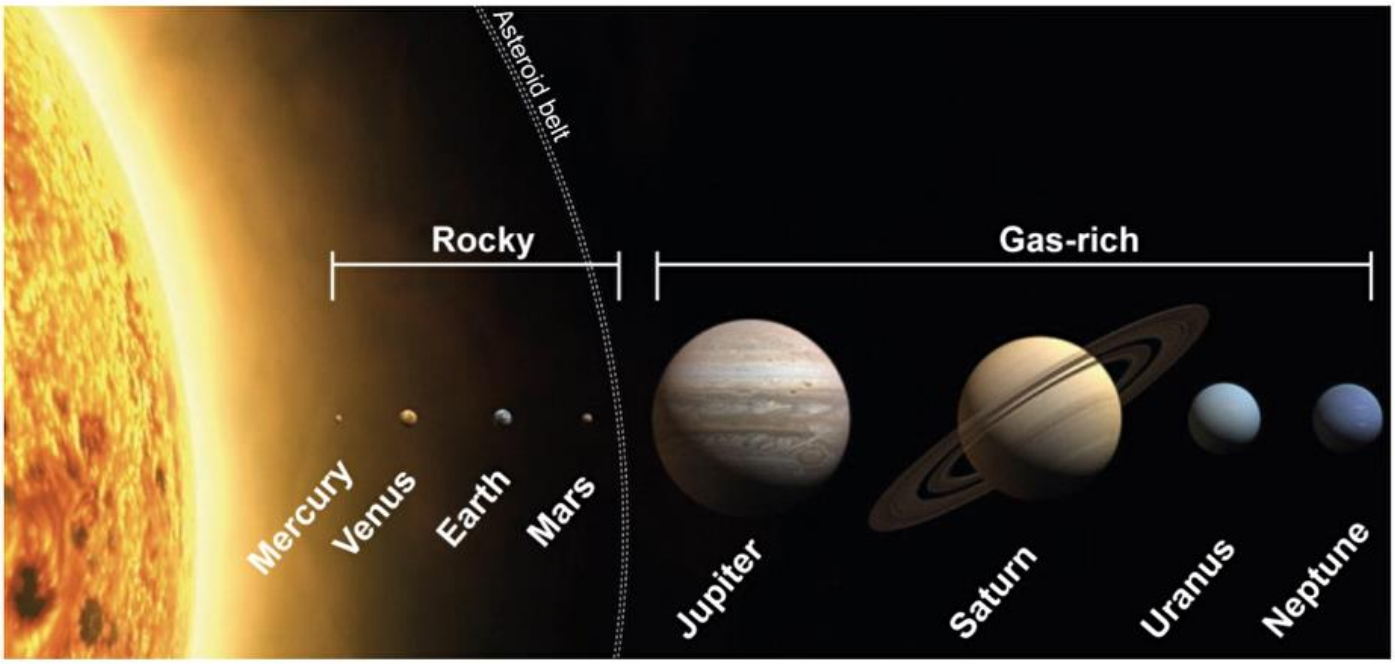
Question 1 (9 marks)

All of the planets in our solar system orbit around the Sun, which is a star. Many reactions take place on the surface of a star. These reactions produce large amounts of energy. Exoplanets are planets outside our solar system that orbit around other stars. Scientists are interested in the structures of stars, planets and other objects in the universe. In our solar system, planets may be rocky or gas-rich. Exoplanets can also be either rocky or gas-rich.



Question 1a (1 mark)

Rocky planets consist mainly of magnesium (Mg), silicon (Si) and iron (Fe). **Select** the number of electrons in the outer shell of an atom of magnesium.

Magnesium Select

Question 1b (2 marks)

Using the periodic table, **state** the group and period of silicon.

Group:

Period:

Question 1c (1 mark)

Select the region of the periodic table where iron is located.

Select

Question 1d (4 marks)

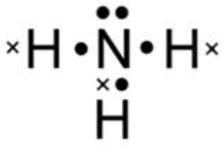
Some of the major components of gas-rich planets are helium (He), hydrogen (H_2) and ammonia (NH_3). **Explain** why hydrogen occurs as diatomic molecules, but helium does not.

B I U x_2 x^2 Ω Σ Styles

Question 1e (1 mark)

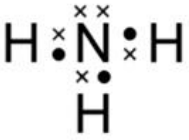
Select the diagram that shows the Lewis structure (electron dot or dot cross diagram) of ammonia, NH_3.

A.

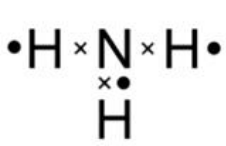


B.

C.



D.



Select

Question 2 (12 marks)

Scientists studying space wonder whether life would be possible on planets other than the Earth. Most believe that, if molecular oxygen is present on a planet, then life is possible on this planet. But molecular oxygen itself is not a sign of life on a planet, because it might have formed from water. Samples collected from the Moon contain several isotopes of oxygen.

Question 2a (2 marks)

Oxygen occurs as a mixture of three isotopes, which have 8, 9 and 10 neutrons respectively. **Calculate** the mass number of the isotope which has 9 neutrons.

B I U x_2 x^2 Ω Σ Styles

Question 2b (1 mark)

Molecular oxygen has been found on the Moon and detected on exoplanets. For life to exist, an atmosphere of at least 16 % must be present. **Suggest** why the presence of molecular oxygen does not necessarily indicate the presence of life.

B I U x_2 x^2 Ω Σ Styles

Question 2c (1 mark)

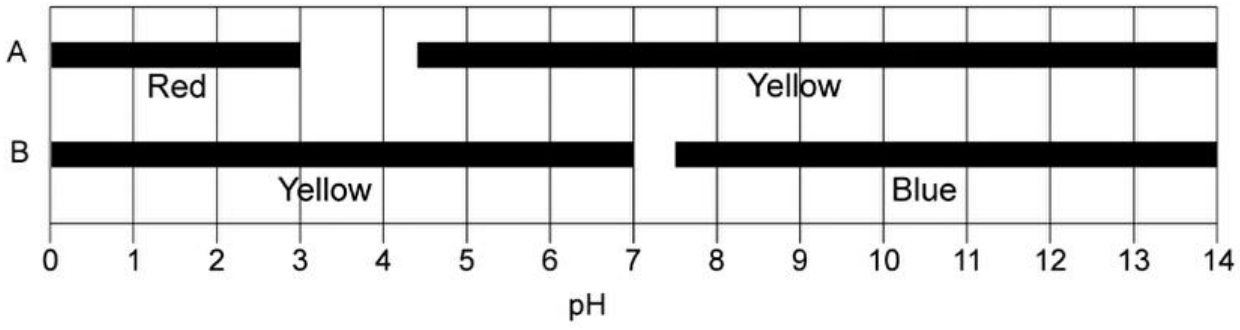
Calculate the relative molecular mass of carbon dioxide containing one atom of oxygen-16 and one atom of oxygen-18.

