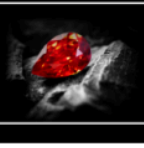
Question 1 (6 marks)

Historically, materials such as jade, ruby and pearls have been used to decorate jewellery. Different materials have different colours which are based on their chemical composition.

Material	Colour	Formula
 Pearl	White	$CaCO_3$
 Jade	Green	$NaAlSi_2O_6$
 Ruby	Red	Al_2O_3

Question 1a (2 marks)

One element is present in all three of these materials. **Identify** the group and period of this element.

Group: Period:

Question 1b (3 marks)

The image below shows an object made of jade that was found at an archaeological site. It has a mass of 75 g.

Calculate the number of moles of jade in the object assuming the chemical formula of jade is $NaAlSi_2O_6$. Give your answer to 2 significant figures.

Question 1c (1 mark)

The main compounds in both ruby and jade are listed in the table above, but they get their colour from the chromium present as an impurity.

Select the section of the periodic table in which chromium is found.

Select

Question 2 (7 marks)

Thermochromism is a process where objects change colour at different temperatures. Some examples are shown below.

Question 2a (1 mark)

T-shirt after being touched by a hand for a few minutes and then removed.

Select the type of change that takes place when a hand is placed on the T-shirt.

Select

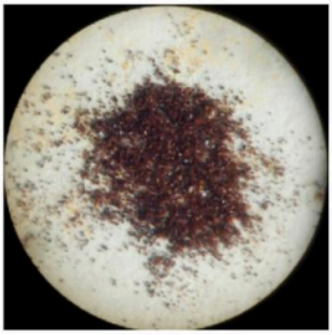
Question 2b (1 mark)

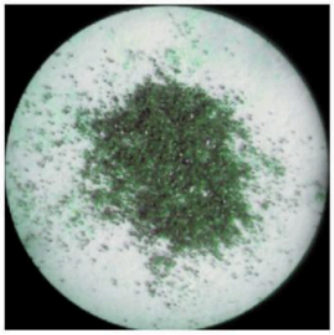
When the hand is removed, after a short period of time, the T-shirt changes back to its original colour. **State** the scientific term for this type of reaction.

B I U x_2 x^2 Styles

Question 2c (1 mark)

One of the chemicals that can be used for thermochromic changes is copper (I) iodide. This is a brown-coloured material which changes to green when the temperature is above 60 °C.





©

State the formula for copper (I) iodide.

Question 2d (3 marks)

Use the information in part (b) to **suggest** the colour of a **cup** painted with copper (I) iodide in the following conditions.

Room temperature	
Containing hot coffee	
Refrigerator	

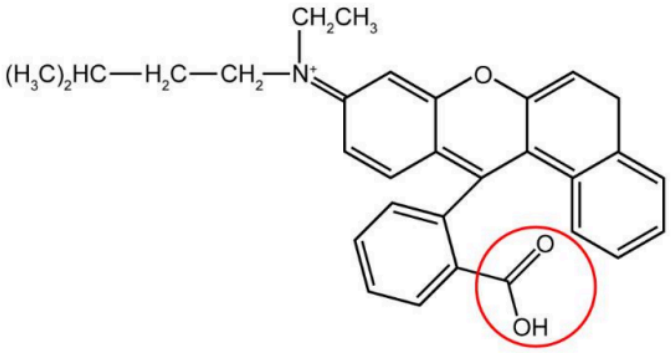
Reset

Question 2e (1 mark)

Organic compounds can also be used for their thermochromic properties. An example of a thermochromic compound is shown below.

Question 2e (1 mark)

Organic compounds can also be used for their thermochromic properties. An example of a thermochromic compound is shown below.



Select the name of the circled organic group.

Select

Question 3 (15 marks)

Advertisements for various goods and services can be found throughout history. Signs have evolved over time, especially in the type of materials used to make them. Due to technological advancement, materials used for signs have evolved over the years from papyrus to wood, metal and even neon. Today, metal coated with paint or plastic is a popular choice.

Question 3a (1 mark)

Suggest why the material used to make signs has changed over time.

Question 3b (1 mark)

Previously, many signs were made using painted iron. Over time, signs became damaged and the iron started to corrode.

The chemical reaction that takes place during corrosion produces iron (III) oxide. **State** the chemical formula for iron (III) oxide.

Question 3c (2 marks)

The word equation for this reaction is:

iron + oxygen → iron (III) oxide

This is a redox reaction. **State** which element has been oxidized and which element has been reduced in this reaction.

Oxidized:

Reduced:

Question 3d (3 marks)

Signs have been made using tubes filled with noble gases. The first noble gas to be used in these tubes was neon, which is why we refer to them as neon lights. These gases produce distinctive colours when electricity is passed through the tubes. The colour of the light produced depends on the gas in the tube, for example, krypton produces a green-yellow colour.

There are several isotopes of krypton that are stable and can be used in light tubes. The most common isotopes of krypton are $^{82}_{36}Kr$ and $^{84}_{36}Kr$. Using the periodic table, **determine** the missing values to complete the following table.

There are several isotopes of krypton that are stable and can be used in light tubes. The most common isotopes of krypton are $^{82}_{36}Kr$ and $^{84}_{36}Kr$. Using the periodic table, **determine** the missing values to complete the following table.

Isotope	$^{82}_{36}Kr$	$^{84}_{36}Kr$
Electrons		
Protons	36	36
Neutrons		

Question 3e (1 mark)

When electricity is passed through certain gases, fires or explosions may occur. **Suggest**, with reference to their electronic structure, why this is not the case with noble gases.

Question 3f (1 mark)

In certain parts of the world, green lights are sometimes visible in the night sky. These lights are caused by oxygen gaining energy from solar flares.

