Eton College King's Scholarship Examination 2020

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.

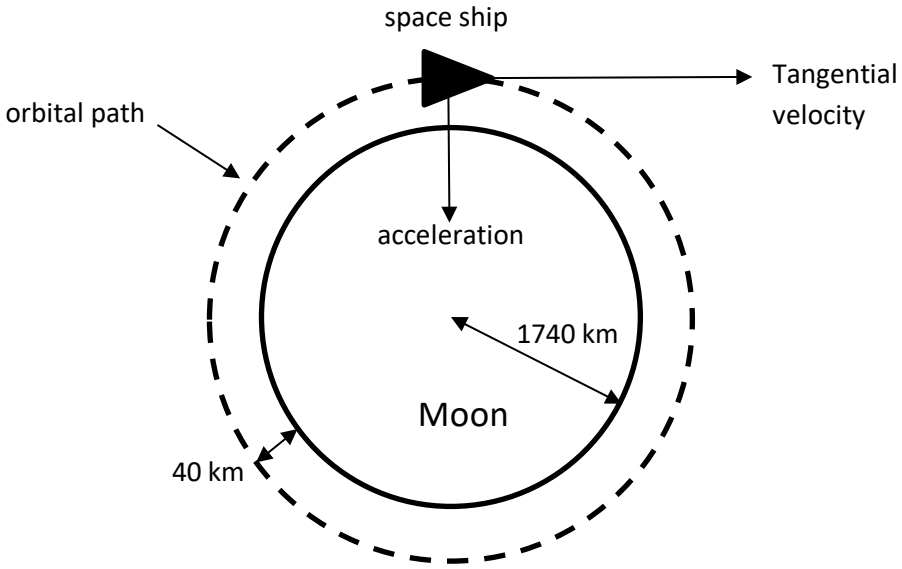
Total Marks Available: 70

For examiners' use only.

1	2	3	4	5	TOTAL [70]

Do not turn over until told to do so.

1. A 20 tonne space ship is orbiting the Moon 40 km above its surface. The radius of the Moon is 1,740 km and it is 380,000 km from the Earth.



(a) Mission Control, back on the Earth's surface, is communicating with the astronauts in the space ship.

i. Explain why there is a delay between sending a message from Earth and receiving a reply.

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_____

_____ **[1]**

ii. Calculate the length of the time delay. The speed of light in a vacuum is $3x10^8$ m/s.

_____

_____

_____ **[1]**

The gravitational field strength at the altitude of the space ship is 1.6 N/kg.

(b) Calculate the weight of the space ship.

_____

_____ **[1]**

(c) Newton's Second Law of Motion states that,

$$F = ma$$

where F is the resultant force on an object, m is the mass of the object and a is its acceleration.

i. If the space ship's weight is the only force it experiences, calculate its acceleration. Include the correct units.

_____

_____

_____ **[1]**

ii. Comment on its value compared with other data you have been given.

_____

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_____ **[1]**

iii. Given your previous answer and without any calculation state the acceleration due to gravity near the Earth's surface.

_____

_____ **[1]**

(d) Any object moving in a circle of radius, *r,* with a tangential speed, *v,* must have an acceleration, *a,* towards the centre of that circle such that,

$$a = \frac{v^2}{r}$$

i. Calculate the tangential velocity, *v,* of the space ship in this orbit.

