Eton College King's Scholarship Examination 2023

SCIENCE 1 (Theory)

(60 minutes)

*Candidate Number:*_____

Remember to write your candidate number on every sheet in the space provided.

*You should attempt **ALL** the questions. Write your answers in the spaces provided.*

The maximum mark for each question or part of a question is shown in square brackets.

Calculators are allowed. In questions involving calculations, all your working must be shown.

Total Marks Available: 70

For examiners' use only.

|	1	2	3	4	5	TOTAL [70]

Do not turn over until told to do so.

1. This question is about forces.

A rocket similar to that which launched NASA's space shuttle has a total mass before take-off of 2000 tonnes (1 tonne = 1 x 10^3 kg), and provides a thrust at take-off of 24 MN (1 MN = 1 x 10^6 N).

The thrust remains constant and g, the gravitational field strength, remains constant at 10 N/kg. Air resistance can be neglected.

(a) Label the diagram below using arrows to represent the forces acting upon the rocket during take-off. Include numerical values – *calculations are required.*   **[4]**
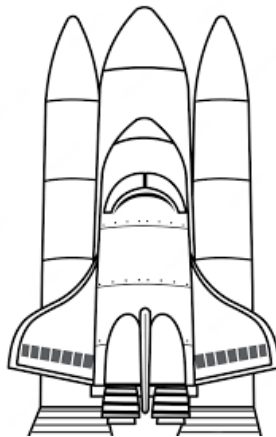
Newton's second law of motion states that if an object has an unbalanced force, F, acting upon it the object will accelerate in proportion to its mass, m, according to the formula:

$$F = ma$$

(b) Calculate the acceleration, a, of the rocket at take-off. Your answer should include a suitable unit.

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_____ **[3]**

The acceleration of an object can be considered to be the *change in speed* of an object per second.

(c) To reach orbit, the shuttle has to achieve a speed of 8.0 km/s. Calculate the time taken, in seconds, for the shuttle to achieve this speed given the acceleration calculated in (b).

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_____ **[3]**

In fact, the gravitational field strength is not constant during the rocket's journey. The graph below illustrates the variation in the Earth's gravitational field with height above the Earth's surface.

Variation of gravitational field strength from surface of Earth
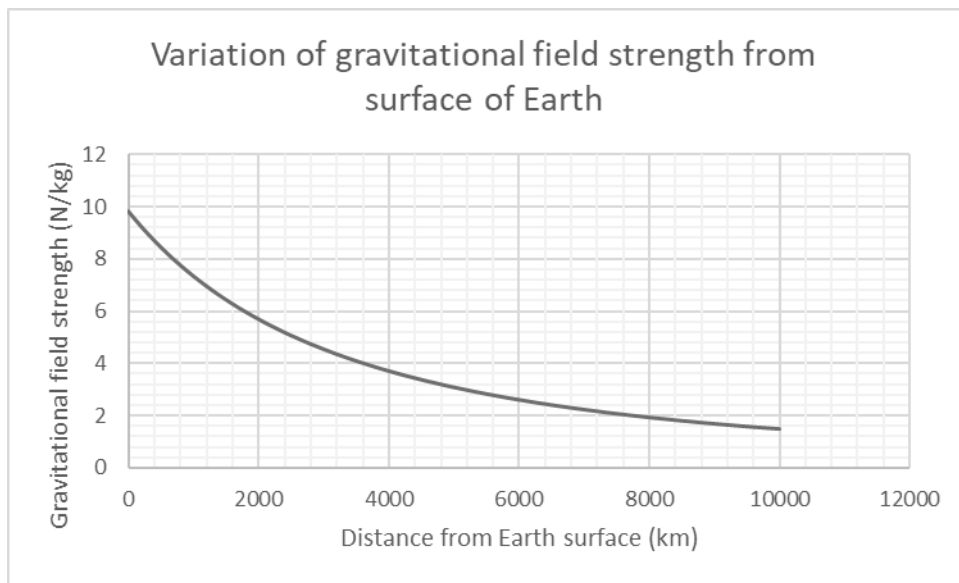
(d) In part (c) we assumed that gravitational field strength, g, was constant. State the effect of varying gravitational field strength on the time taken for the rocket to reach a speed of 8 km/s.

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_____ **[1]**

(e) Using your understanding of physics, explain your answer to part (d).

