Eton College King's Scholarship Examination 2022

SCIENCE 1 (Theory)

(60 minutes)

Candidate Number:_____

<u>Remember to write your candidate number on every sheet in the space provided.</u>

*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 solutions.

A solution can be prepared by dissolving a solute in a solvent, with the rate of dissolving being affected by a range of different factors, such as the temperature of the solvent.

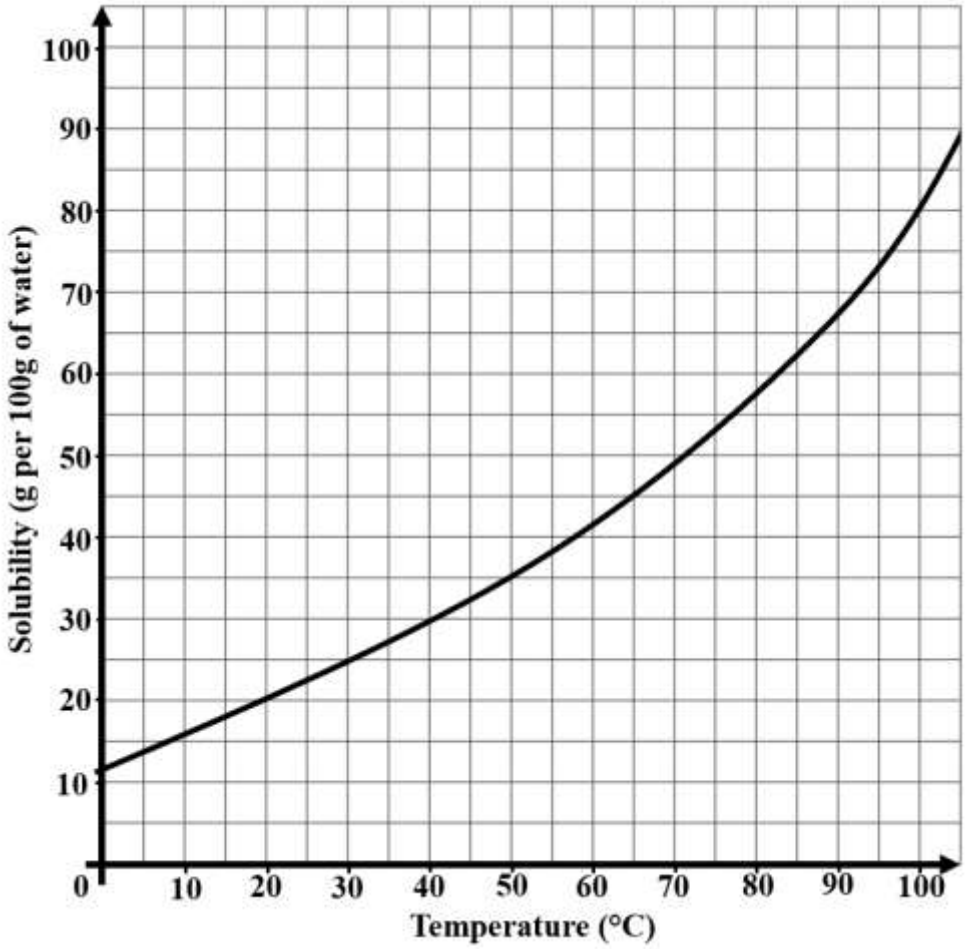
(a) State one other factor that can affect the rate at which solutes dissolve in a given volume of solvent.

_____ **[1]**

The solubility of a substance is measured by the maximum mass of solute which can dissolve in 100 g of a solvent at a particular temperature to form a saturated solution.

$$\text{Solubility (g per 100g of solvent)} = \frac{\text{mass of solute (g)}}{\text{mass of solvent (g)}} \times 100$$

Solubility curves can be plotted to show how the solubility of a solid changes with temperature. The solubility curve below is for copper sulfate in water.



(b) Name the solute being used.

_____**[1]**

(c) Explain, in detail, why the solubility of this solute increases at higher temperatures.

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_____**[3]**

The solubility curve tells us that the solubility of copper sulfate in water at 65 °C is 45 g per 100g of water.