Question 2d (2 marks)

Carbon dioxide gas is soluble in water. One way to test if a solution contains carbon dioxide is to use an indicator to determine its pH. Different indicators change colour over different ranges of pH.

This media contains no audio

The chart below shows the colour changes for two indicators, indicator A and indicator B.



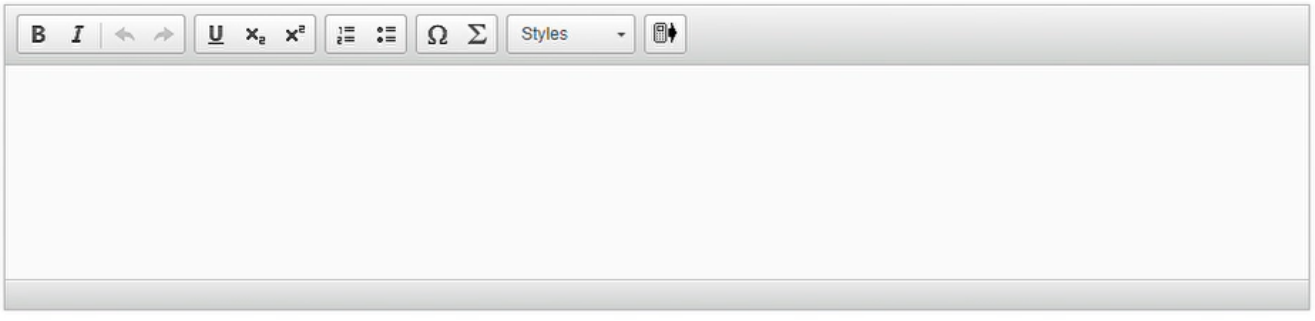
Use information from the chart to **determine** the **range** of pH possible for the carbon dioxide solution.

Question 2e (2 marks)

There is evidence of specific chemical reactions on the surface of some exoplanets. One of these reactions is the decomposition of carbon dioxide:

$$2CO_2(g) \rightarrow 2CO(g) + O_2(g)$$

Suggest why the rate of the decomposition reaction increases the closer the exoplanet is to the star it orbits.



Question 2f (2 marks)

Carbon dioxide can be re-formed in the presence of catalysts.

$$2CO(g) + O_2(g) \xrightarrow{\text{Catalyst}} 2CO_2(g)$$

Outline the role of a catalyst in a chemical reaction.

Question 2g (2 marks)

Several nations are showing renewed interest in going back to the Moon. So far, they have sent un-manned probes to orbit or land on the Moon. Future missions could involve building a space station or mining the Moon's resources.

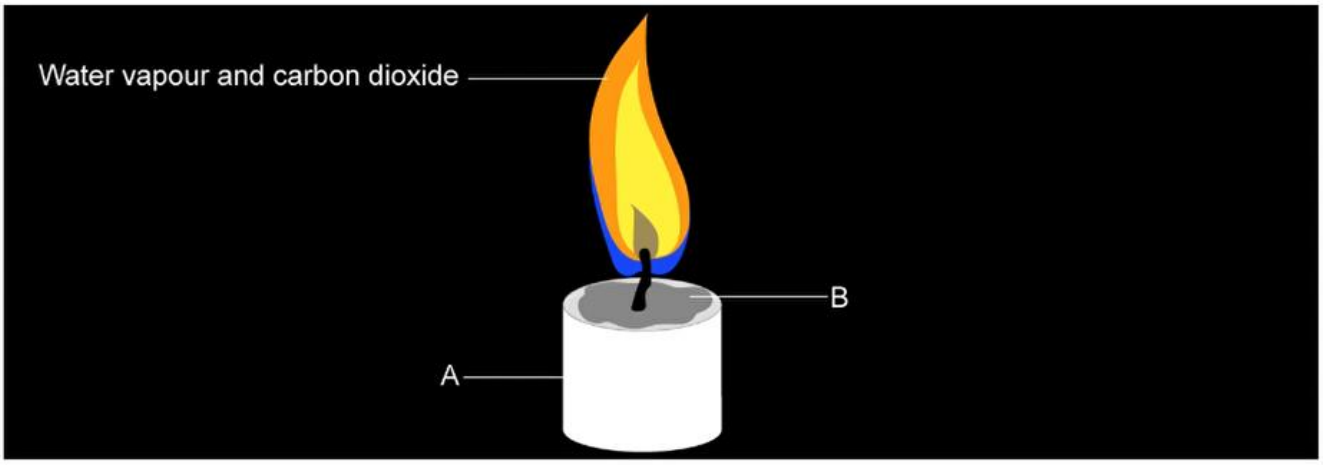
Suggest two additional reasons why nations are interested in going back to the Moon, and are launching these missions.

Question 3 (16 marks)

Candles can be used for a variety of reasons, such as relaxing or in ceremonies. The length of time that a candle burns will determine its use.

Question 3a (2 marks)

Several changes occur when a candle burns.



©

Select the state of the candle at A and B in the diagram above.

A: Select B: Select

Question 3b (2 marks)

Wax is composed of hydrocarbons with the formula $C_{25}H_{52}$. Another hydrocarbon in the same class is C_5H_{12}. **State** the name and chemical class of C_5H_{12}.

Name:

Chemical class:

Select

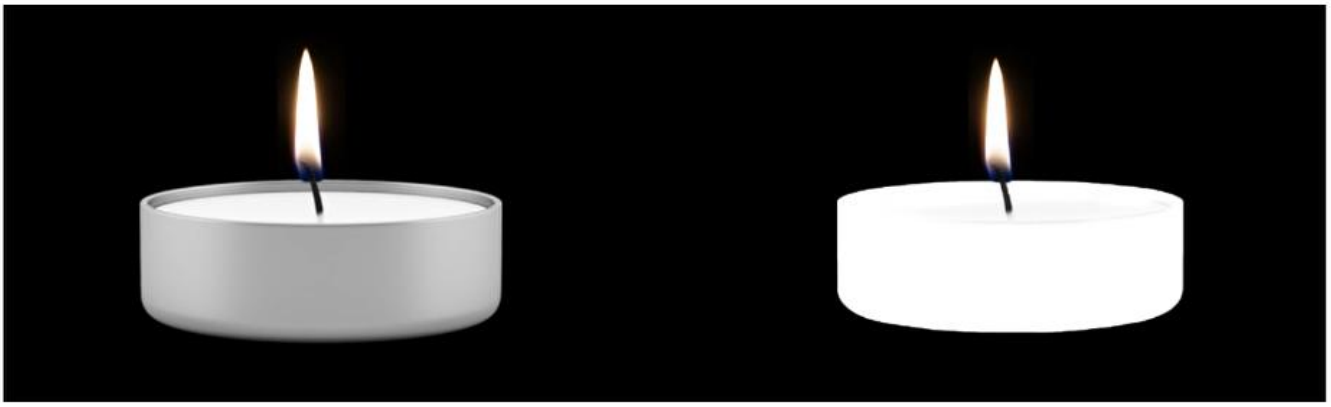
Question 3c (2 marks)

Select numbers to balance the equation showing complete combustion of C_5H_{12}.