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_____ **[3]**

2. This question is about organisms.

One of the ways scientists can confirm that organisms belong to a particular Kingdom is by looking at their cells. The cells of organisms in different Kingdoms will have similarities and differences in their structures.

(a) Complete the table below by placing a tick in the box if a structure is present, and a cross if it is not.

Organelle	Plant Cell	Animal Cell
Cell Membrane		
Cell Wall		
Chloroplast		
Mitochondrion		
Nucleus		

[2]

(b) Fungi are organisms that belong to a kingdom of their own, separate to plants and animals. They share features with both. Fungal cells have cell membranes, cell walls, mitochondria and nuclei. They can be single-celled or multicellular.
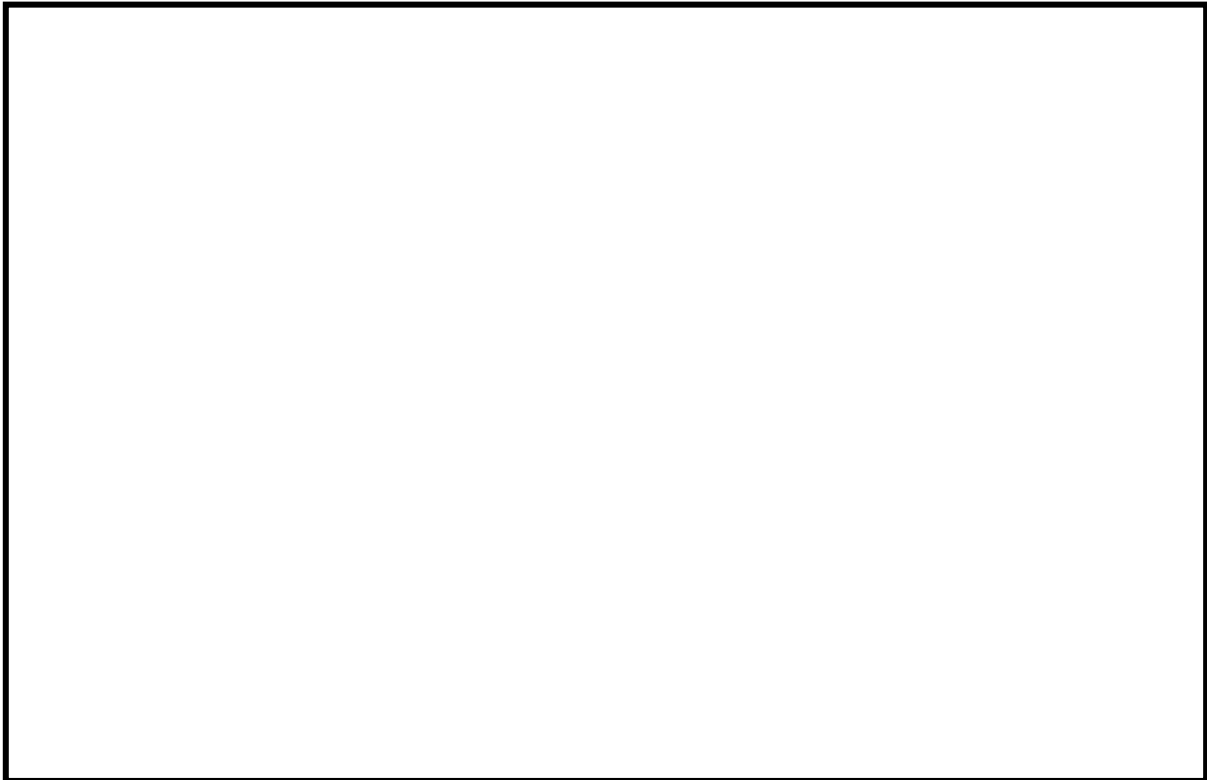
Discuss whether fungi are more closely related to animals or plants.

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_____ **[2]**

(c) Many fungi act as decomposers. They are responsible for breaking down and consuming any dead organisms that don't get eaten by another consumer. Read the passage below, then produce a food web featuring every organism mentioned, **plus fungi.**

"The grey squirrel is an invasive species in the United Kingdom. Owing to its size, it can often outcompete native red squirrels for food. Both like to store acorns from oak trees for the winter months. Despite its many advantages, the grey squirrel is still hunted by foxes just as much as the red squirrel is. Foxes will supplement their diets with rabbits, which are easy to hunt as they cannot climb oak trees and often forage for grasses at ground level."