(d) Use the solubility curve to find the solubility of copper sulfate in water at 50 °C.

_____

_____**[1]**

(e) If 200 g of water was used to prepare a saturated copper sulfate solution at a temperature of 100 °C, what mass of copper sulfate crystals form if the solution was then cooled to 40 °C? Show your working.

_____

_____

_____**[3]**

When we have more than one type of solute dissolved in the same solution, we then refer to the solution as a **mixture**.

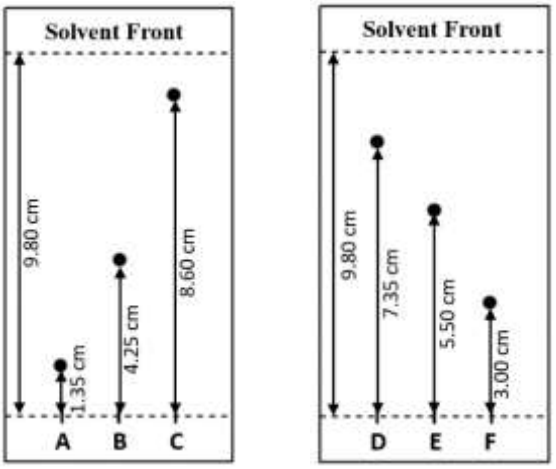
Paper chromatography can be used to separate a mixture of soluble solids and relies on the principle that different compounds have different solubilities in a given solvent. The more soluble a substance is, the further it will travel up the piece of chromatography paper.

Chromatograms show the results of separating the components of a mixture using paper chromatography and can be analysed to measure R_f values of particular compounds in a specific solvent. They show how far the compound has travelled and how far the solvent has travelled (solvent front) in a given amount of time.

Calculating the R_f value of a compound allows chemists to identify unknown substances because it can be compared with R_f values of known substances under the same conditions. To do so, the following equation is used:

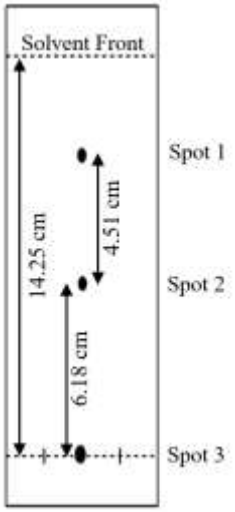
$$R_f = \frac{\text{distance moved by the spot}}{\text{distance moved by the solvent front}}$$

Here chromatograms of known dyes A-F are shown below with a table of their Rf values to 3 decimal places (diagrams not to scale).



Dye	Rf Value (3 d.p.)
A	0.138
B	0.434
C	0.878
D	0.750
E	0.561
F	0.306

You can now use these Rf values to identify which dyes are present in the mixture being analysed on the following chromatogram.



(f) Calculate Rf values for spots 1 and 2 to three decimal places and state which known dyes are present in the unknown mixture. Show your working.

_____

_____ **[1]**

(g) Suggest a reason why the dye(s) at spot 3 didn't move up the chromatogram.

_____**[1]**

(h) In a separate experiment, an unknown substance, X, was identified as part of a mixture. When a chromatogram was produced, the R_f value of X was found to be 0.90 and the solvent front was $7.2\ cm$. Calculate the distance moved by substance X on this chromatogram to two decimal places. Show your working.

_____

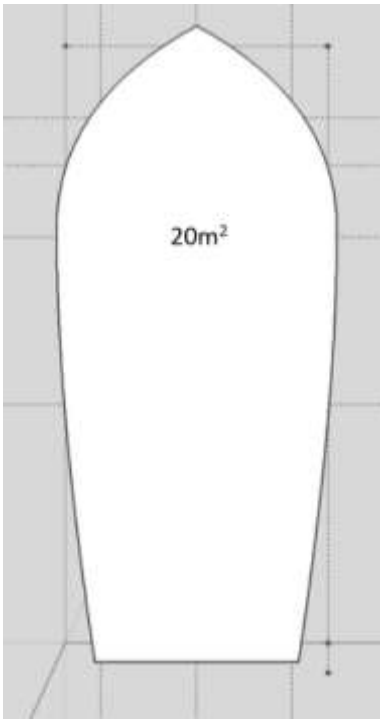
_____**[2]**

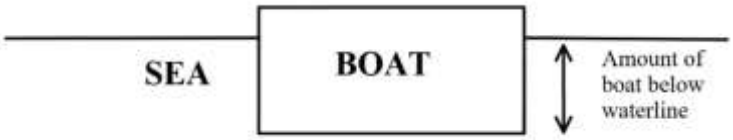
(i) State a factor that could be changed which would affect the R_f value of substance X.