Oxygen is found in group 6 of the periodic table. **State** the electronic configuration of oxygen.

Question 3g (2 marks)

Outline the bonding that is found in oxygen molecules.

B I x_2 x^2 Styles

Question 3h (2 marks)

The following diagrams show the structure of the layers and the composition of the Earth's atmosphere.

Diagram A | Diagram B

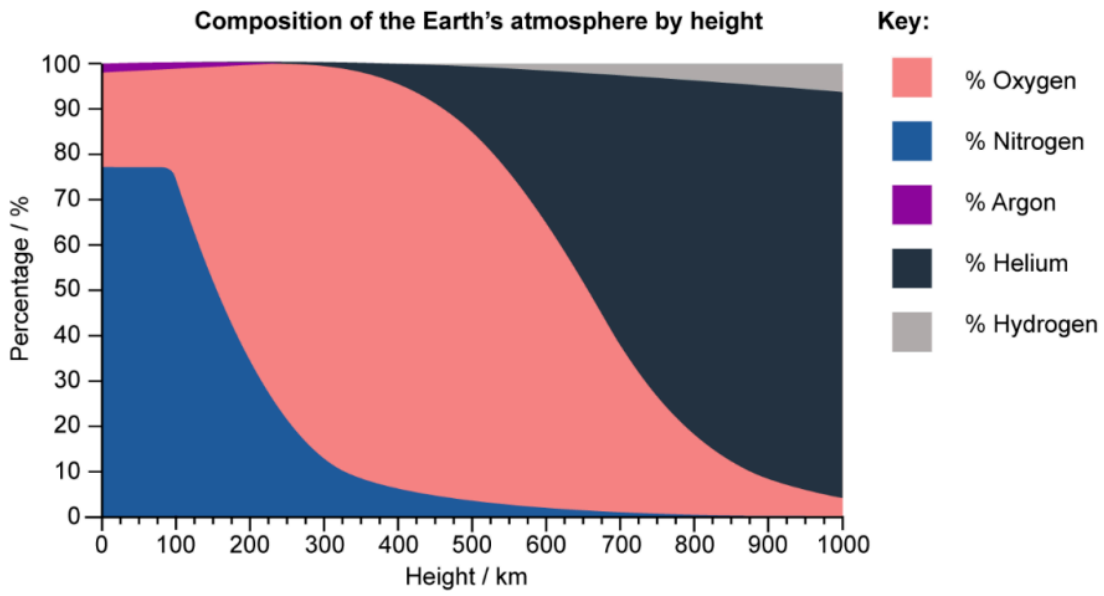
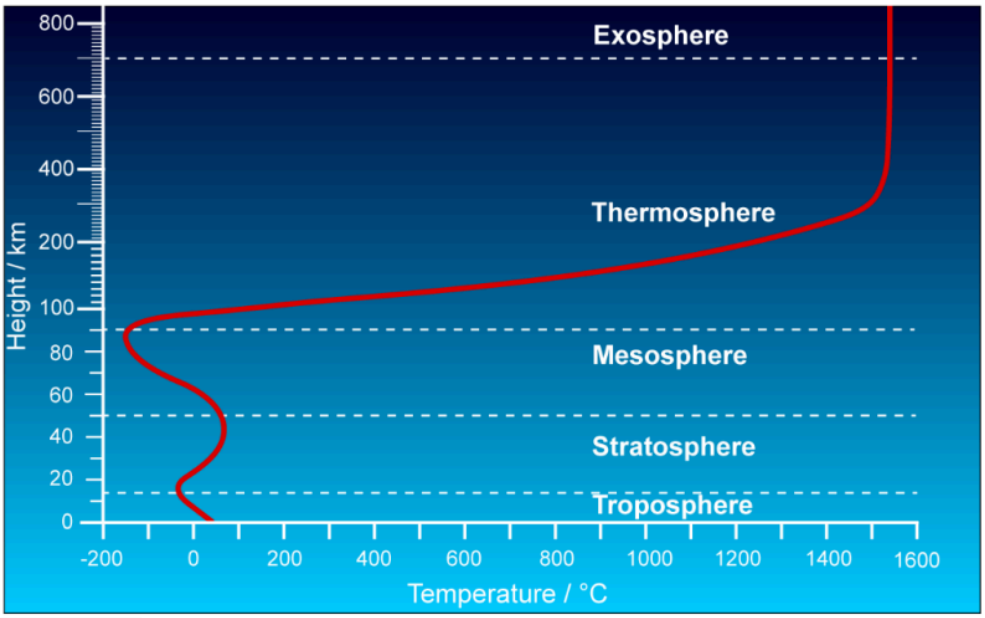


Diagram A | Diagram B



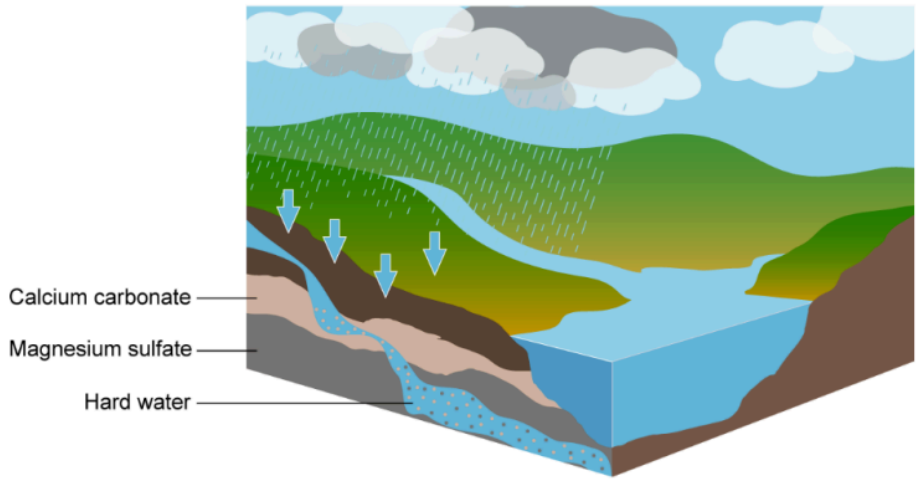
Identify which layer of the atmosphere contains particles with the highest kinetic energy. **Justify** your answer.