? $C_5H_{12}(l)$ + ? $O_2(g)$ → ? $CO_2(g)$ + ? $H_2O(g)$

Question 3d (3 marks)

A student wanted to compare the time it took different candles to burn. One candle was in a metal holder and the other candle was not.



Formulate a hypothesis for the student's question.

If the candle is contained in a metal holder then the time taken for the candle to burn will Select because:

Question 3e (1 mark)

A student wanted to investigate the effect of altitude on how quickly a candle burns, so she took some candles on a camping trip up a mountain.

Her processed data is shown in the table below.

Altitude / m	Rate of wax combustion / g min^{-1}
990	0.161
2700	0.130
3200	0.110
3720	0.106
4700	0.0906

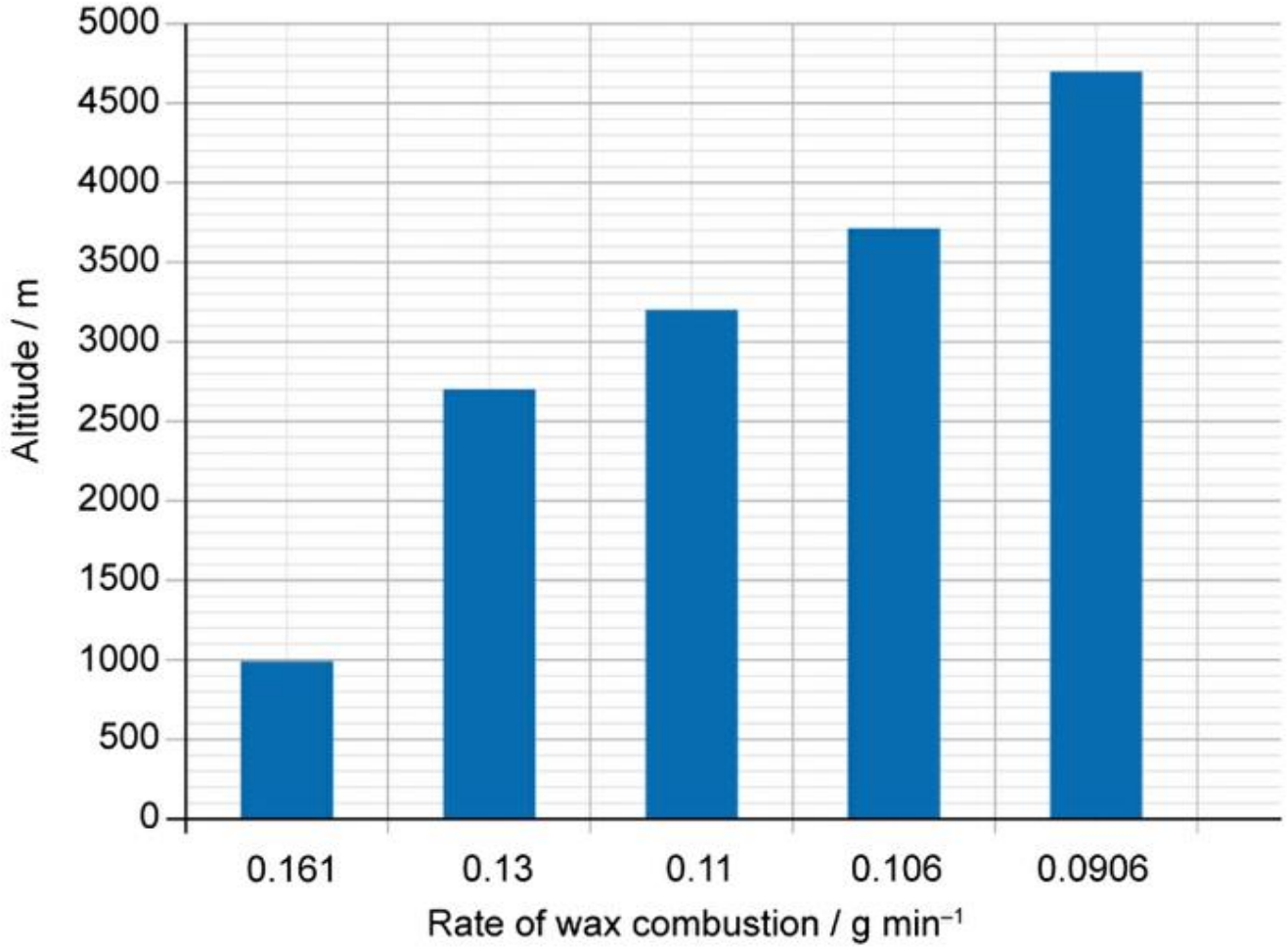
State the rate of wax combustion at an altitude of 3720 m in standard form.

B I U x_2 x^2 Ω Σ Styles

Question 3f (2 marks)

The student produced a graph of her results, which is shown below.

Rate of wax combustion with change in altitude



Identify two errors in the presentation of the data in the graph above.

B I U x_2 x^2 Ω Σ Styles

Question 3g (4 marks)

The student repeated the experiment the following day. The results are in the table below.

Altitude / m	Rate of wax combustion / g min^{-1}	
	Day 1	Day 2
990	0.161	0.148
2700	0.130	0.119
3200	0.110	0.108
3720	0.106	0.095
4700	0.0906	0.082

The equipment set up on each day is shown below:

Equipment used on day 1

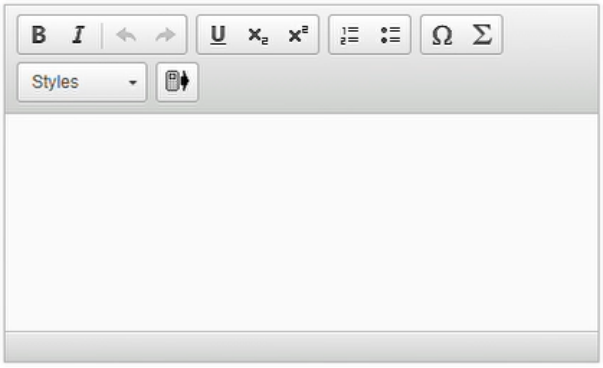
©

Equipment used on day 2

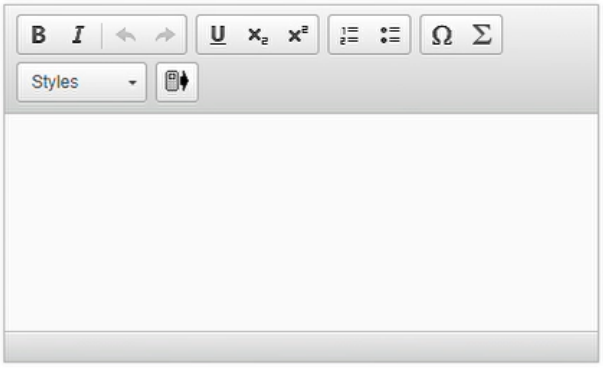
©

Outline why the sets of results are different and **suggest** how the **rate** of wax combustion would be affected.