_____**[1]**

2. This question is about pressure and forces.

Archimedes' principle states that the upward buoyant force that is exerted on a body immersed in a fluid, whether fully or partially, is equal to the weight of the fluid that the body displaces. A flat-bottomed scuba diving boat with a three-person crew of divers has a cross-sectional area of $20\ m^2$ and a total laden mass of $3000\ kg$. You can assume the density of water is $1000\ kg/m^3$.





(a) How much of the boat is below the waterline? State your answer in metres.

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_____

_____**[3]**

(b) The boat sails down a freshwater stream and into the sea (salt-water is more dense than fresh water). Explain whether the boat sits higher or lower as it enters the sea.

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_____**[2]**

One of the divers gets off the boat to go under water where they experience a greater pressure on them than at the surface.

(c) Describe the vertical motion of the boat immediately after the diver enters the water.

_____

_____**[1]**

(d) Explain why, as the diver goes under water, there is an increase in pressure on the diver.

_____

_____**[1]**

(e) At the water's surface the pressure is $100\,000\ N/m^2$ due to the atmosphere. At $10\ m$ underwater the pressure is double what it is at the surface due to the mass of water. What would the pressure on the diver be at $25\ m$?

_____

_____

_____**[3]**

The pressure change due to the depth in a fluid applies in the atmosphere, but the rate of change is less due to the difference in the density between air and water. The density of air is $1.3\ kg/m^3$ while the density of water is $1000\ kg/m^3$. For this question we will assume the density of the atmosphere is constant throughout.

(f) Show that at an altitude of approximately $3800\ m$ the pressure is half of that at sea level.

_____

_____

_____**[2]**

(g) The summit of Ben Nevis is $1345\ m$ above sea level. What is the pressure at the summit of Ben Nevis?

_____

_____

_____**[2]**

3. This question is about energy and momentum.

Conservation of momentum and conservation of energy are important laws in physics. These two laws can be used to calculate the speed of a bullet using a ballistic pendulum.

The momentum of an object is given by the following equation

$$\text{momentum} = \text{mass} \times \text{speed}$$

(a) Consider a bullet of mass $0.0035\ kg$ travelling at a speed of $105\ m/s$. Calculate the momentum of the bullet and give the unit of momentum.

[Note: the units on the left-hand side of the equation must be the same as the units on the right-hand side]

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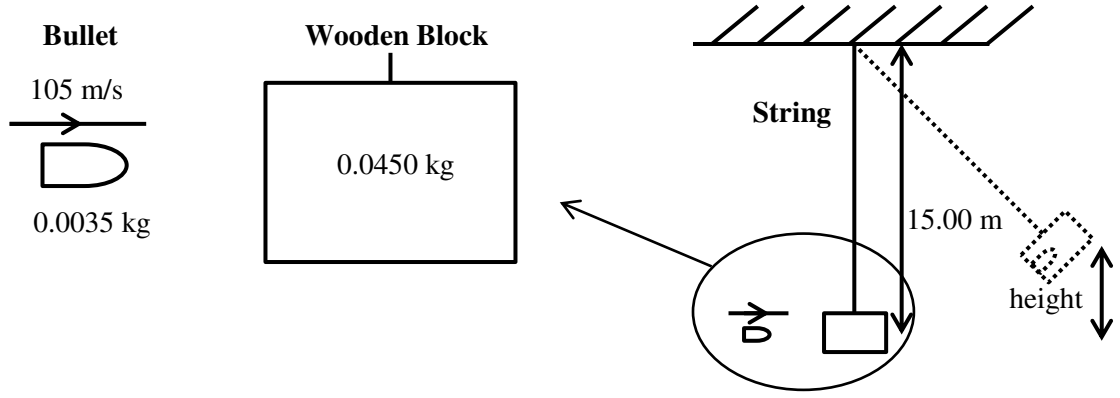
_____

_____ **[2]**

When two objects collide, the conservation of momentum law states that the sum of the momentum of the two objects before the collision equals the sum of the momentum of the two objects after the collision.