Question 3i (2 marks)

When oxygen gains energy from solar flares it becomes unstable. The gained energy is lost naturally from the unstable oxygen and is released as green light. Use the diagram in part (h) to **suggest** which layer of the atmosphere you would expect to find the green lights in. **Justify** your answer.

Question 4 (17 marks)

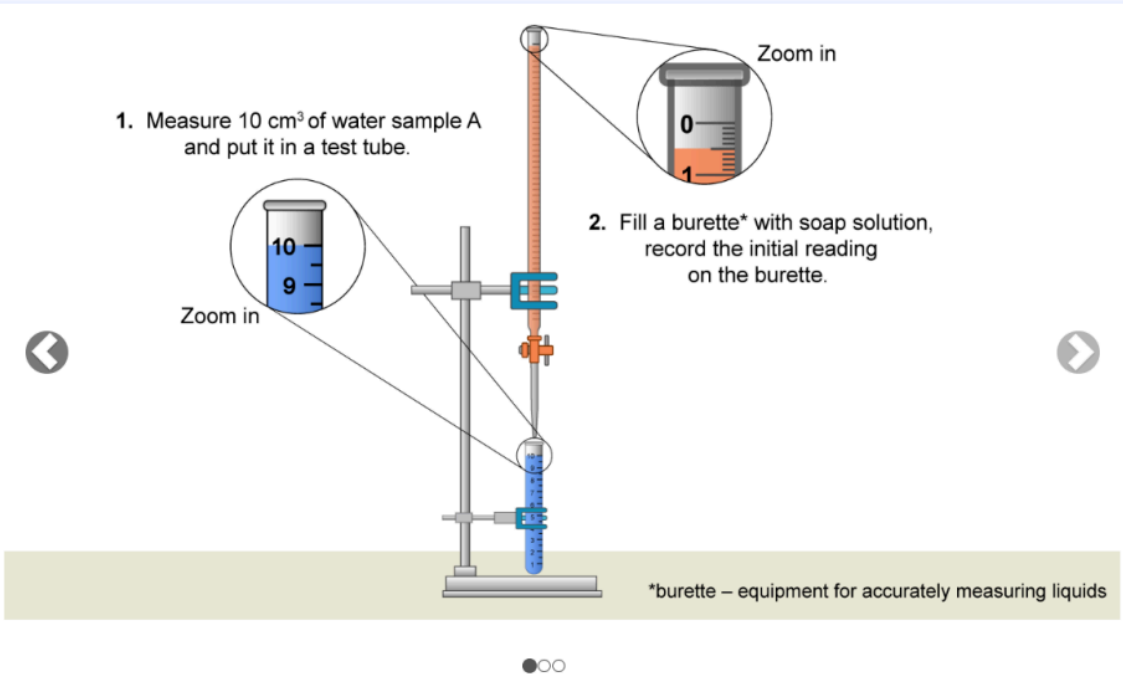
In some parts of the world, water can be described as "hard", whilst in others, it can be described as "soft". After rain falls on land, the water passes through rocks containing calcium carbonate and magnesium sulfate. As the water passes through the rocks it picks up Ca^{2+} ions, Mg^{2+} ions, HCO_3^- ions and SO_4^{2-} ions. Whether water is hard or soft depends on the quantity of dissolved salts it contains. The higher the concentration of salts, the harder the water.



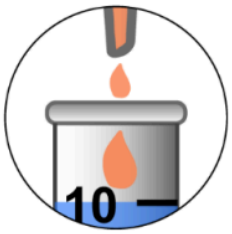
A group of students at an MYP school wanted to test five samples of water taken from different locations to see how hard they are. They carried out research and found that soft water lathers well when mixed with soap but hard water does not.

The students wanted to measure how much soap solution was needed for the lather to last for 30 seconds. They set up the following experiment:

This media is interactive


1. Measure 10 cm³ of water sample A and put it in a test tube.
Zoom in
10
9
Zoom in
0
1
2. Fill a burette* with soap solution, record the initial reading on the burette.
*burette – equipment for accurately measuring liquids

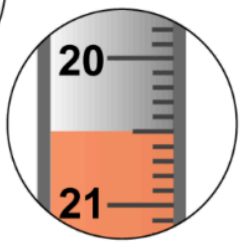
3. Add 1 cm^3 of soap solution to the water sample.



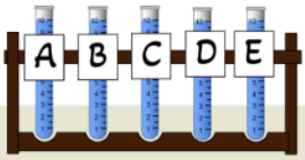
Add a stopper to the test tube and shake it for 10 seconds.

4. Wait for 30 seconds to see if the lather disappears.

5. If the lather disappears, continue adding the soap solution 1 cm^3 at a time and shake until the lather lasts for 30 seconds.



