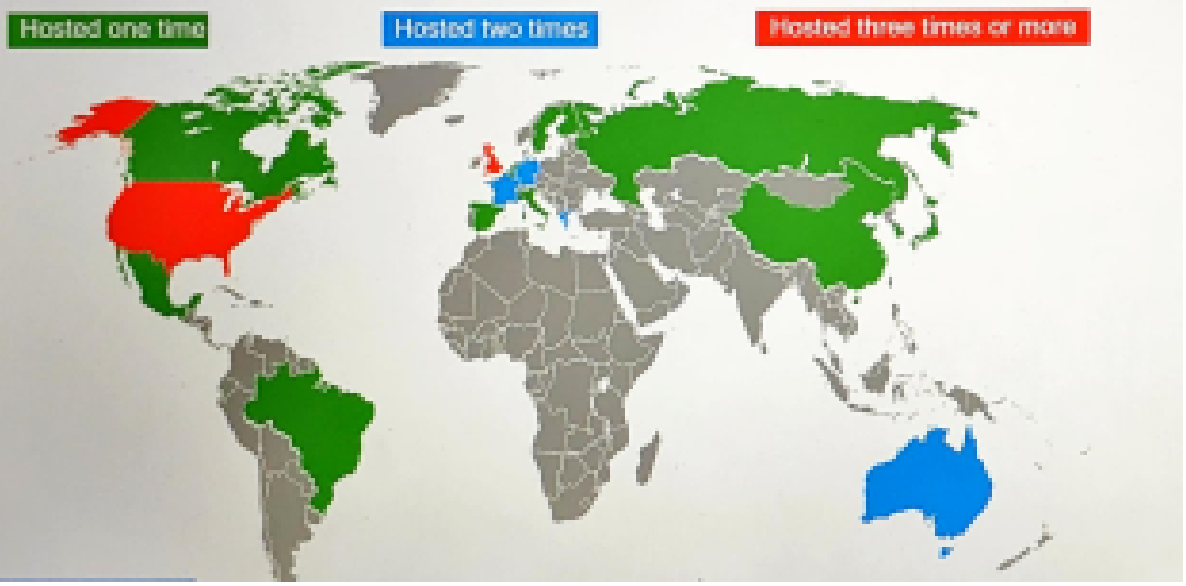
The 2016 summer Olympic Games held in Brazil were popularly called the Rio Olympics. The Rio Olympics were considered an important event in the history of the Olympic Games as it was the first time the Games were held in a country in South America.

