Question 1a (1 mark)

One of the main aims of alchemists was to transform metals such as lead and iron into gold. To help with this process, alchemists produced acids to react with the metals. One such mixture of acids was called *aqua regia* which is a combination of hydrochloric acid and nitric acid. *Aqua regia* is still used today in the purification process of gold (Au).

Select the region of the periodic table where gold can be found.

Select

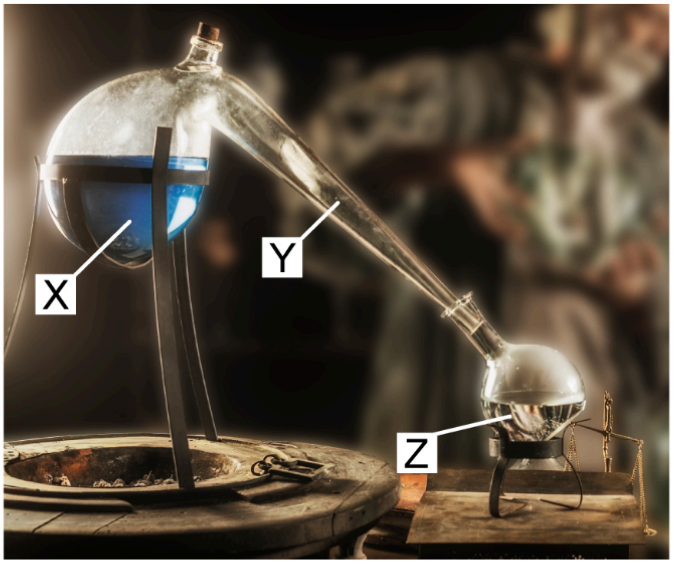
Question 1b (1 mark)

Alchemists were interested to see how substances could be decomposed or separated into their components. One technique developed by alchemists is distillation. **Select** the property that allows liquids to be separated by distillation.

Select

Question 1c (4 marks)

Use particle theory to **describe** the state changes that take place from X to Y and Y to Z on the image below.



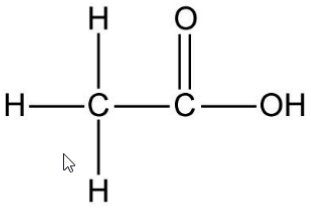
X to Y

Question 1d (1 mark)

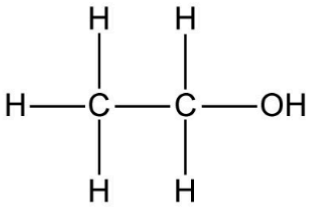
When wine is distilled, a pure alcohol called ethanol is obtained. **Select** the diagram showing the structure of ethanol.

Select

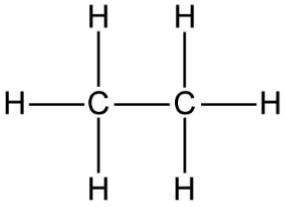
A.



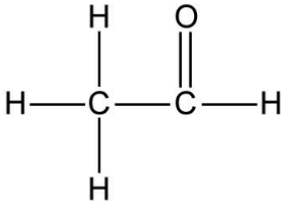
B.



C.



D.



Question 1e (2 marks)

Another acid used by alchemists was sulfuric acid. Sulfuric acid (H_2SO_4) was produced through a number of chemical reactions starting with iron vitriol, now known as iron sulfate ($FeSO_4$).

Calculate the formula mass for $FeSO_4$.

Question 2 (11 marks)

Carbon dioxide (CO_2) has many uses, for example to remove caffeine from coffee, in smoke machines, as a component in fire extinguishers, to keep food cold and to make carbonated drinks.

Question 2a (1 mark)

CO_2 has a boiling point of -78 °C. Solid CO_2 is known as dry ice.

Select the type of bonding in a molecule of carbon dioxide.

Select

Question 2b (3 marks)

CO_2 is soluble in water, acts as a preservative and is non-toxic. Champagne contains CO_2 at high pressure. The image below shows a bottle of champagne opening.

When a bottle of champagne is opened, **explain** why the cork will fly off, champagne sprays out and bubbles are seen.

Question 2c (4 marks)

The amount of CO_2 in the atmosphere is increasing. There are global organizations working towards reducing the effects of CO_2 on climate change. One possible solution is to react CO_2 with hydrogen to produce methanol (CH_3OH) which can then be used as a carbon-neutral fuel.