The bullet collides with a stationary block of wood with a mass of $0.0450\ kg$ that is hanging from a $15.00\ m$ long string.



(b) Explain why the initial momentum of the wooden block is zero even though it has a much greater mass than the bullet.

_____

_____ **[1]**

(c) State the combined momentum of the bullet and the wooden block after the collision.

_____

_____ **[1]**

(d) The bullet embeds itself into the block of wood. Use the conservation of momentum to show that the speed of the block with the bullet embedded is about $8\ m/s$.

_____

_____

_____ **[2]**

The kinetic energy, KE, of an object is given by the following equation

$$\text{KE} = \frac{1}{2} \times \text{mass} \times \text{speed}^2$$

(e) Calculate the KE of the **combined wooden block and bullet** just after they have collided.

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_____

_____ **[2]**

The combined wooden block and bullet swing upwards on the string to a maximum height.

The gravitational potential energy, GPE, of an object is given by the following equation

$$\text{GPE} = \text{mass} \times 10 \times \text{height}$$

Here we will only deal with KE and GPE. In this case, the conservation of energy means

$$\text{change in KE} = \text{change in GPE}$$

(f) Taking the initial GPE to be zero and the final KE to be zero, use the conservation of energy to show that the maximum height above the ground the wooden block and bullet will swing to is about $3\ m$.

_____

_____

_____

_____ **[3]**

The ballistic pendulum is set up again with a new piece of wood with the same mass and on a piece of string with the same length. This time the bullet has the same mass but travels faster. The combined wooden block and bullet rise to a height of $11.50\ m$.

(g) Determine the approximate speed of the bullet and clearly explain your reasoning.