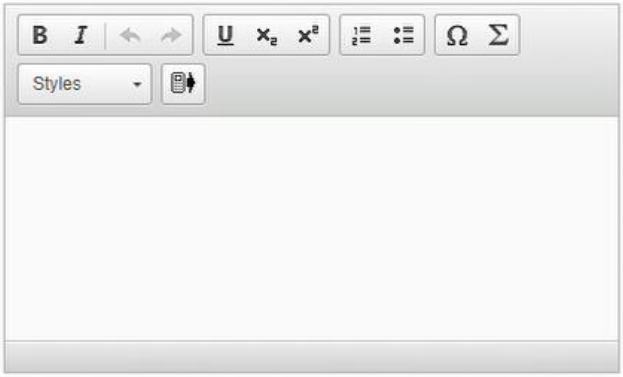
Reason 1:



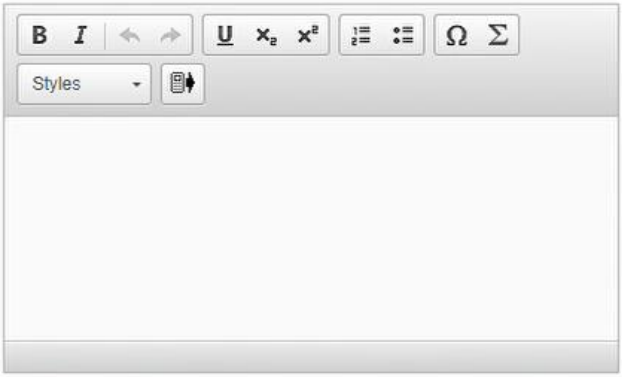
Reason 2:



How the rate of wax combustion would be affected:



How the rate of wax combustion would be affected:



Question 4 (10 marks)

Some candles have fragrance added to them to provide relaxation or a memory of an experience. A student did a comparison between two candles: one fragranced with vanilla and one fragranced with strawberry.

Vanilla candle
in a glass jar

Strawberry candle
in a glass container

©

His results are shown below:

Vanilla candle in a glass jar

Container	Mass / g	Burn time / hours
1	185	29.0
2	185	24.3
3	185	28.0
Average		27.1

Strawberry candle in a glass container

Container	Mass / g	Burn time / hours
1	114	32.0
2	114	28.5
3	114	29.5
Average		

Question 4a (2 marks)

State the independent variable and the dependent variable in **this** investigation.

Independent variable:

Dependent variable:

Question 4b (2 marks)

Calculate the average burn time for the strawberry candle.

Styles

Question 4b (2 marks)

Calculate the average burn time for the strawberry candle.

B I U x_2 x^2 Ω Σ Styles

Question 4c (1 mark)

The student's friend examined the data and suggested that the average burn time for a vanilla candle should be 28.5 hours and not 27.1 hours. **Suggest** a reason for this different average time.

B I U x_2 x^2 Ω Σ Styles

Question 4d (3 marks)

The student hypothesized that the candle with vanilla fragrance would take a longer time to burn because the candle had a smaller surface area. Use the data in the tables above part (a) to **evaluate** the validity of the student's hypothesis.

B I U x_2 x^2 Ω Σ Styles

Question 4e (2 marks)

Suggest one improvement to increase the validity of the method. **Justify** your answer.

Improvement:

B I U x_2 x^2 Ω Σ Styles

Justification:

Question 5 (12 marks)

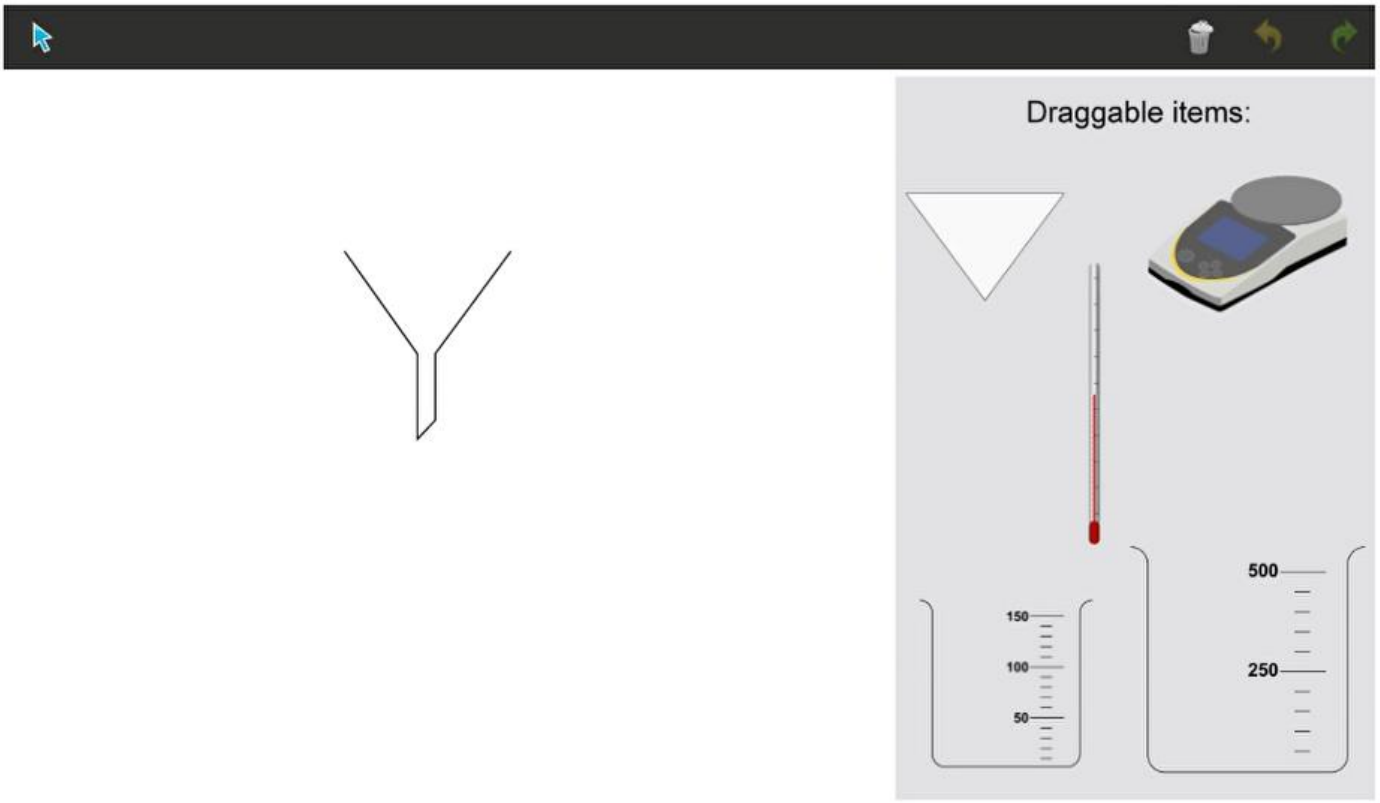
Coffee is one of the most widely consumed drinks in the world.