[4]

(d) Suggest what would happen to the population of fungi in the ecosystem from part (c), above, if a viral disease spread through the squirrel population and killed all the squirrels.

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_____ [2]

(e) A lichen is an organism composed of a fungus and a cyanobacterium, living in a symbiotic relationship.

There are three types of symbiotic relationships:

- Mutualism – where two different species benefit each other.
- Commensalism – where two species have no significant impact on each other.
- Parasitism – where one species has a negative effect on another.

In this case, the fungus relies on the cyanobacterium to live. Cyanobacteria are able to live as part of a lichen with a fungus, or on their own entirely.

Design an experiment that would confirm whether the parts of a lichen (fungus and cyanobacterium) were exhibiting a mutualistic, commensal, or parasitic relationship.

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_____ **[4]**

3. This question is about plants.

Photosynthesis is a process by which plants, algae and certain bacteria use the energy from sunlight to make food.

(a) Write the word equation for photosynthesis in the space below.

_____ **[1]**

(b) Explain why photosynthesis is such an important process for life on Earth.

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_____ **[3]**

One of the most famous experiments to investigate photosynthesis in plants was carried out by the chemist Jan Baptist van Helmont in 1648. He weighed a young willow tree before planting it in a large pot containing a known mass of dry soil, after which he did nothing other than water it regularly for the next five years. After five years, he discovered that the willow tree weighed 74 kg more than it did at the start and that the dry mass of the soil was largely unchanged, having declined just a few grams. Van Helmont concluded that the plant had grown by drinking water.

(c) Explain whether or not you agree with his conclusion.

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_____ **[3]**

(d) Suggest a reason why the mass of the soil had declined.

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_____ **[2]**

Another experiment was carried out to investigate the effect of light intensity on gas exchange in two different plant species. The graph below shows the volume of CO_2 (carbon dioxide) taken up or given out per hour at different light intensities for the two species, A and B.
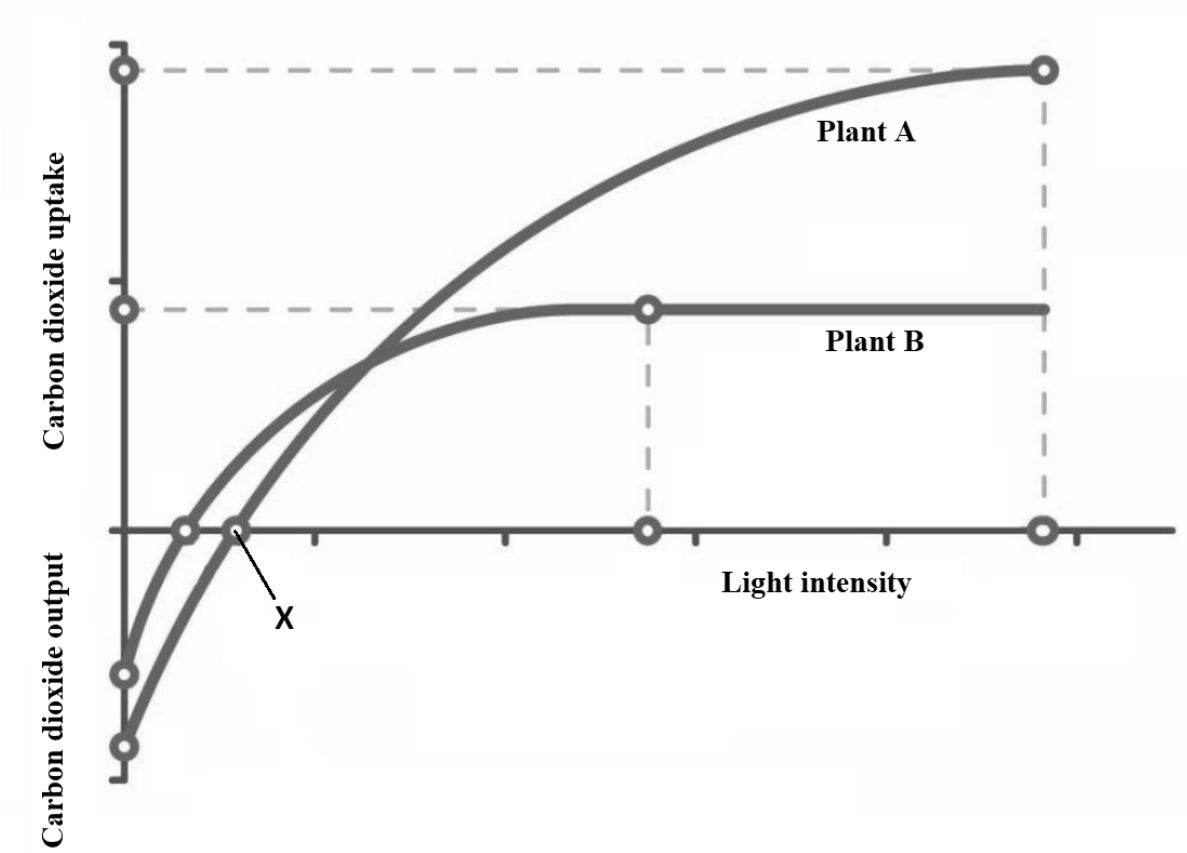
(e) Explain why there is no net gas exchange at point X for plant A.