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_____

_____

_____

_____ **[2]**

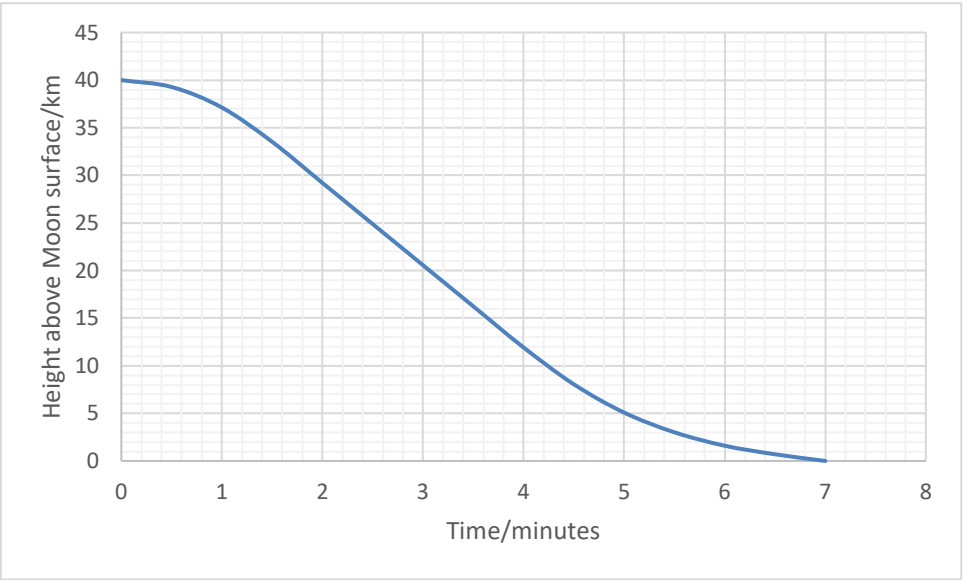
ii. State the radial speed (the speed towards the centre of the circle).

_____

_____ **[1]**

The space ship fires its rockets to bring it to a stationary hover relative to the moon. It then switches off the rockets so that the space ship goes into freefall. After a while the rockets are fired again to eventually bring the space ship to a halt at the Moon's surface. (This is not how they do it but it makes the physics much easier for us!)

The following graph shows how the space ship's height above the Moon's surface varies with time.



(e) Describe in as much detail as you can the motion of the space ship between 1.5 minutes and 4.0 minutes.

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_____ **[1]**

(f) Compare the upward thrust exerted by the rocket on the space ship with the weight of the space ship, justifying your answer:

i. between 0.0 minutes and 1.5 minutes;

_____

_____ **[1]**

ii. between 4.0 minutes and 7.0 minutes.

_____

_____ **[1]**

(g) As the space ship goes from a stationary hover above the Moon's surface to being stationary on the Moon's surface its total energy store reduces. The Law of Conservation of Energy states that the total energy of a closed system must remain constant. What has happened to the energy the space ship has lost?

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_____ **[2]**

2. A balanced diet includes appropriate quantities of a variety of components, including carbohydrates, fats, vitamins and minerals.

(a) Name two other components of a balanced diet.

1. _____ 2. _____ **[1]**

(b) The most abundant mineral in the human body is calcium, and almost all of the calcium in a human is found in the skeleton.

Give two functions of the human skeleton.

1. _____

2. _____ **[2]**

(c) A group of research scientists investigated the mass of six people and compared their bone mass to total body mass. Some of the results are shown below:

	Bone mass (kg)	**Total body mass (kg)**	**Proportion of body mass that is bone (%)**
Male 1		62.1	14.5
Male 2	7.7	70.0	
Male 3	12.6		14.0
Female 1	8.2	120.0	6.9
Female 2	9.1	72.8	12.5
Female 3	6.3	63.0	10.0

i. Calculate and add the missing values in the table. **[2]**

ii. The percentage of body mass that is bone varies widely between individuals. Suggest and explain possible reasons for this variation.