_____

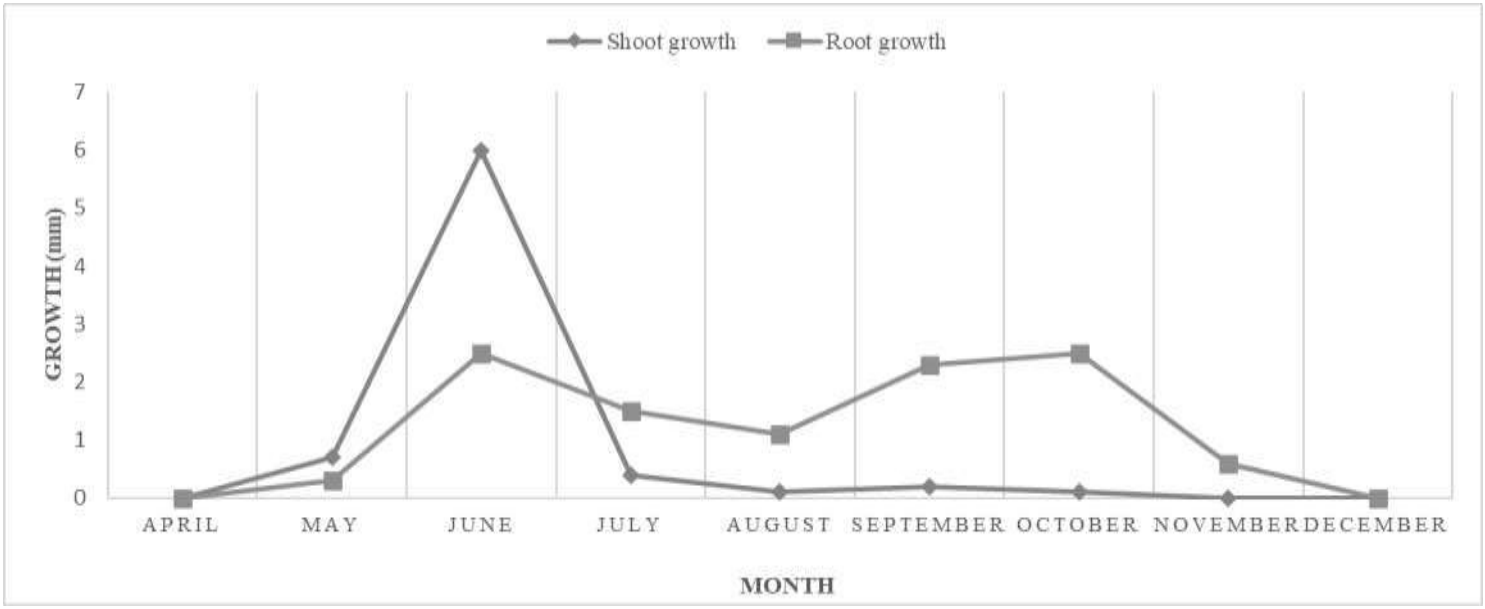
_____

_____

_____ **[3]**

4. This question is about plant growth.

The chart below shows the average daily growth (in mm) of shoots and roots in a species of North American pine tree.



Shoots and roots are examples of biomass.

(a) What process does a plant rely upon to produce the glucose required for biomass production?

_____ **[1]**

(b) Suggest two reasons why shoot and root growth (measured in mm per day) may not be an accurate measure of biomass production.

_____

_____

_____ **[2]**

(c) Explain why root growth ceases in winter.

_____

_____

_____

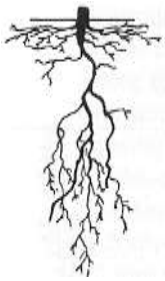
_____ **[3]**

(d) Suggest a reason why most shoot growth precedes the period of most root growth.

_____

_____ **[1]**

Study the diagrams of these root systems.



(e) Roots are able to grow sideways and/or downwards. Given that the amount of energy available for growth is limited, explain the possible advantages to a tree of having root growth that is:

i. mostly sideways

_____

_____ **[2]**

ii. mostly downwards

_____

_____ **[2]**

(f) What microscopic structures, vital for obtaining mineral ions from the soil, can you not see on the diagrams above?

_____ **[1]**

(g) How are these structures specifically adapted to adsorb water and mineral ions?

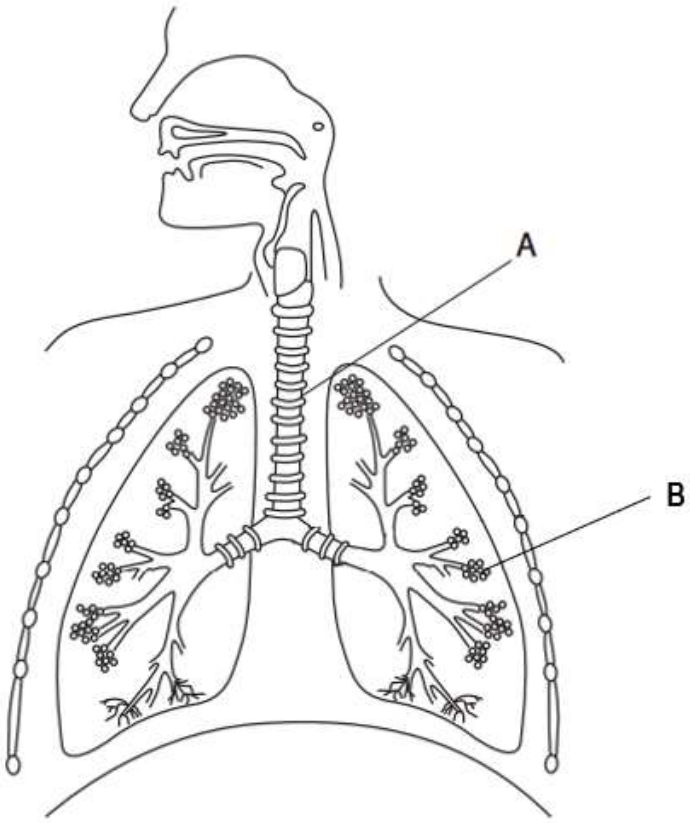
_____ **[1]**

(h) Name one mineral ion that is absorbed by these roots and what it is needed for.

_____ **[1]**

5. This question is about the human respiratory system.

The diagram below shows the breathing system in humans.