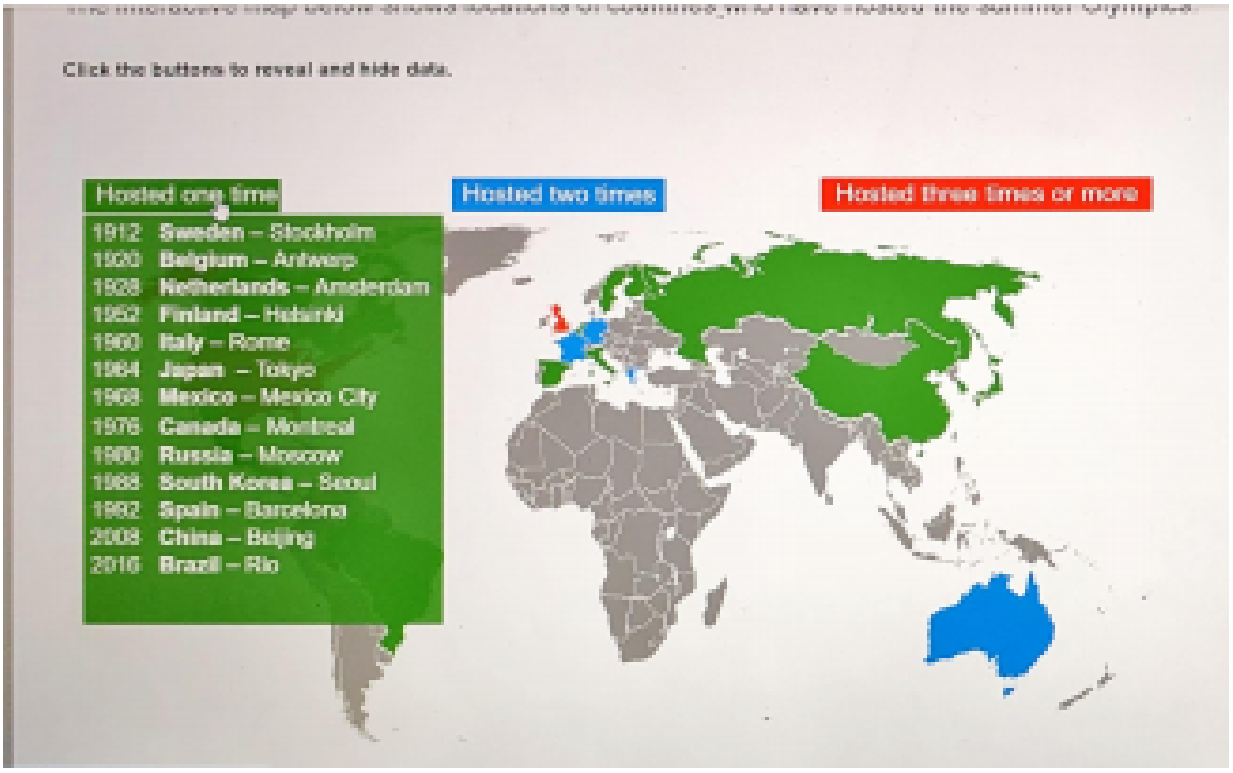
Rio2016

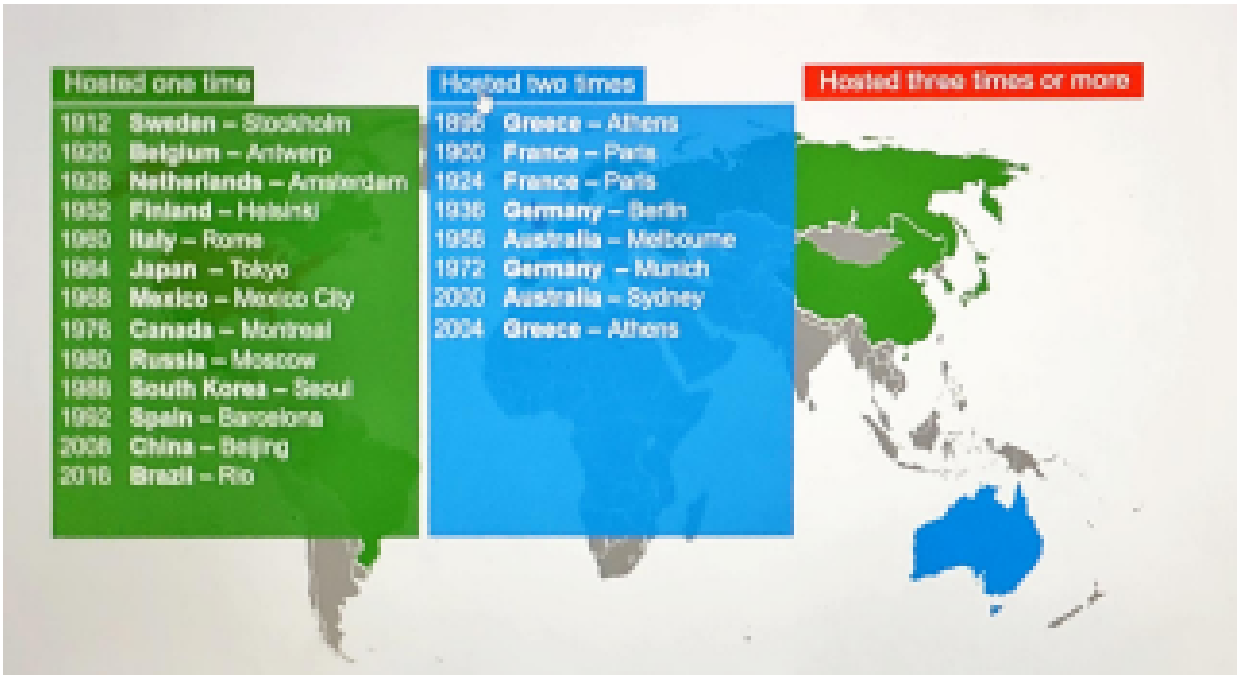
There is one host country selected for every Olympic Games. The host country is given money to make arrangements for the Games. This gives an economic benefit to the host country and provides employment for many people.