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_____ **[2]**

(f) One of these two plant species has evolved to survive, grow, and reproduce on the forest floor, below a canopy of taller plants. State which one you think it is and explain your choice using the information provided.

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_____ **[3]**

4. This question is about carbon dioxide and its associated chemical reactions.

Some of the reactions described are reversible: they can go in either direction, depending on the conditions. The symbol $\rightleftharpoons$ indicates a reversible reaction.

Calcium carbonate occurs in chalk and limestone. It is used to produce the solids calcium oxide and calcium hydroxide. Calcium carbonate decomposes when strongly heated in an open container:

$$CaCO_3 \rightleftharpoons CaO + CO_2 \qquad \textbf{Reaction 1}$$

Calcium oxide reacts readily with water to form calcium hydroxide:

$$CaO + H_2O \rightarrow Ca(OH)_2 \qquad \textbf{Reaction 2}$$
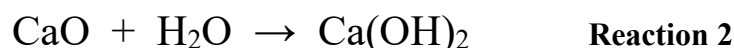
"Limewater" is a solution of calcium hydroxide in water. Its reaction with carbon dioxide is:

$$Ca(OH)_2(\ ) + CO_2(\ ) \rightarrow CaCO_3(\ ) + H_2O(\ ) \qquad \textbf{Reaction 3}$$

(a) State symbols, (s, l, g or aq), are sometimes included in chemical equations to indicate whether each substance is present as a solid, a liquid, a gas, or dissolved in water as a solution (aqueous). Fill in the empty brackets in the equation for **Reaction 3** to show the correct state symbols. **[1]**

(b) Some calcium oxide was placed in a dish on a laboratory bench and weighed each day. Suggest two reasons why an increase in mass might be observed.

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_____ **[2]**

(c) It has been suggested that **Reaction 3** could be used to remove carbon dioxide from the atmosphere and so prevent global warming. Use the information in the question to suggest one difficulty with this approach.

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_____ **[1]**

Calcium carbonate, carbon dioxide and water will combine together in a reversible reaction to produce an aqueous solution of calcium hydrogencarbonate, $Ca(HCO_3)_2$.

$$CaCO_3 + CO_2 + H_2O \rightleftharpoons Ca(HCO_3)_2 \qquad \textbf{Reaction 4}$$
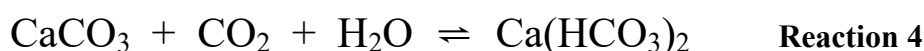
(d) Carbon dioxide was bubbled into a test tube of limewater. The bubbling was continued for a long time. What would you expect to see?

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_____ **[2]**

(e) Tap water containing dissolved calcium hydrogencarbonate is known as "hard water". Abigail heated some hard water in an evaporating basin, and then told her teacher that she had produced some solid calcium hydrogencarbonate. The teacher said this was not correct. Explain what had happened.