Coffee is produced by grinding coffee beans and then extracting the coffee from the grounds by filtration. This produces approximately six million tonnes of waste coffee grounds that go to landfill each year. Companies have been looking for different ways to use coffee grounds. Examples include their use in the production of biofuels, in fertilizers and as a means of capturing greenhouse gases such as methane and carbon dioxide. An emerging use is compacting coffee grounds to make coffee logs. Coffee logs can be burned in place of wood to produce energy.

The first stage of making coffee logs is to treat the grounds with an organic solvent. Esters, which give the coffee smell, dissolve in the solvent. The mixture is then filtered, producing a liquid fraction and a solid fraction.

Question 5a (2 marks)

Organise the equipment below to show how to separate the solid and liquid fractions from the coffee ground/solvent mixture.



Question 5b (1 mark)

Organic solvents are chemicals which can be used to dissolve a solute. Hexane is an example of an organic solvent. **Select** the hazard symbol for hexane.

A. 

B. 

C. 

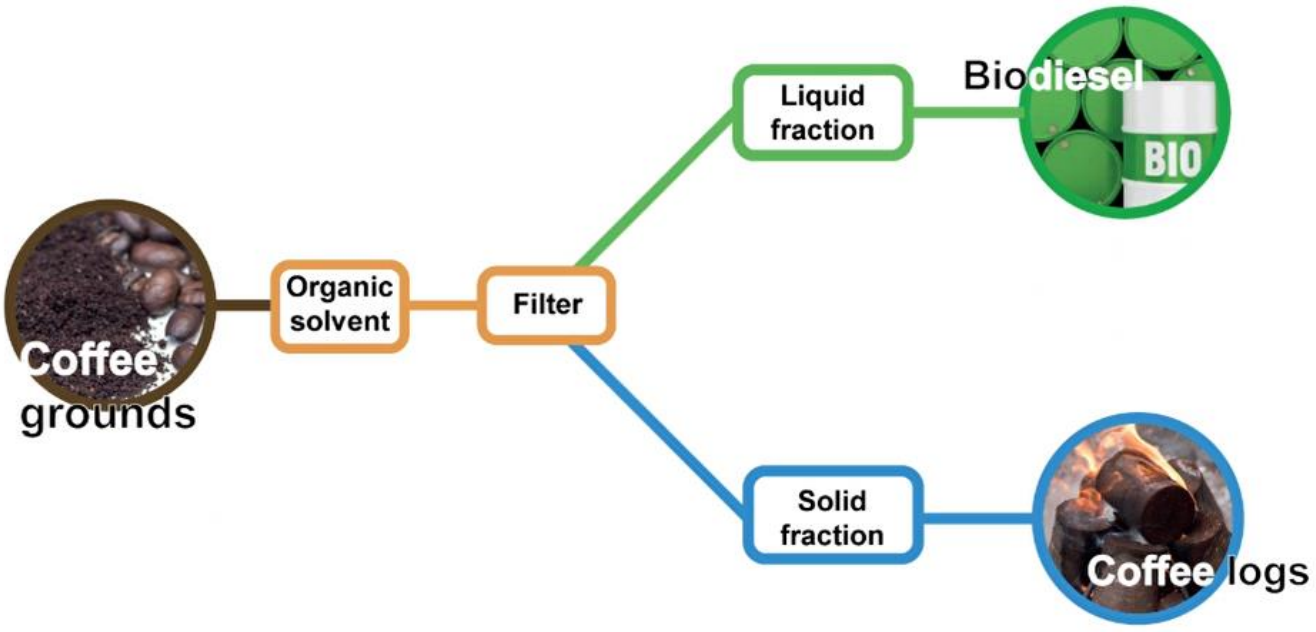
D. 

©

Select

Question 5c (6 marks)

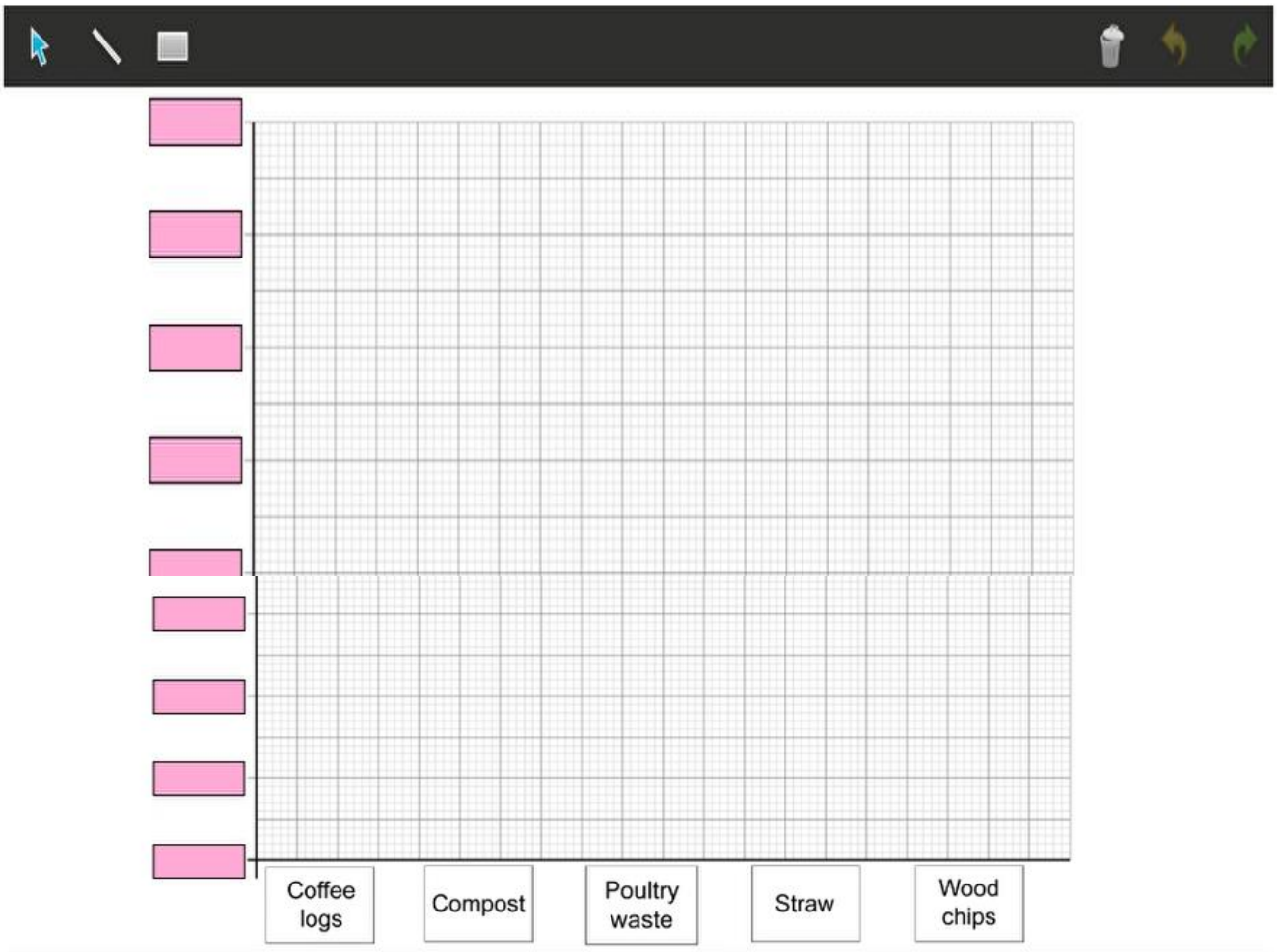
Once the coffee grounds have been treated with the organic solvent, they can be treated further to produce biodiesel or solid fuel, as shown in the diagram below.