The interactive map below shows locations of countries who have hosted the summer Olympics.

Click the buttons to reveal and hide data.




Click the buttons to reveal and hide data.
Hosted one time
1912 Sweden – Stockholm
1920 Belgium – Antwerp
1928 Netherlands – Amsterdam
1952 Finland – Helsinki
1960 Italy – Rome
1964 Japan – Tokyo
1968 Mexico – Mexico City
1976 Canada – Montreal
1980 Russia – Moscow
1988 South Korea – Seoul
1992 Spain – Barcelona
2008 China – Beijing
2016 Brazil – Rio
Hosted two times
Hosted three times or more


Hosted one time
1912 Sweden – Stockholm
1920 Belgium – Antwerp
1928 Netherlands – Amsterdam
1952 Finland – Helsinki
1960 Italy – Rome
1964 Japan – Tokyo
1968 Mexico – Mexico City
1976 Canada – Montreal
1980 Russia – Moscow
1988 South Korea – Seoul
1992 Spain – Barcelona
2008 China – Beijing
2016 Brazil – Rio
Hosted two times
1896 Greece – Athens
1900 France – Paris
1924 France – Paris
1936 Germany – Berlin
1956 Australia – Melbourne
1972 Germany – Munich
2000 Australia – Sydney
2004 Greece – Athens
Hosted three times or more