Carbon-neutral means that it does not change the overall level of CO_2 in the atmosphere.
The equation for this process is shown below.

$$CO_2\,(g) + 3H_2\,(g) \rightarrow CH_3OH\,(g) + H_2O\,(g)$$

Calculate the mass of methanol that can be produced from 440 kg of CO_2 gas. You should give your answer in grammes (g) in standard form.

Question 2d (3 marks)

The rate of production of methanol from hydrogen and carbon dioxide is low. The rate can be increased by using a catalyst.

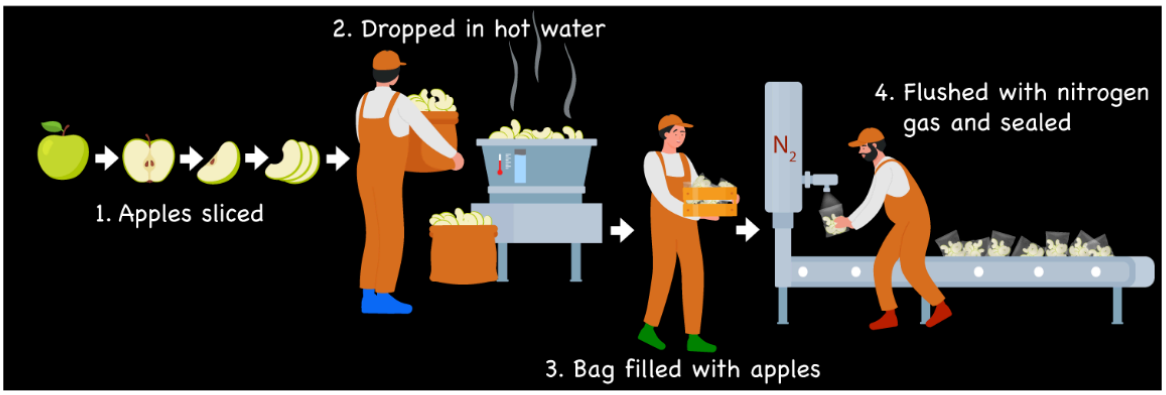
Explain how a catalyst works to increase the rate of methanol production.

Question 3 (8 marks)

Some gases have low reactivity with other chemicals. These gases can be used in industry, and for the preservation and transportation of food.

Question 3a (1 mark)

Apple slices can be packaged and used for snacks. The process is shown below.



When sliced apples come into contact with air, they turn brown. **Select** which gas in air causes apples to turn brown when sliced.

Select

Question 3b (2 marks)

Nitrogen and argon can be added to food packets to remove air. **State** the correct group for nitrogen and correct period for argon.

Nitrogen group: Argon period:

Question 3c (3 marks)

Use the electronic configuration of argon to **explain** why it does not form compounds.

Question 3d (2 marks)

Some light bulbs can be filled with argon. Over time, the argon leaks from the light bulb and is replaced by air. The images below show that a light bulb can explode if the argon is replaced by air.

Outline why the bulb might explode if the argon is replaced by air.

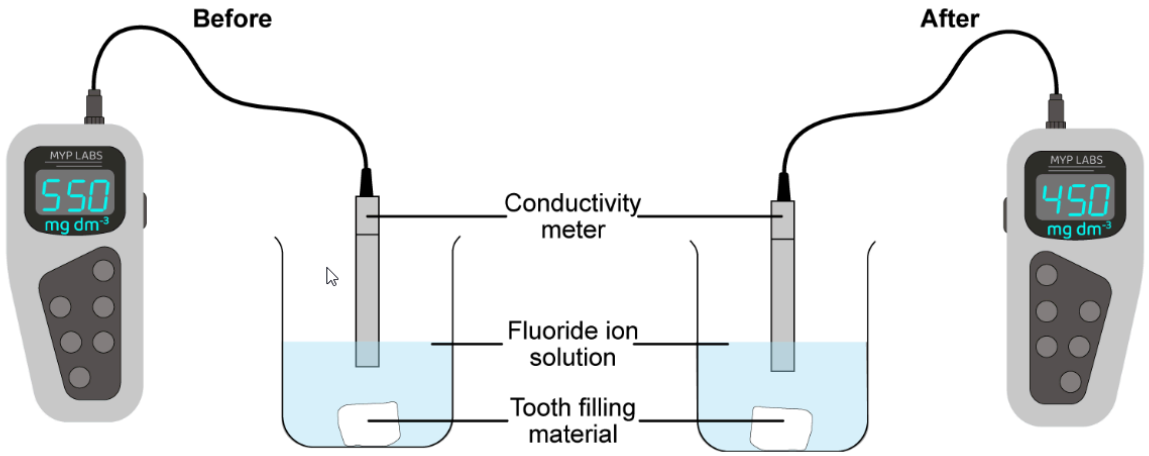
Many different materials have been developed to repair teeth and bones. Examples of materials used for filling holes in teeth are shown below.