6. Record the final reading on the burette.



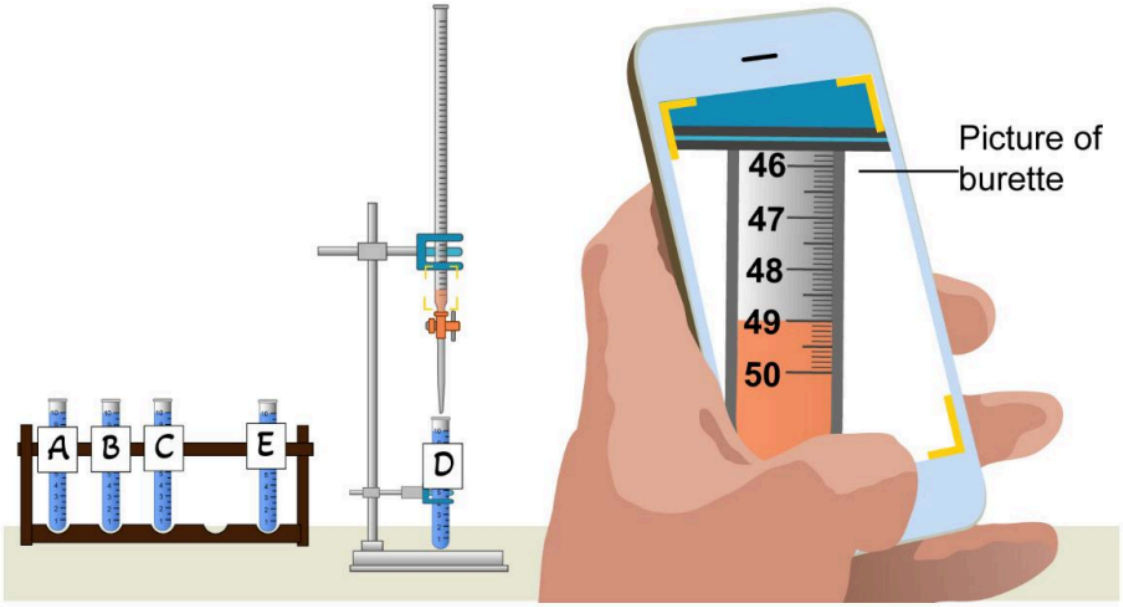
7. Repeat with water samples B, C, D and E.

Their results for all five water samples are shown in the table below.

This table cannot be edited

Water sample	Initial reading on the burette / cm^3	Final reading on the burette / cm^3	Volume of soap solution used / cm^3
A	0.5	20.5	20.0
B	11.0	21.0	
C	0.0	25.0	25.0
D	25.0		
E	9.5	22.5	13.0

The students did not read the final burette reading for water sample D. Instead, they took pictures of the burette.



Question 4a (2 marks)

Determine the final volume in the burette for water sample D by reading the burette in the picture. Give your answer with an appropriate number of decimal places.

B I U x_2 x^2 Ω Styles

Question 4b (2 marks)

Calculate the volumes of soap used in water samples B and D.

B I U x_2 x^2 Ω Styles

Question 4c (5 marks)

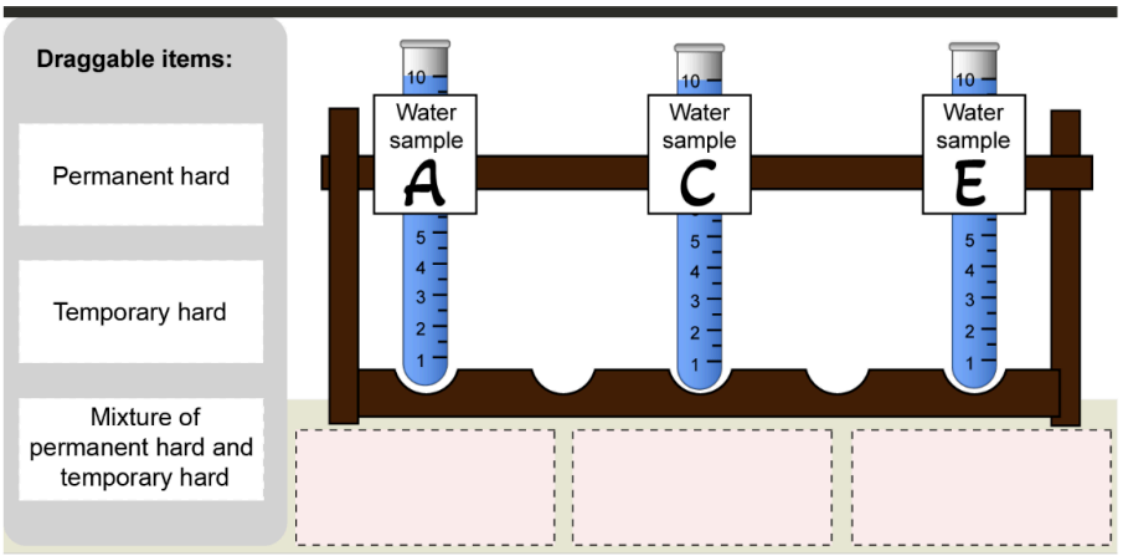
The hardness of water can be of two types, temporary and permanent. Temporary hardness is caused by dissolved calcium hydrogen carbonate and permanent hardness is caused by dissolved calcium sulfate and magnesium sulfate. Whilst temporary hardness can be removed by boiling, permanent hardness cannot.

The students also wanted to determine whether the hardness in the five samples of water is temporary or permanent.

They boiled all five water samples and repeated the experiment in part (a). The volume of soap solution needed to make a lather that lasts for 30 seconds for samples A, C and E are shown below.

Water sample	Original volume of soap / cm^3	Volume of soap added after boiling / cm^3
A	20.0	10.0
C	25.0	25.0
E	13.0	8.0

Based on the results and the knowledge that temporary hardness can be removed through boiling, **identify** each of the three samples as permanent hard, temporary hard or a mixture of permanent and temporary hard. **Justify** your answers.