Hosted one time
1912 Sweden – Stockholm
1920 Belgium – Antwerp
1928 Netherlands – Amsterdam
1952 Finland – Helsinki
1960 Italy – Rome
1964 Japan – Tokyo
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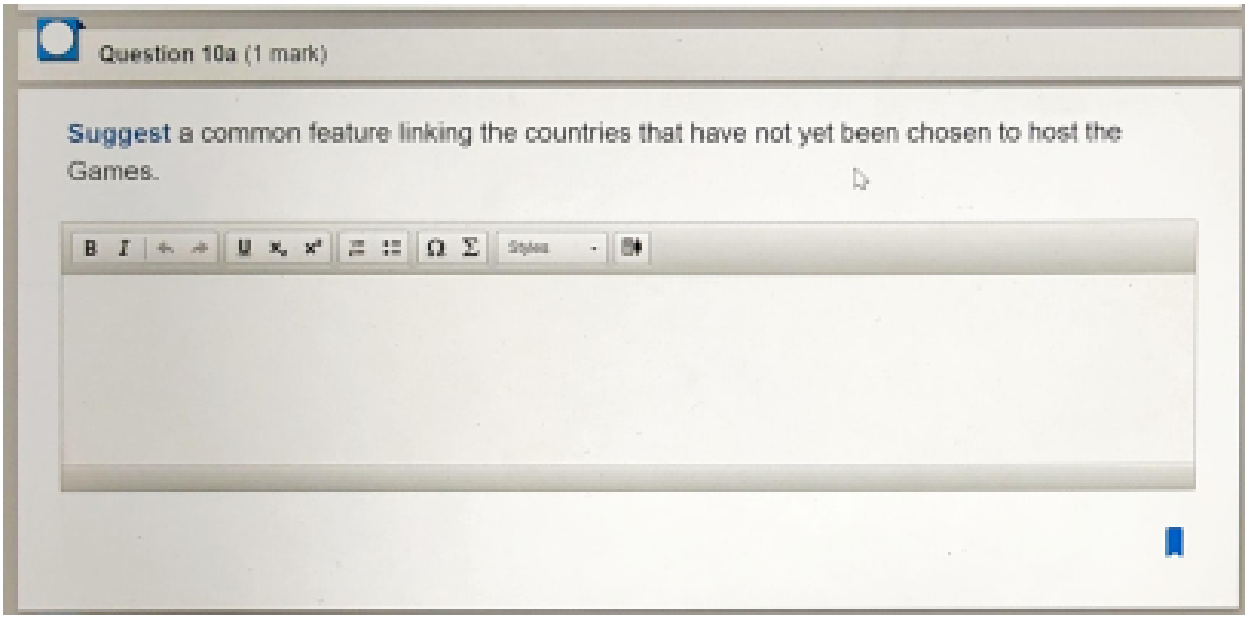
1988 South Korea – Seoul
1992 Spain – Barcelona
2008 China – Beijing
2016 Brazil – Rio
Hosted two times
1896 Greece – Athens
1900 France – Paris
1924 France – Paris
1936 Germany – Berlin
1956 Australia – Melbourne
1972 Germany – Munich
2000 Australia – Sydney
2004 Greece – Athens
Hosted three times or more
1904 USA – St Louis
1908 UK – London
1932 USA – Los Angeles
1948 UK – London
1984 USA – Los Angeles
1996 USA – Atlanta
2012 UK – London


Question 10a (1 mark)
Suggest a common feature linking the countries that have not yet been chosen to host the Games.

Question 10b (3 marks)

The host country builds the infrastructure for the Games, for example stadiums, swimming pools and running tracks, accommodation and transportation systems.

The development of these new systems is not only very expensive but also requires a large amount of building materials such as concrete and other materials to build roads, iron and steel for buildings, railway tracks and stadiums. The iron used in the construction is extracted from iron ore which is an important resource.

Iron ore is often extracted from open-pit mines. Iron ore is mainly iron oxide (Fe_2O_3). When an open-pit mine is in an area of heavy rainfall, the rain water washes away large amounts of iron oxide that end up in nearby lakes and rivers. Iron oxide (Fe_2O_3) reacts with water to form iron hydroxide and turns the colour of the water reddish-brown.

$$Fe_2O_3(s) + 3H_2O(l) \rightarrow 2Fe(OH)_3(aq)$$

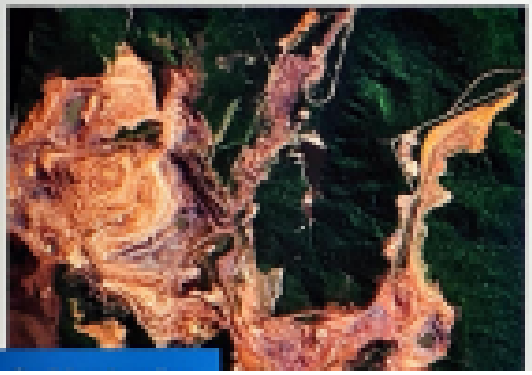
State the effect of the iron oxide on the hydrogen ion concentration of lakes and rivers around open-pit mines. **Justify** your answer by using scientific knowledge and understanding.

Question 10c (4 marks)

Discuss how the changes in the water in the lakes and rivers in part (b) could have consequences on the living organisms in the water.