Amalgam An alloy of mercury and other metals	**Composite** A plastic-based material	**Gold** A pure metal	**Ceramic** A material made from clay
			

The natural material of our teeth is protected by fluoride ions (F^-) which are present in toothpaste and mouthwash and sometimes in drinking water. Areas of the world that do not add F^- ions to drinking water have increased tooth decay, resulting in more fillings.

Question 4b (4 marks)

A conductivity meter can be used to measure the change in concentration of F^- ions. The student uses a solution with a known concentration of F^- ions with each filling material and determines how the concentration of F^- ions changes after 10 minutes.



Identify the independent variable, the dependent variable and two control variables in this investigation.

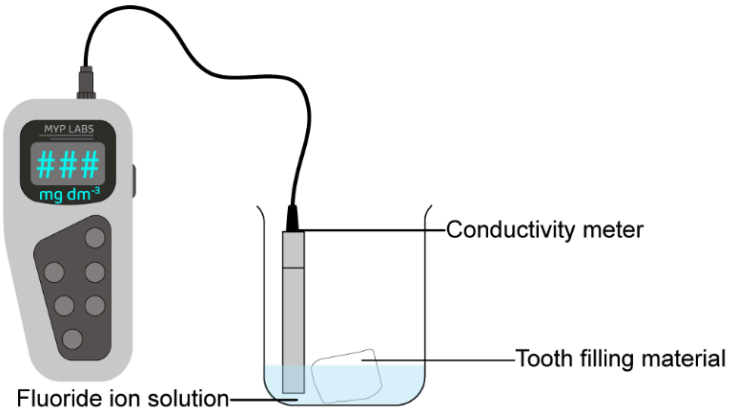
Question 4a (1 mark)

A student wanted to investigate whether the F^- ions protect filling materials in the same way as natural teeth.

State a research question for the student's investigation.

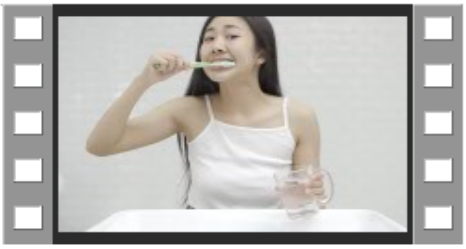
Question 4c (2 marks)

A second student repeated the investigation with the following set up.



Comment on the validity of the second student's method compared with that of the first student. **Justify** your answer.

Q.4d video 1

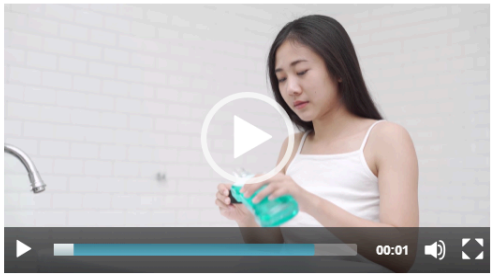


Q.4d video 2

Question 4d (3 marks)

Mouthwash is a common source of F^- ions.

This media contains no audio



Mouthwash might be used after brushing with toothpaste to clean teeth further.

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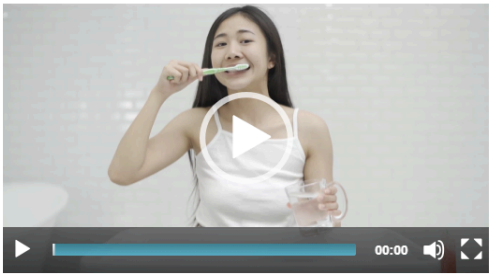


Formulate a testable hypothesis to determine if using mouthwash and toothpaste is more effective at cleaning teeth than toothpaste alone.

Question 4e (2 marks)

The students decided to use the method in part (b) to test different brands of mouthwash on one type of tooth filling material. Their processed data is shown below.

Brand	Initial conductivity / mg dm^{-3}	Conductivity after 10 minutes /mg dm^{-3}		
		Trial 1	Trial 2	Trial 3
A	165	150	153	157
B	110	103	105	30
C	220	212	211	209
D	198	179	176	175

Identify the anomalous result and **suggest** an experimental reason that may have produced this result.