Draggable items:
Permanent hard
Temporary hard
Mixture of permanent hard and temporary hard
Water sample A
Water sample C
Water sample E
10
5
4
3
2
1

Question 4d (2 marks)

The following data was obtained by the students from a water company. Use the data to **formulate** a hypothesis that links the permanent hardness of water to the concentration of different salts.

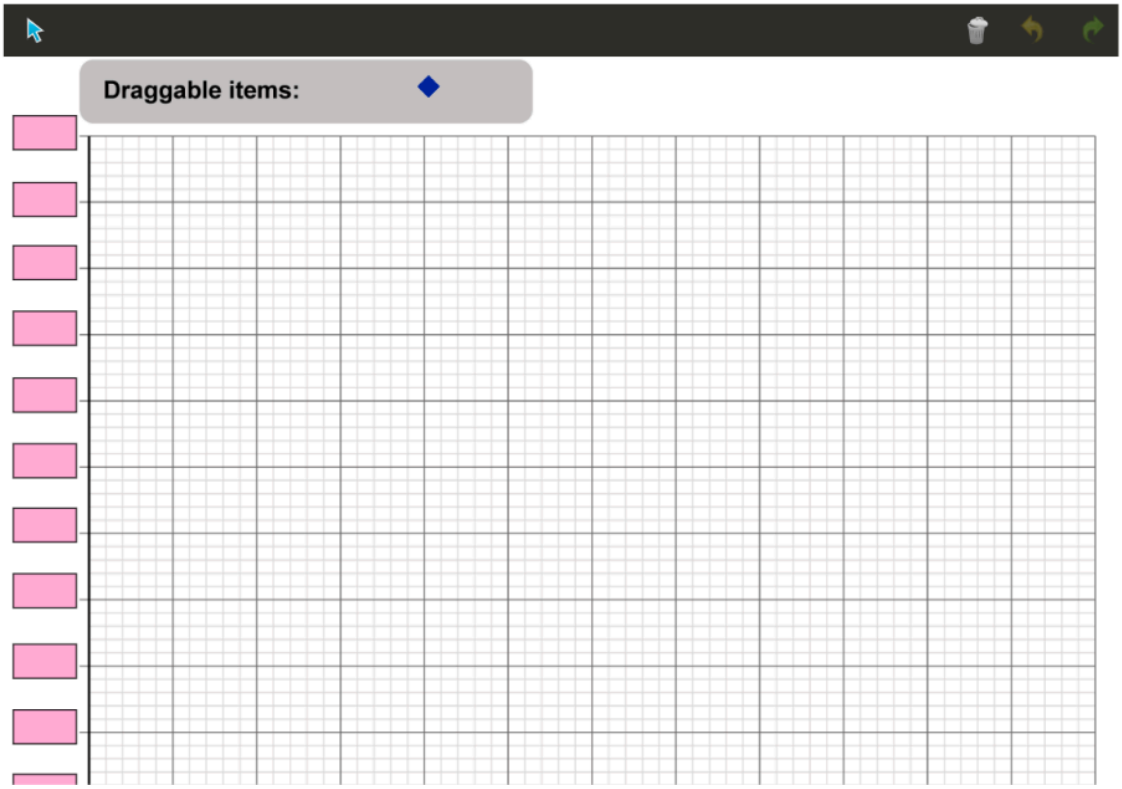
	Concentration of calcium sulfate / mg dm^{-3}	Concentration of magnesium sulfate / mg dm^{-3}	Concentration of sodium hydrogen carbonate / mg dm^{-3}	Permanent hardness / mg dm^{-3}	pH
Soft	7.5	7.5	96.0	11	6.5
Slightly hard	30.0	38.0	96.0	44	7.4
Moderately hard	60.0	57.0	96.0	90	7.6
Hard	130.0	120.0	96.0	170	7.8
Very hard	240.0	260.0	96.0	300	8.2

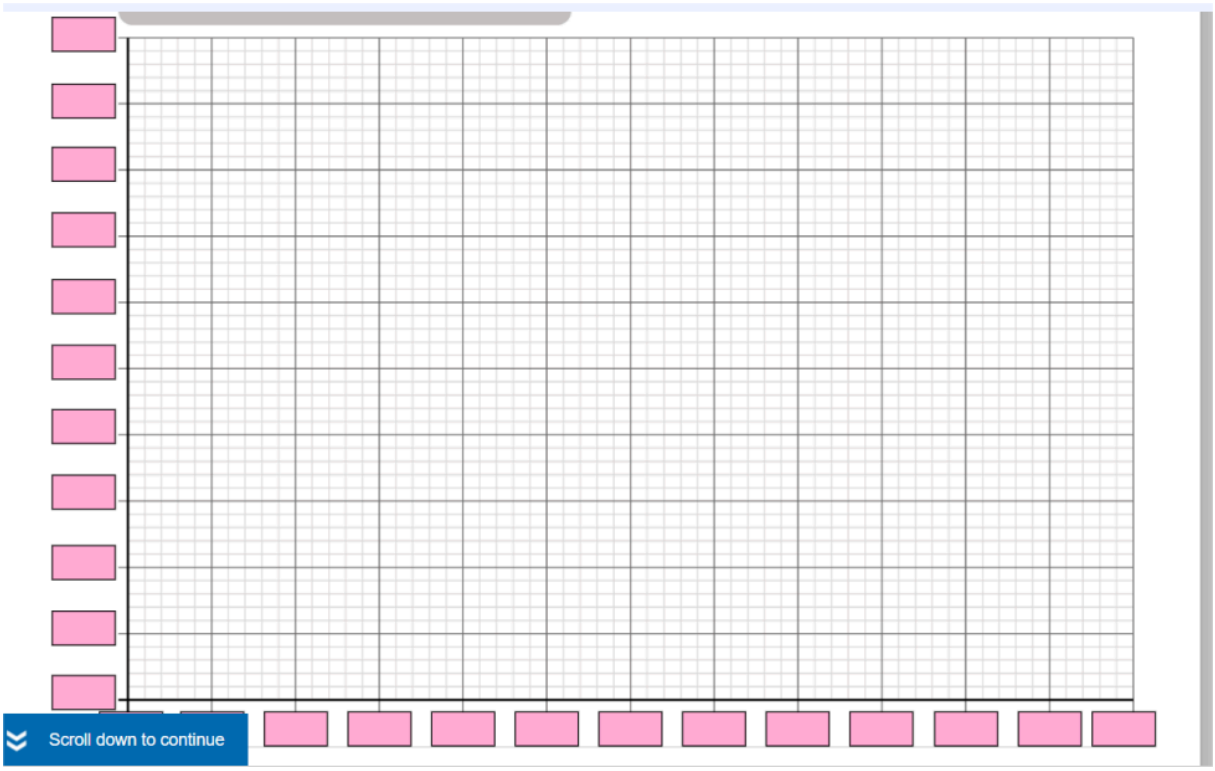
If the mass of the dissolved salts increases then the permanent hardness of the water will Select