(a) Name structure A.

_____ **[1]**

(b) Name the process that occurs at B.

_____ **[1]**

(c) Explain how B are adapted to their function.

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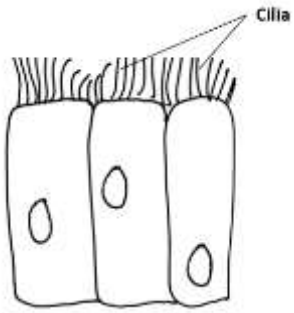
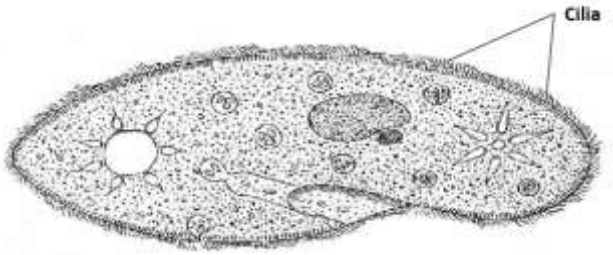
_____ **[2]**

Structure A is lined with specialised cells called ciliated cells. Their structure is shown below.



Unicellular organisms such as *Paramecium* also have cilia. The diagram below shows a *Paramecium*.



(d) Suggest how the function of the cilia in the human breathing system differ to that of the *Paramecium*.

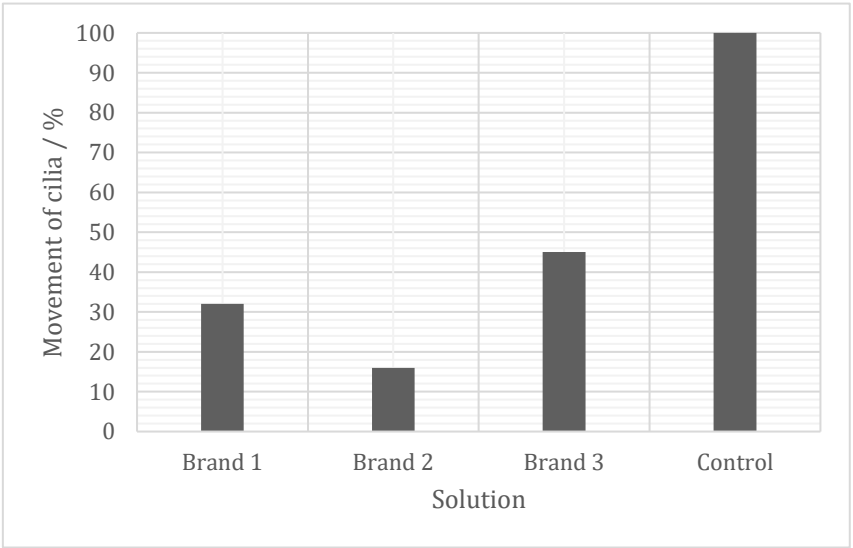
_____

_____ **[2]**

Chemicals in cigarette smoke affect the cilia in the airways.

An experiment was set up to investigate the effect of different cigarette brands on cilia activity. The scientists used *Paramecium* to show cilia movement. The chemicals in the tobacco from different brands were dissolved in water. One *Paramecium* was then placed in the solution from each brand and a microscope was used to observe the proportion of cilia movement. A control solution was used to enable comparison.

The results are shown below.



(e) Suggest what the scientists used as a control solution.

_____ **[1]**

(f) The scientist conducting the research made the statement that 'smoking tobacco reduces the movement of cilia in human airways'. Justify why this conclusion may not be valid.

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_____

_____

_____ **[3]**

Chronic obstructive pulmonary disease (COPD) is the collective name of a group of lung conditions that can cause breathing difficulties. Smoking is the main cause of COPD.

(g) Name two other conditions caused by smoking.

_____

_____ **[2]**

There is currently no cure for COPD, however people may use inhalers to reduce their symptoms. The inhalers deliver drugs called corticosteroids into their airways.

The image shows a person using an inhaler.

(h) Suggest the effect of using an inhaler to treat symptoms of COPD.

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_____

_____ **[2]**

[End of paper]