Question 4f (3 marks)

Calculate the average conductivity after 10 minutes for Brand D. You should give your answer to an appropriate number of significant figures and include the unit.

Question 4g (1 mark)

Use the data in part (e) to **justify** the best choice of mouthwash.

Question 4h (1 mark)

F^- in low concentrations can be good for healthy teeth however higher concentrations can cause unwanted effects on the body. Scientists have suggested that 50% of people will suffer unwanted effects with an intake of F^- ions above 5 mg kg^{-1} of body weight. On average, a three-year-old has 20 teeth, this increases to 32 in a full set of adult teeth.

How much toothpaste to use	Age	Recommended mass of toothpaste
	Under 3	0.25 g
	3–6 years	0.50 g
	7+ years	1.00 g

Suggest why the recommended mass of toothpaste increases as children grow.

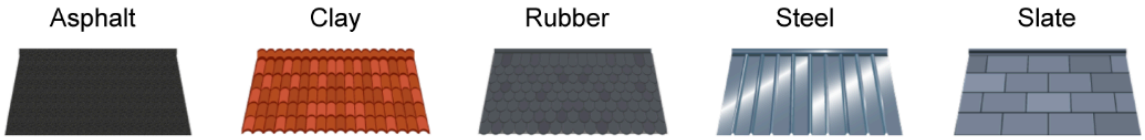
Question 5 (20 marks)

Despite efforts in the industrial world to reduce pollution, acid rain is present. Designing cheap and sustainable shelters that can be long lasting and resist weather conditions is a challenge.



Question 5b (18 marks)

You are given a (10 cm × 10 cm) sample of each type of roofing material for you to model its rate of reaction with acid rain using 1 mol dm^{-3} HCl.



Design an experiment that will determine the rate of reaction of HCl with each type of roofing material. In your answer you should include:

- the independent variable, the dependent variable and two additional control variables
- a list of equipment you will use
- details of your method
- details of the data you will collect
- how you will ensure that your method is safe.

Question 5a (1 mark)

A student has been researching rooftops made of recycled material. One of the challenges in using recycled material to build sustainable rooftops is their reaction with acid rain.

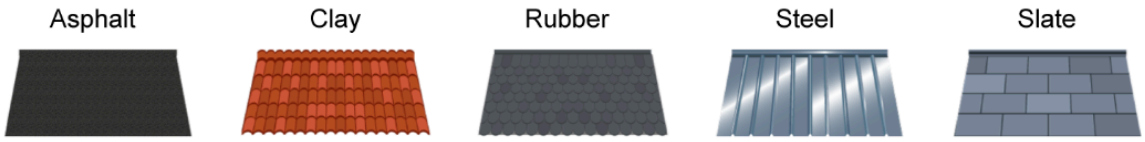
The student placed a piece of recycled steel rooftop in acid. An image of their results is shown below.

Select how you can tell a chemical reaction has taken place in the image.

Select

Question 5b (18 marks)

You are given a (10 cm × 10 cm) sample of each type of roofing material for you to model its rate of reaction with acid rain using 1 mol dm^{-3} HCl.



Design an experiment that will determine the rate of reaction of HCl with each type of roofing material. In your answer you should include:

- the independent variable, the dependent variable and two additional control variables
- a list of equipment you will use
- details of your method
- details of the data you will collect
- how you will ensure that your method is safe.

Question 5c (1 mark)

Climate conditions are different around the world. Roofing used in one country may not be suitable for a different country. **Suggest** a different independent variable linked to climate that could be investigated.

Question 6 (13 marks)

Food often contains chemicals which can react with metal over time causing corrosion. Cutlery is made of a metal which is cheap to produce and then plated using electrolysis to give the cutlery a more expensive look.