The solid fraction is often referred to as biomass. In this process, the biomass is made into coffee logs. The coffee logs can be burned to produce energy. The table below shows some data for different forms of biomass compared with coffee logs.

	Straw	Wood chips	Compost	Poultry waste	Coffee logs
Energy content / MJ tonne^{-1}	14 400	13 000	11 500	10 800	18 000
Cost / US$ tonne^{-1}	45	110	33	16	118
How easy to burn?	hard	easy	hard	hard	easy

Plot the energy content of biomass fuels data shown in the table. You should **label** the axes and use the tools in the drawing palette to create your graph.


Coffee logs
Compost
Poultry waste
Straw
Wood chips

Title:

x axis:

y axis:

Question 5d (1 mark)

The coffee logs and the biodiesel obtained from coffee grounds can be used to produce energy.
Select the type of process used to produce energy.

Select

Question 5e (2 marks)

Suggest why it is important to recycle coffee grounds. **Justify** your answer.

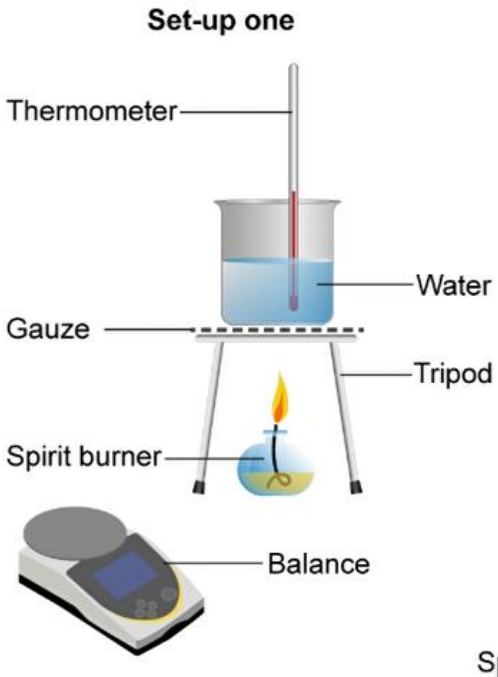
B I U x_2 x^2 Ω Σ Styles

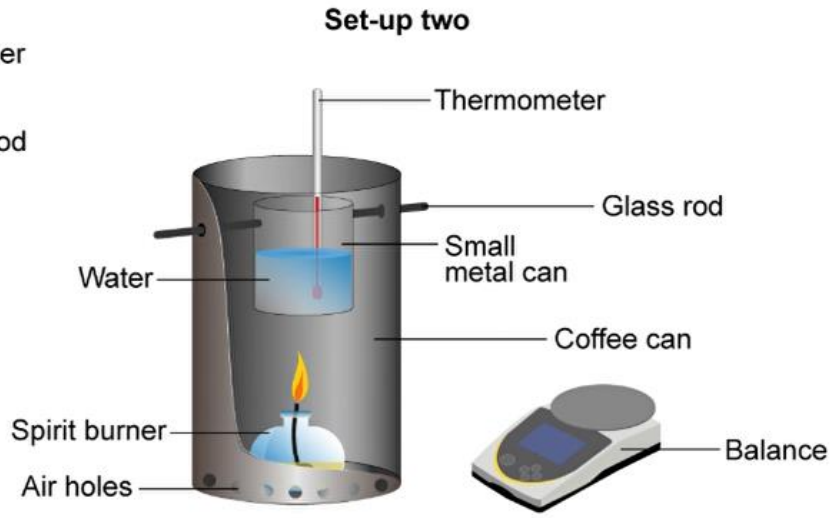
Question 6 (16 marks)

Different fuels release different amounts of energy when they burn, depending on their chemical composition. Ideally, a good fuel will release more energy per unit mass when burned. This is a simplified way of stating energy density. Energy density can be determined by measuring the mass change of the fuel burned to produce a specific temperature increase.

The diagram below shows two ways to set up equipment to determine the energy density of a liquid fuel. A student wants to investigate the energy density of five new **solid** fuels A, B, C, D and E.