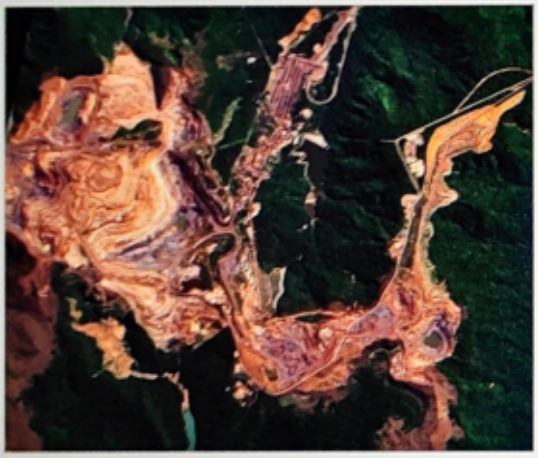
Question 11 (17 marks)

The image shows Carajás, an open-pit mine which is in a remote location of the Amazon rainforest in Brazil. Terraced layers of red earth reveal how minerals are removed from the surface, one layer at a time. The red-tan exposed earth contrasts with the deep green rainforest which is still untouched.



Open-pit mining operations are accompanied by heavy bulldozers to break the rocky soil and trucks in the area that carry away the mined ore. The mining operations produce a lot of dust which causes pollution.

In 2007, 296 million metric tons of iron ore were mined. The mine is estimated to contain about 18 billion tons of iron ore, plus gold, manganese, copper and nickel.



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Referring to the satellite image shown above and the information provided in this task, **discuss** and **evaluate** the positive and negative consequences of iron ore mining. In your answer you should consider:

- the impacts on the environment
- the economic impacts on the local community
- the wider impacts of industrial processes at the mine
- two suggestions of how future scientists could reduce the impact of mining processes
- a concluding appraisal of all of the issues you have discussed.

Question 12 (4 marks)

Reduce, *reuse* and *recycle* are the three Rs of sustainability. For decades, the steel industry has been reducing the need for raw materials and encouraging reuse of existing products. Steel is the world's most recycled material.

The graphs below show information about how steelmaking has become more sustainable over recent years.

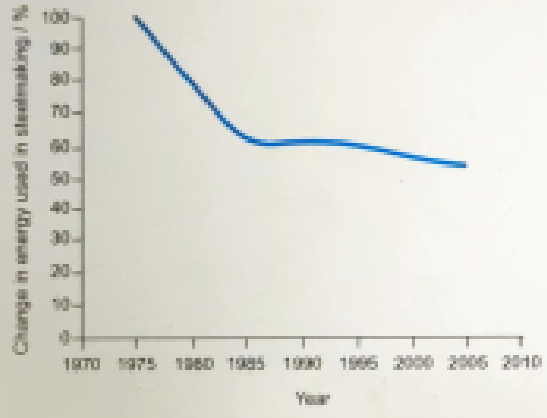
This media is interactive

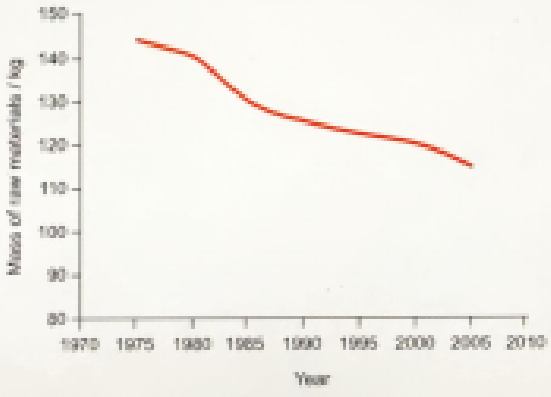
Percentage change in energy used in steelmaking in North America, Japan and Europe compared to 1975

Mass of raw materials needed to produce 100 kg of steel in North America, Japan and Europe 1975–2005

Percentage change in energy used in steelmaking in North America, Japan and Europe compared to 1975

Mass of raw materials needed to produce 100 kg of steel in North America, Japan and Europe 1975–2005





Using information from this task, **outline** how greater use of the three Rs of sustainability could reduce the use of natural resources and could benefit the wider global community.