Because:

B I U x_2 x^2 Styles

Plot a graph of pH against permanent hardness of water.




Scroll down to continue

x axis label:

Styles

y axis label:

Styles

Question 4f (2 marks)

After analysing the results, the students concluded that hard water is acidic. **Comment** on the validity of their conclusion. **Justify** your answer.

Question 5 (12 marks)

When water with temporary hardness is boiled, the soluble calcium hydrogen carbonate ($Ca(HCO_3)_2$) decomposes according to the following reaction:

$$Ca(HCO_3)_{2(aq)} \rightarrow CaCO_{3(s)} + CO_{2(g)} + H_2O_{(l)}$$

The calcium carbonate formed is not soluble in water and deposits itself in hot water pipes and appliances like kettles, irons and washing machines. The deposits are called limescale and they can cause appliances to stop working unless the limescale is removed. This process is called descaling.

Limescale can be removed by reacting it with an acid.

Calcium carbonate + acid → calcium salt + carbon dioxide + water

A group of students decided to investigate which acid is best for removing the limescale from a used hot water pipe. They used short sections of the pipe and placed them in different acids. They used hydrochloric acid, lactic acid, phosphoric acid and citric acid. They also tested a shop-bought liquid descaler.

Question 5a (1 mark)

The following symbol was found on two of the acids used. **Select** the hazard represented by the symbol.

Select

Question 5b (1 mark)

Formulate a research question for the students' investigation.

Question 5b (1 mark)

Formulate a research question for the students' investigation.

B I U x_2 x^2 Styles

Question 5c (4 marks)

State the variables in this investigation.

Independent variable:

Question 5d (2 marks)

The students presented their data in the table below.

Acid	Mass of pipe	
	Before descaling	After descaling
Hydrochloric acid	28	23.5
Lactic acid	35.0	32.4
Phosphoric acid	25	22
Citric acid	27.0	25.5
Shop-bought descaler	31	27.0

Suggest two ways in which the students' data **presentation** could be improved.

Question 5e (2 marks)

Use the results collected by the students to **determine** which acid is most effective at removing limescale. **Justify** your answer.

B I x_2 x^2 Styles

Question 5f (1 mark)

A second group of students noticed that the masses before descaling in the table in part (d) were all different. **Suggest** a reason why the masses before descaling were different.

Question 5f (1 mark)

A second group of students noticed that the masses before descaling in the table in part (d) were all different. **Suggest** a reason why the masses before descaling were different.

Question 5g (1 mark)

The students only carried out this investigation once. **Comment** on how this will affect the validity of the data collected.

Question 6 (19 marks)

Limescale inside kettles can reduce their heating efficiency. As part of a wider service as action project, some students want to help the school community save energy by advising them on how to descale their kettles.

Ethanoic acid is commonly available in households as vinegar. In line with the principles of green chemistry, the students want to find out the lowest concentration of ethanoic acid that would remove a given mass of limescale.

Question 6a (1 mark)

Suggest why the students have decided to test ethanoic acid and not hydrochloric acid.

Question 6b (18 marks)

To model limescale, the students have decided to use calcium carbonate. They are provided with standard laboratory equipment and the following chemicals:

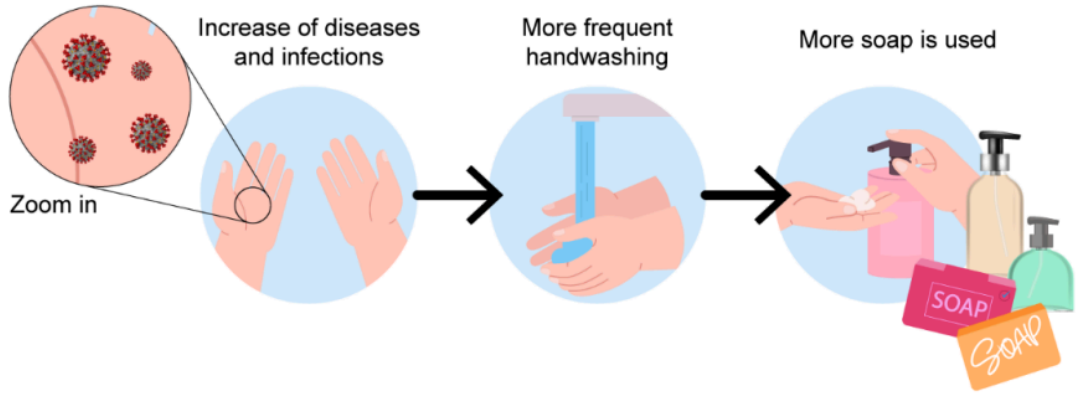
- distilled water
- different sized pieces of calcium carbonate
- vinegar with an ethanoic acid concentration of 1.5 mol dm^{-3}.