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_____ **[2]**

A "phase diagram" is used to show at which temperatures and pressures a substance will exist as a solid, a liquid or a gas. The phase diagram for carbon dioxide is shown. One "atmosphere" is the normal pressure at sea level on the Earth. The scales on the axes have been adjusted to make the important features of the diagram stand out clearly.
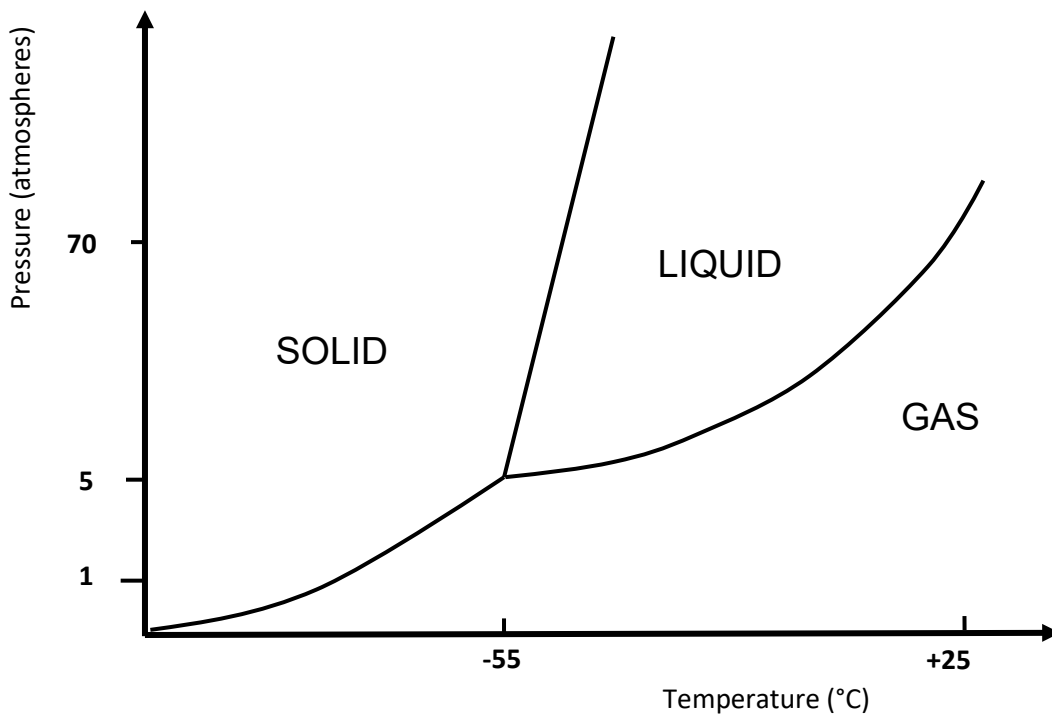
(f) Use the phase diagram to explain what will happen if a test tube of carbon dioxide gas is cooled to a very low temperature. Show on the diagram how you deduced your answer.

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_____ **[2]**

(g) Explain how a fire extinguisher, kept in a building at 25°C, can contain liquid carbon dioxide.

_____ **[1]**

(h) Beatrice commented, "The phase diagram tells me that liquid carbon dioxide is less dense than solid carbon dioxide". Explain how Beatrice deduced this from the diagram. You may add notes to the diagram if this helps your answer.

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_____**[2]**

(i) Some bacteria can produce energy from the reaction of carbon dioxide with hydrogen:

$$CO_2 \; + \; \text{.......} H_2 \; \rightarrow \; CH_4 \; + \; \text{......} H_2O \qquad \textbf{Reaction 5}$$
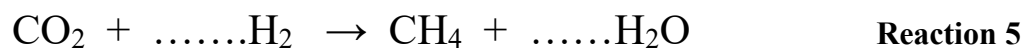
The equation shown needs to be balanced, by adjusting the numbers of molecules so that for each type of atom, the total number present before the reaction is the same as the total number in the products. Add numbers to the two dotted lines to balance the equation.

[1]

5. This question is about rates of reaction.

The rate of a chemical reaction between magnesium and hydrochloric acid is measured by Cassandra. Cassandra uses the following experimental set up with the hydrogen gas produced being collected over water in a measuring cylinder:
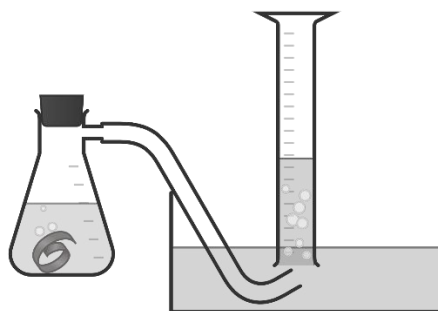
The temperature is maintained at a steady 25°C by a heater, and a magnetic stirrer ensures that the acid concentration is even throughout. The magnesium is present as a coil of thin ribbon, so all sides are exposed to the acid. There is excess acid present.