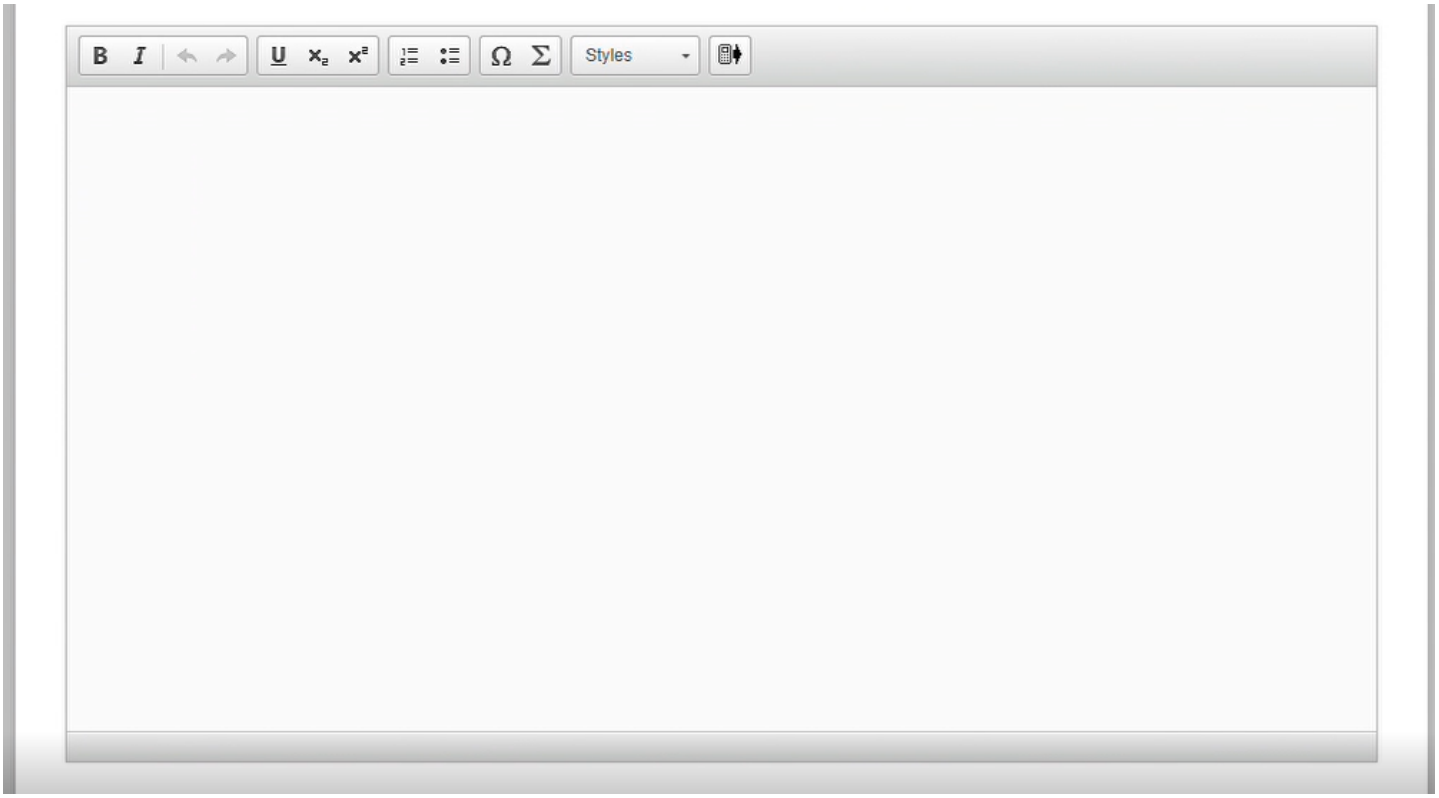
and E.





Design an investigation to find out which fuel has the highest energy density. In your answer, you should include:

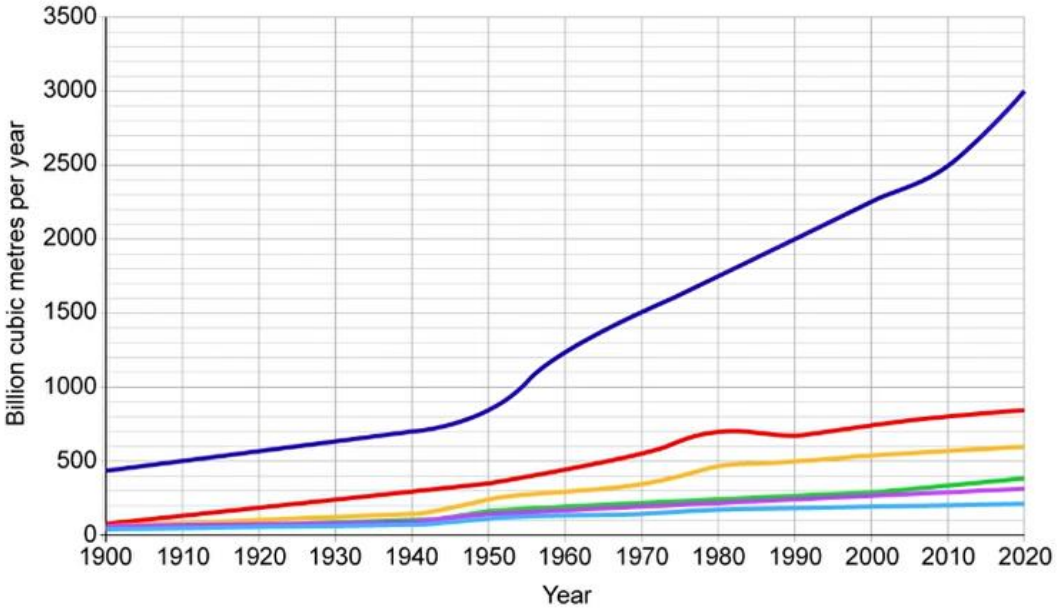
- an identification of the independent, dependent and two control variables
- a justification of which equipment set-up you will use
- details of the method to allow you to collect sufficient data
- how you will ensure that your method is safe.



Question 7 (12 marks)

Global water consumption has changed dramatically over the last 120 years. The graph below shows the change in water consumption for each region during this period.

Global water consumption 1900–2020



Question 7a (1 mark)

Use the graph to **identify** the region that had the smallest increase in water consumption between 1900 and 1980.

Question 7b (2 marks)

Use the graph to **state** the water consumption in Asia in 1995.

Question 7c (1 mark)

Suggest a reason why the water consumption in Asia has increased dramatically during the period shown on the graph.

Over 15 million people in the United States of America (USA) obtain their water from private water wells. The water in the wells comes from groundwater. When it rains, any water that is not used by plants or trees flows through layers of soil and rocks and into the ground. This is the water that is used in water wells. If the ground is contaminated due to pesticides, fertilizers, sewage, landfills or other urban runoffs, then the water also becomes contaminated.

The table below shows contaminants that may be present in water from wells and the symptoms or diseases they cause.

Contaminant	Size / μm	Source	Symptoms or diseases
E. coli	0.5–2	Bacteria from waste food contamination or broken sewage pipes	Diarrhea, urinary tract infections, pneumonia
Giardia	4–6	Parasites from broken sewage pipes	Diarrhea, cramping, nausea, vomiting
Hepatitis A	0.055–0.065	A virus from broken sewage pipes	Can cause major liver disease
Heavy metals	<0.001	Mineral deposits, plumbing, mining	Liver damage, kidney damage or cancer
Fuel	<0.005	Industrial areas or fuel dumping	Irritation to digestive system
Nitrates	<0.005	Fertilizers	Can reduce the blood's ability to carry oxygen. In infants, this can be fatal.

Kamal and Sandra have moved into a home in the USA that has a private water well. They need to purchase a filtration device to use in their home to make their water safe for drinking. They are choosing between a ceramic core unit and an activated carbon unit. The information for each unit is shown in the table below. An individual would typically use around 2 dm^3 of water a day for drinking and cooking.

	Ceramic core unit	Activated carbon unit
Cost of unit / US$	166.00	92.00
Cost of filters / US$	67	26
Filter life span / months	12	6
Water flow / $dm^3\ min^{-1}$	1.8–3.8	1.2–2.5
Filter pore size / μm	0.22	0.60
Operating temperature / °C	5–30	–1–51

Question 7d (2 marks)

Select the most important feature of the filter that is needed in a filtration device. **Justify** your answer.