Design an experiment to investigate the minimum concentration of ethanoic acid required to remove limescale. In your answer, you must include:

- the independent variable, the dependent variable and two control variables
- a list of the equipment that you will use
- the method you will follow
- the details of the measurements you will take to collect sufficient data
- any safety precautions you will need to take.

Question 7 (17 marks)

Handwashing with soap reduces the spread of diseases and infections caused by microbes. The COVID-19 pandemic increased the frequency of handwashing globally. When assessing the environmental impact of soap, it is important to consider both the soap and its packaging. The materials used in soap packaging will have environmental impacts. For example, the packaging may be produced using crude oil-based or plant-based materials. Also, it may be possible to recycle some types of packaging and others may biodegrade.



The video below shows the production process of different types of plastic.

Plastics are widespread in modern life. Each type has different properties to meet the requirements of particular uses. The majority of plastics used today have many disadvantages, as they cause high levels of pollution during their production and do not break down at the end of their useful lifespan.

Scientists are looking to produce plastics that have less of an environmental impact. There are now more choices for manufacturers to select from when designing a product.

Plastics can be split into two groups: those made from crude oil and those made from plant-based materials.

Ethene from crude oil can be used to make polyethene—a strong structure with bonds that are hard to break.

Polyethene, can be made using ethanol obtained from plants.

Obtaining the raw materials for these two groups of plastic will have different environmental impacts.

The production of plant-based plastics does not necessarily have a lower impact on the environment and not all of them biodegrade.

These two groups can be split even further into plastics that can be broken down and those that cannot.

Biodegradable plastics break down naturally over time into simple molecules, which means there is no plastic waste.

The production of plant-based plastics does not necessarily have a lower impact on the environment and not all of them biodegrade.

These two groups can be split even further into plastics that can be broken down and those that cannot.

Biodegradable plastics break down naturally over time into simple molecules, which means there is no plastic waste.

Following the increase in handwashing, there has been a corresponding increase in the amount of waste packaging from liquid soap. How can science be used best to solve the problem of increased pollution from plastic packaging?

Scroll down to continue

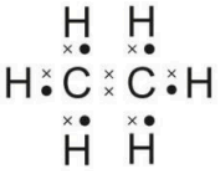
Question 7a (1 mark)

Ethene can be used to produce a crude-oil-based non-biodegradable plastic called polyethene.

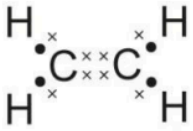
Select the Lewis structure of ethene.

Select

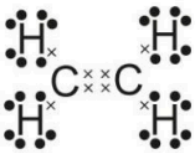
A.



B.



C.



D.

Question 7b (16 marks)

As seen in the video, different compounds produce different types of plastics with different properties. The table below shows information about three different types of plastic.

	Crude-oil-based non-biodegradable	Plant-based non-biodegradable	Plant-based biodegradable
Strength / MPa	98	55.8	11.2
Stretch before breaking / %	55.4	5.58	9.3
Greenhouse gas emission in production	High	Low	Low
Production cost	Low	High	High

	Crude-oil-based non-biodegradable	Plant-based non-biodegradable	Plant-based biodegradable
Strength / MPa	98	55.8	11.2
Stretch before breaking / %	55.4	5.58	9.3
Greenhouse gas emission in production	High	Low	Low
Production cost	Low	High	High
Is the plastic biodegradable?	No Plastic only physically breaks into smaller pieces	No Plastic only physically breaks into smaller pieces	Yes Plastic chemically breaks down into water and carbon dioxide Needs specific conditions to biodegrade

Scroll down to continue

Is the plastic biodegradable?	No Plastic only physically breaks into smaller pieces	No Plastic only physically breaks into smaller pieces	Yes Plastic chemically breaks down into water and carbon dioxide Needs specific conditions to biodegrade
Can the plastic be recycled?	Yes	Yes	No if mixed with non-biodegradable plastics
Resources needed in production	Crude oil	Fields, fertilizer and pesticides to grow plants	Fields, fertilizer and pesticides to grow plants

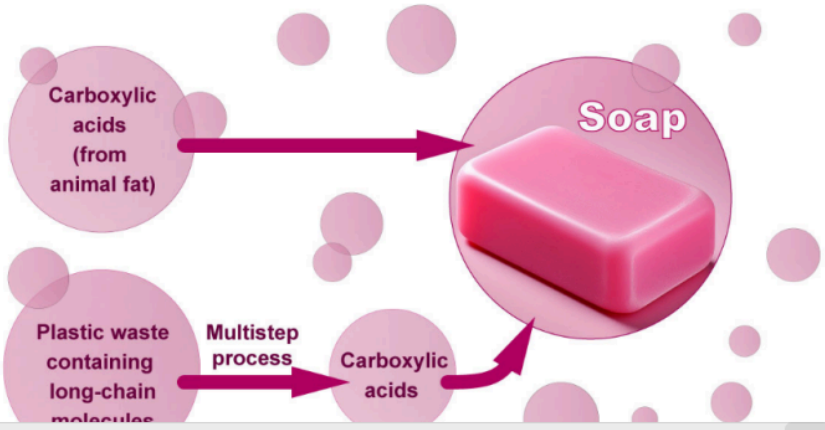
Using the information provided and your wider MYP knowledge, **discuss** and **evaluate** the different types of plastic used for liquid soap packaging. In your answer, you should include:

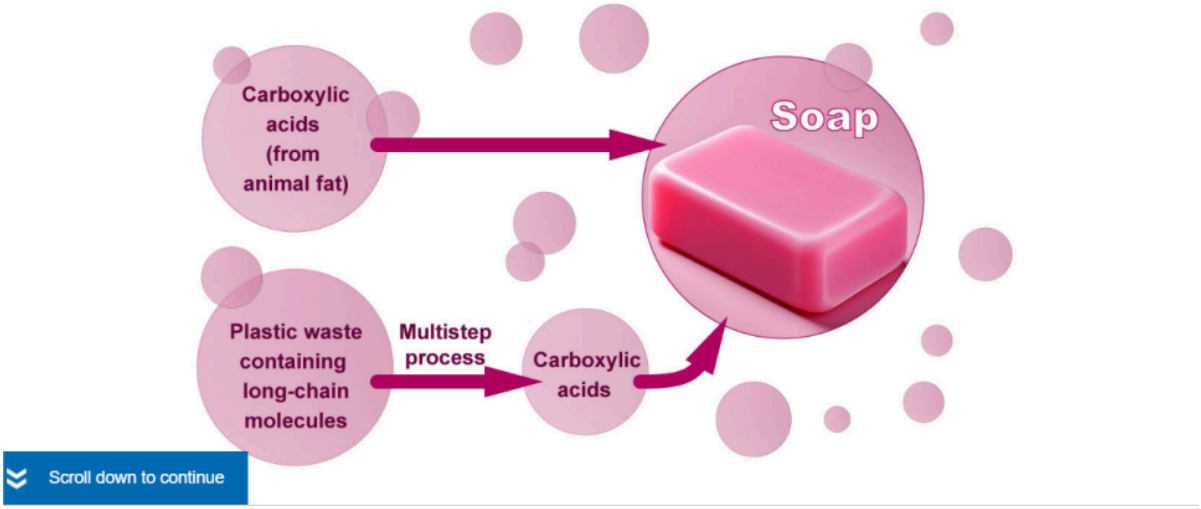
- a justification of the **properties** needed for the **plastic** used in liquid soap packaging
- a comparison of the suitability of the three types of **plastic** for liquid soap packaging
- the economic impacts of the three types of plastic
- the environmental impacts of the three types of plastic
- your choice with justification.

Question 8 (7 marks)

Traditionally, soaps are made from naturally occurring materials such as animal and plant fats (containing carboxylic acids) and wood ash. When these materials are combined with water, a simple soap is produced. When society became industrialized, the animal and plant fats were replaced with carboxylic acids obtained from crude oil. Fragrances and colours were added to make the soap more appealing.

A recent technical innovation uses waste plastic as an alternative source of the carboxylic acids used to make soap. In a multistep process, the long-chain molecules in plastic are converted into carboxylic acids which are then reacted with an alkaline solution to make soap.




Carboxylic acids (from animal fat)
Soap
Plastic waste containing long-chain molecules
Multistep process
Carboxylic acids
Scroll down to continue

With more frequent handwashing, more soap is released directly into the sewage system and, eventually, into the environment. This can reduce the water quality of lakes and rivers, causing harm to fish, aquatic plants and soil. As the ingredients of soap are transferred into the ecosystem, there is a need for eco-friendly cleaning agents.

Recently, there has been a return towards using more natural ingredients in soaps. Natural ingredients, such as vegetable oils and plant and fruit extracts, have been reported to have antimicrobial properties.

The table below gives some information about different types of soap.

	Natural soap	**Crude-oil-based soap**	**Soap made from recycled plastic**
Raw materials	Plant or animal fat	Crude oil	Recycled plastic
Toxic potential	Low toxic potential as no additives are needed	High toxic potential as additives are needed	Not yet known
Antimicrobial properties	Naturally occurring antimicrobial properties	Needs additives for antimicrobial properties	Needs additives for antimicrobial properties
	Intermediate cost	Lowest cost	Highest cost

	Natural soap	Crude-oil-based soap	Soap made from recycled plastic
Raw materials	Plant or animal fat	Crude oil	Recycled plastic
Toxic potential	Low toxic potential as no additives are needed	High toxic potential as additives are needed	Not yet known
Antimicrobial properties	Naturally occurring antimicrobial properties	Needs additives for antimicrobial properties	Needs additives for antimicrobial properties
Cost	Intermediate cost	Lowest cost	Highest cost
Availability	Limited availability	High availability	Very limited availability
Allergy risk	Potential allergies or sensitivities to natural ingredients	Potential allergies or sensitivities to additives	Potential allergies or sensitivities to additives

Using information from the table and your wider MYP studies, **discuss** the issues an individual would consider when choosing which type of soap to use. In your answer, you should include:

- a comparison between the production processes of soap made using recycled plastic and one other type of soap

Toxic potential	Low toxic potential as no additives are needed	High toxic potential as additives are needed	Not yet known
Antimicrobial properties	Naturally occurring antimicrobial properties	Needs additives for antimicrobial properties	Needs additives for antimicrobial properties
Cost	Intermediate cost	Lowest cost	Highest cost
Availability	Limited availability	High availability	Very limited availability
Allergy risk	Potential allergies or sensitivities to natural ingredients	Potential allergies or sensitivities to additives	Potential allergies or sensitivities to additives

Using information from the table and your wider MYP studies, **discuss** the issues an individual would consider when choosing which type of soap to use. In your answer, you should include:

- a comparison between the production processes of soap made using recycled plastic and one other type of soap
- two social impacts that could be considered when choosing between these two types of soap.