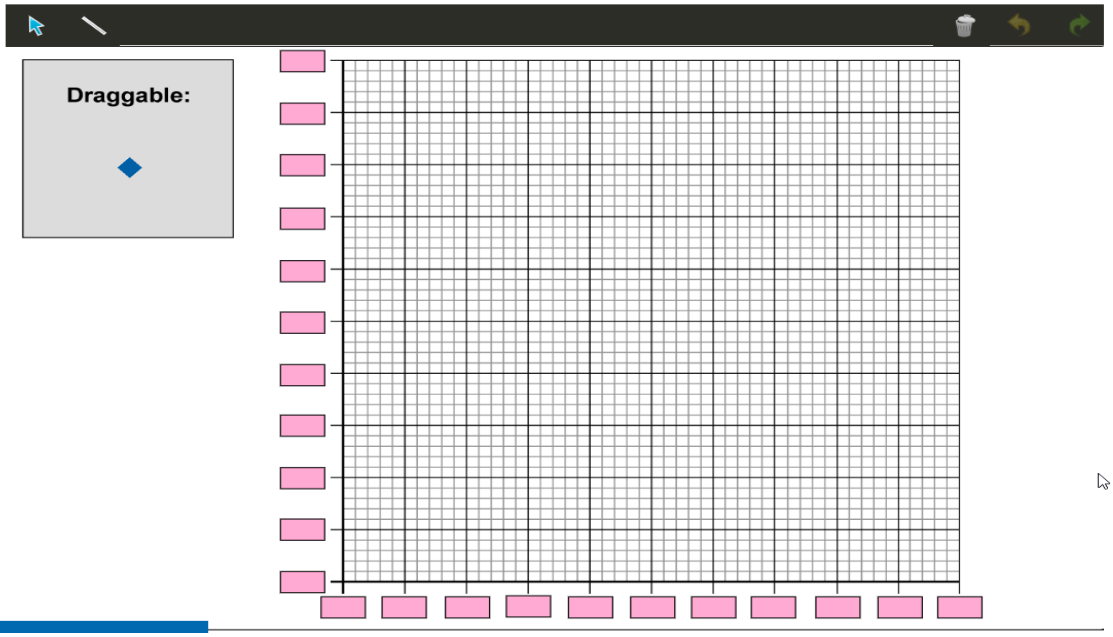
Question 6a (6 marks)

A student wants to model the reaction between electroplated cutlery and sodium chloride (NaCl). To replace the cutlery, the student uses iron nails that have been electroplated with zinc. The student investigated the effect of NaCl concentration on the rate of corrosion. The student measured the mass lost by the nail after 7 days.

0.0 mol dm^{-3} 0.1 mol dm^{-3} 0.3 mol dm^{-3} 0.5 mol dm^{-3} 0.8 mol dm^{-3}

Concentration of NaCl / mol dm^{-3}	Mass lost in 7 days / mg			
	Trial 1	Trial 2	Trial 3	Average
0.0	10	8	12	10
0.1	16	19	19	18
0.3	45	39	45	43
0.5	60	55	54	57
0.8	81	89	88	86

Plot a graph of concentration and average mass lost. You should include a line of best fit.



Question 6b (3 marks)

Describe the trend shown in the data in part (a). **Suggest** the purpose of the trial at 0.00 mol dm^{-3} NaCl.

Question 6c (3 marks)

Before their investigation, the student wrote the following hypothesis.

> If the NaCl concentration increases, then less mass will be lost from the nail after 7 days because there are more collisions between particles of NaCl in the solution.

Use the data in part (a) to **evaluate** the validity of this hypothesis.

Question 6d (1 mark)

The student used iron nails plated with zinc to model the effect of electroplating on cutlery.

Suggest why nails were used to model cutlery.

Question 7 (10 marks)

Fossil fuels have been used widely as an energy source in everyday life. This has had a negative impact on the environment and so alternative sources of energy are needed. One alternative source of energy is nuclear fission. Nuclear fission releases an enormous amount of energy but also radioactive waste that must be disposed of. This radioactive waste is extremely dangerous and must be disposed of safely.

Question 7a (1 mark)