Select

Justification:

B I U x_2 x^2 Ω Σ Styles

Question 7e (6 marks)

Using the information in the tables above, **explain** the advantages and disadvantages of using a ceramic core unit compared to an activated carbon unit for personal drinking, when obtaining water from a private well. In your answer, you should:

- describe the advantages and disadvantages of a ceramic core unit compared to the activated carbon unit
- justify which would be the most suitable filter for Kamal and Sandra.

B I U x_2 x^2 Ω Σ Styles

Question 8 (13 marks)

The video below shows some different techniques that can be used to make water safe to drink.

Video | Script

Access to clean drinking water is a global issue, as increasing industrialization can lead to contamination of lakes, rivers and streams.

With a growing world population and as cities grow, access to drinking water becomes even more important.

In more economically developed countries, unclean water is treated to produce clean water, which is used for drinking, bathing, laundry and washing dishes.

Urban water treatment is a large-scale process that takes place in water treatment facilities.

Surface water can be treated to make clean drinking water using different techniques. A common technique uses microfiltration and ultrafiltration to remove microorganisms and suspended solids like sand, dirt and debris. This is a low-cost process.

A newer technology uses nanofiltration membranes. The rate of water treatment is faster with this method than with microfiltration, so more water can be treated in a cost-efficient manner. However, the industrial facility is expensive to construct due to the price of the nanofiltration components.

Our sources of surface water and groundwater are fast running out because of population growth and climate change. Seawater is the most abundant source of water on Earth. There are 182×10^9 dm^3 of seawater for each person on Earth. However, the salt content makes it unsuitable for drinking.

Desalination by reverse osmosis is used to treat seawater to make it safe to drink. It is an expensive and energy-intensive technology.

The removed ions are returned to the sea, potentially increasing the temperature and salt concentration of seawater.

Both nanofiltration and desalination allow for the filtration of heavy metals, such as nickel and lead. In reverse osmosis, the heavy metals can clog the membranes.

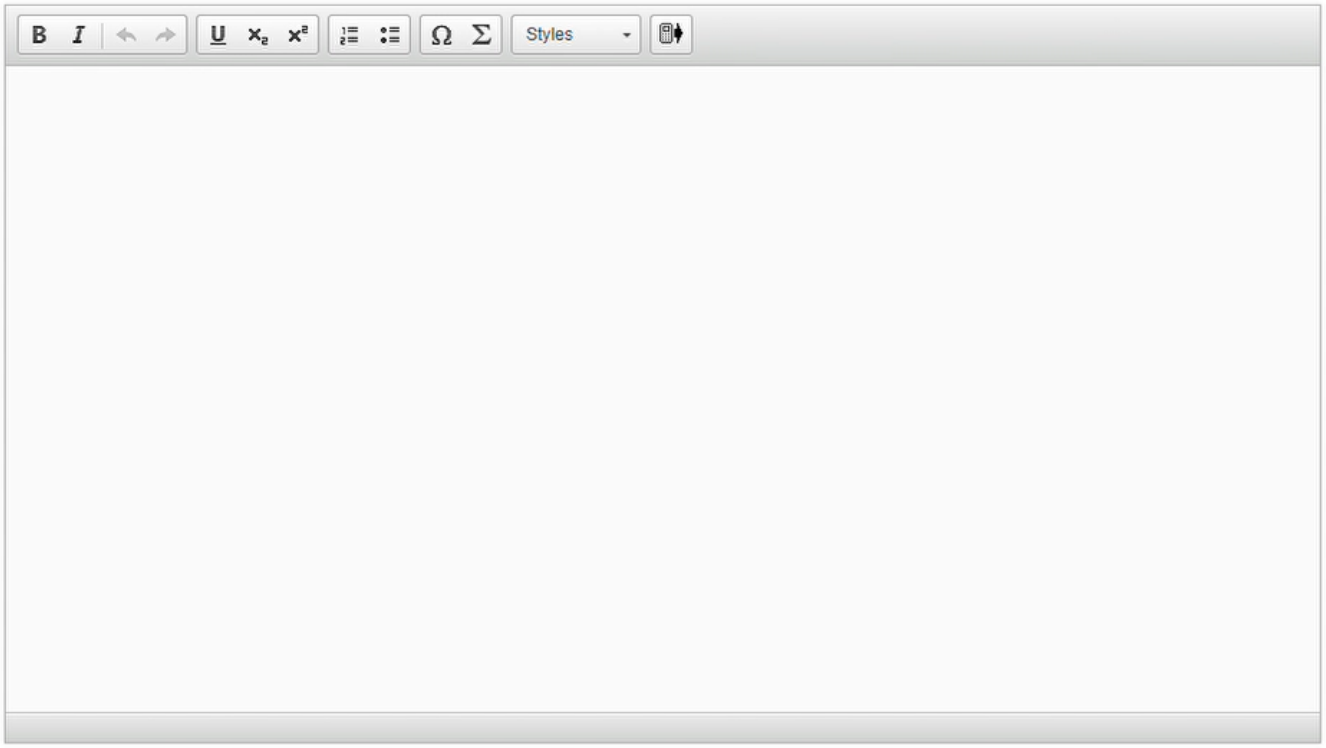
The table below shows some information about some different technologies used for water treatment. The volumes in this table are very large. For comparison, the volume of any Olympic-sized swimming pool is 25 000 m^3.

Method	Filter	Functionality	Lifespan	Output / m^3 per day	Cost of water / US$ per 100 m^3			
					Initial building cost	Replacement parts	Labour costs to run the facility	Total
Microfiltration and ultrafiltration	Metal screen filter	•Removes suspended solids •Removes microorganisms	15 years	8 000	0.15	0.00	0.03 Low skill	0.18
Nanofiltration	Polyester membrane	•Removes suspended solids •Removes Microorganisms •Removes nickel and lead ions	3–5 years	100 000	6.27	2.34	0.30 Low skill	8.91
Desalination by reverse osmosis	Membrane	•Removes suspended solids •Removes microorganisms •Removes nickel and lead ions •Can be used with salt water	2–3 years	250 000	3.66	0.12	1.47 High skill	5.25

The city planners in a coastal region are planning for expansion over the next 10 years. One of their priorities is to ensure an adequate water supply for the increased population. The city is located next to the ocean with farming land next to the city boundaries. The main industry in the city is metal recycling.

Using your knowledge of water purification techniques, information from the video and your wider MYP studies, **discuss** and **evaluate** the different technologies available for water treatment. In your answer, you should include:

- a comparison of the economic implications of each of the three technologies
- an example of the environmental impact of each of the three technologies
- a suggestion of which technology would not be suitable for the city
- an outline of the social aspects of the building and running of a water purification facility
- an appraisal of which purification process should be used for the city.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