The following results are obtained:
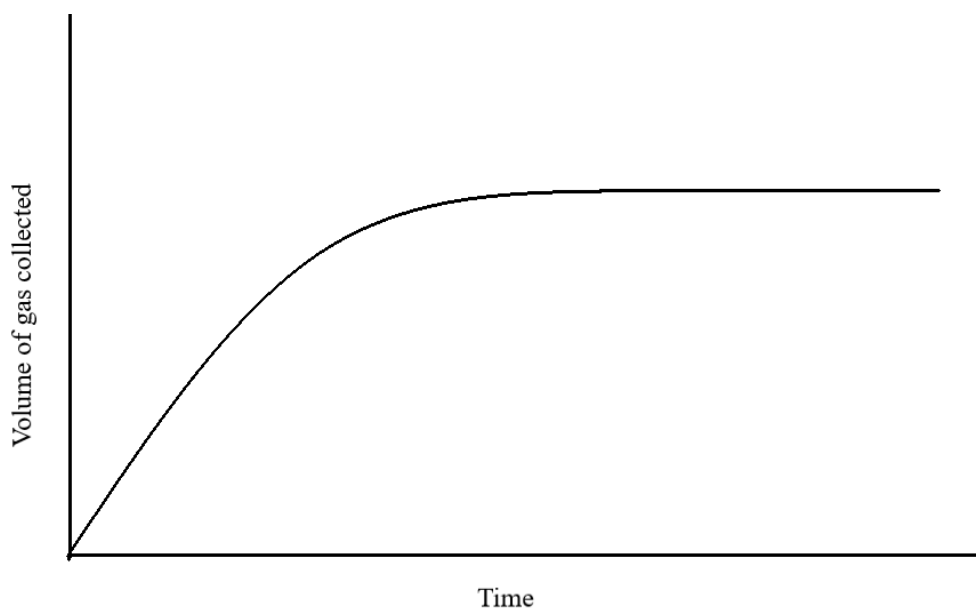
(a) Explain, in terms of particles, the shape of the graph.

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_____[3]

The reaction is performed again with everything the same except that the magnesium ribbon is half the length.

(b) State and explain in terms of particles what is different about the new graph plot of results compared to the old graph plot (you may draw on the graph plot above if you wish).

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_____**[3]**

Another student, Thomas, decides to use the same equipment to examine the rate of reaction between calcium carbonate and hydrochloric acid, collecting carbon dioxide gas this time.

(c) Explain what would be different about the shape of the graph plot obtained in this case.

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_____**[3]**

A third student, William, researches into reactions between two chemicals which take place in solution.
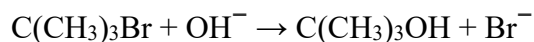
The equation for the reaction is:

$$CH_3CH_2CH_2CH_2Br + OH^- \rightarrow CH_3CH_2CH_2CH_2OH + Br^-$$
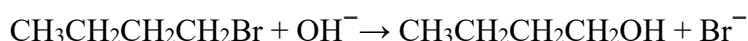
William finds that when the concentration of $CH_3CH_2CH_2CH_2Br$ is doubled the rate doubles and when the concentration of OH^- doubles the rate also doubles. William theorises that this is because the reaction takes place in just one step and so depends on a collision between $CH_3CH_2CH_2CH_2Br$ and OH^-.

He writes the relationship between rate and concentration down as a rate equation:

$$Rate = k[CH_3CH_2CH_2CH_2Br][OH^-]$$

$[CH_3CH_2CH_2CH_2Br]$ means 'concentration of $CH_3CH_2CH_2CH_2Br$' and k is a constant of proportionality.

He then looks at a similar reaction:

$$C(CH_3)_3Br + OH^- \rightarrow C(CH_3)_3OH + Br^-$$

This time William finds that the rate doubles when the concentration of $C(CH_3)_3Br$ doubles, but is unaffected by the concentration of OH^-
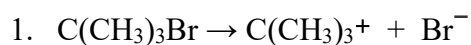
(d) Write the rate equation for the reaction.

_____**[1]**

He says that this means that the reaction cannot take place in a single step.

(e) Explain why William is correct.

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_____**[2]**

William then suggests that the reaction takes place in two steps:

1. $C(CH_3)_3Br \rightarrow C(CH_3)_3^+ + Br^-$

2. $C(CH_3)_3^+ + OH^- \rightarrow C(CH_3)_3OH$

Further research shows this to be correct.

(f) Explain which of the two steps must be the slower.

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_____**[2]**

[End of paper]