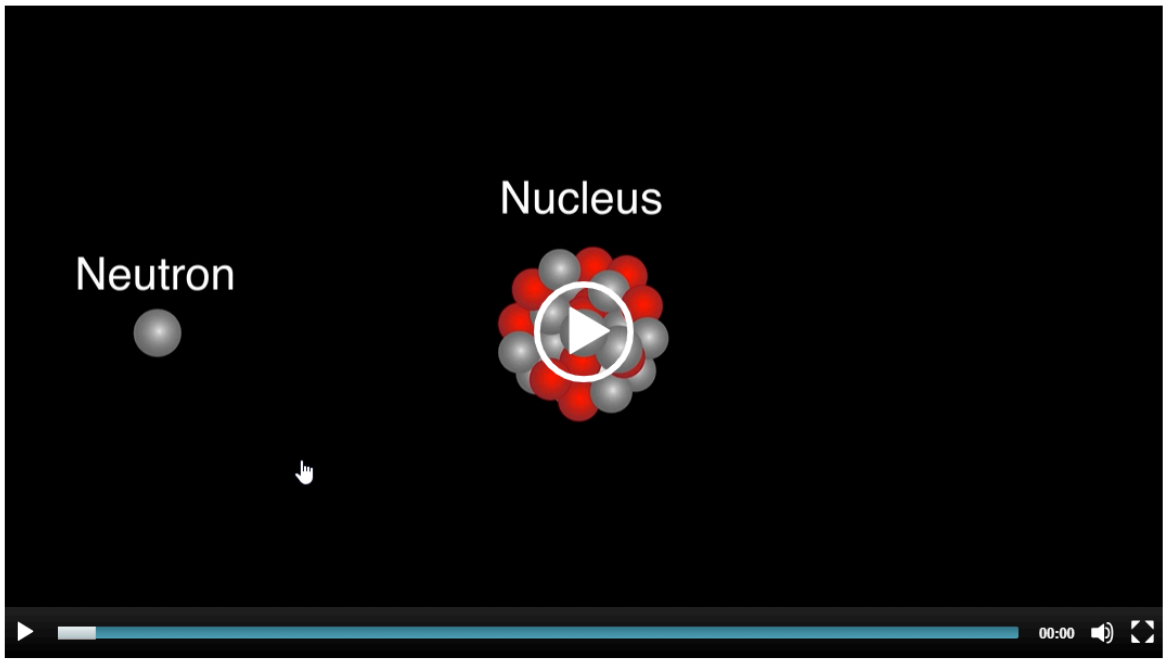
Energy can be obtained from renewable energy sources such as solar and wind or non-renewable sources such as fossil fuels.

In addition to being renewable and non-renewable, **state** one other difference between these two types of energy source.

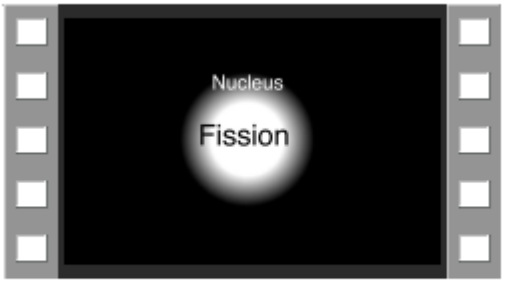
Question 7b (1 mark)

Energy from nuclear fission is produced in nuclear reactors. Nuclear fission happens when a neutron collides with an atom, producing an unstable nucleus which splits into two different atoms, releasing energy. Additional neutrons are also released in the reaction which can start new fission reactions as shown in the animation below.

This media contains no audio



Q.7a



Q.7b video

Question 7c (8 marks)

It is necessary to transport radioactive waste from the nuclear reactor to a storage facility. There are several methods of transport that can be used. These include road, trains, rivers and air. **Discuss** the considerations when choosing a method of transport. In your answer you should include:

- what risks are involved when transporting radioactive waste
- what precautions should be taken when using **each** method of transport
- a conclusion with justification of which is the safest method of transport.

Q.8 Video

Question 8 (12 marks)

When energy is produced from the nuclear fission of uranium-235, the by-products are atoms of barium-141 and krypton-92 which are radioactive. This radioactive waste is extremely dangerous and must be stored or disposed of safely.

The video shows examples of waste disposal and storage methods.

Video | Script

In sea dumping, the waste is sealed in containers and transported to a port. It is then transported on ships away from populated areas where it is dumped in seas or oceans.

Sea dumping was used for more than 50 years but proved to have weaknesses. International organizations became aware of the limitations of dumping waste into seas and oceans. Some of these organizations developed new disposal methods such as underground storage areas called repositories.

In underground storage areas, radioactive nuclear waste is placed in special containers 200 metres to 1000 metres below Earth´s surface. These storage sites have several barriers made of materials such as clay and rock to prevent harmful materials seeping out of the site. Radioactive waste can be stored safely for thousands of years.

Some scientists have suggested that radioactive waste could be disposed of by sending it into space. Using the information above and information from your wider MYP studies, **discuss** and **evaluate** one of the two methods for safe storage of radioactive waste compared to disposal in space. In your answer you should consider:

- effects on the environment of either sea dumping or underground storage
- economic impacts of either sea dumping or underground storage
- advantages and disadvantages of disposal in space
- a justification of your opinion on which is the best method for storing or disposing of radioactive waste.