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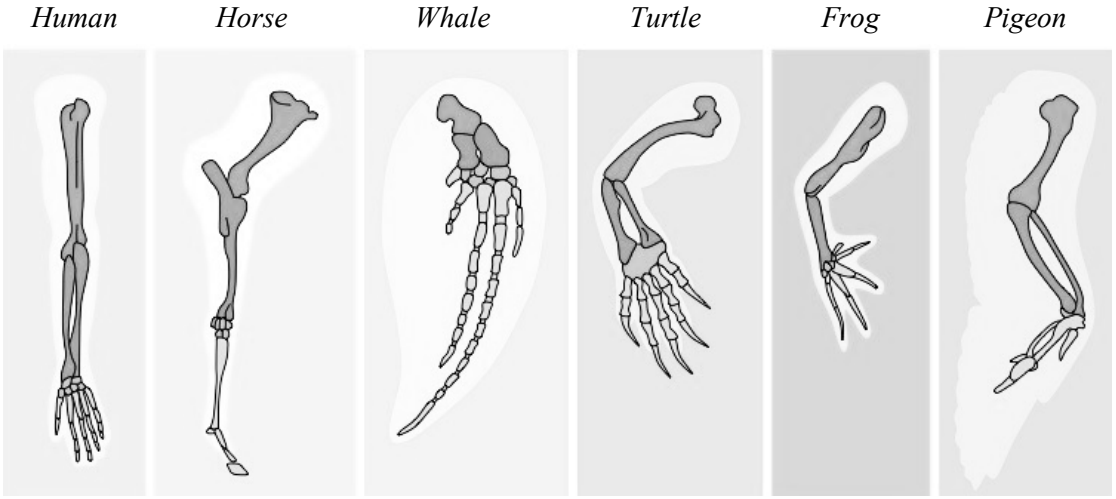
_____ **[4]**

(d) The diagram below shows the arrangement of bones in the forelimbs of several different vertebrates.



i. Complete the table below to identify which vertebrate group each animal belongs to. **[2]**

Animal	Vertebrate group
Human	
Horse	***Mammal***
Whale	
Turtle	
Frog	
Pigeon	***Bird***

The arrangement of bones in vertebrate limbs is evidence that supports the theory that all vertebrate groups are evolutionarily related, and have descended from a common ancestor many millions of years ago.

ii. Explain to what extent you think the bone arrangements of human and pigeon forelimbs support this theory.

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_____ **[3]**

3. **Figure 1** below depicts a section of leaf with arrows indicating the **net movement** of gases into and out of the leaf through holes called stomata.

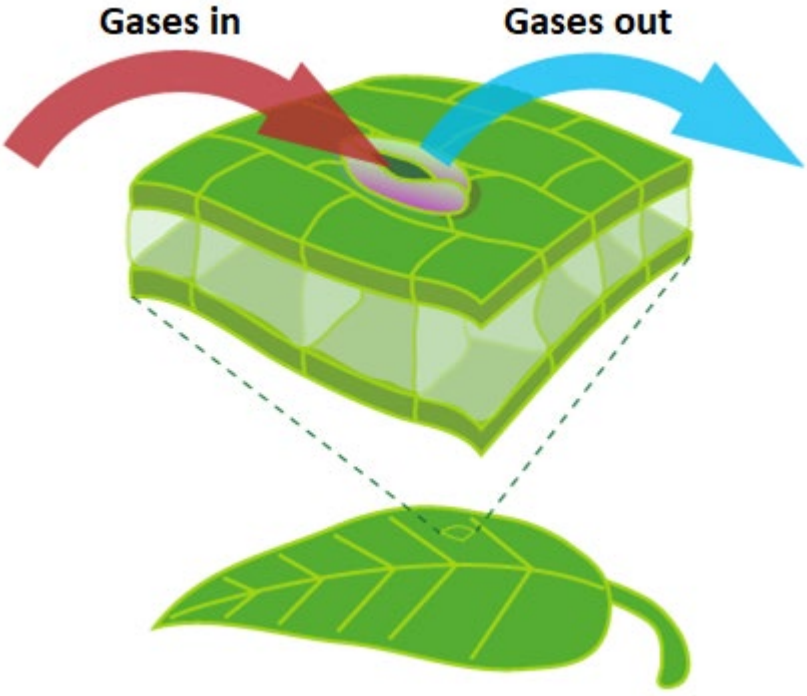


Figure 1. Image modified from evolution.berkeley.edu. (2019)

(a) There are three **key** gases moving into or out of a leaf.

i. Name the three gases moving into and/or out of a leaf.

_____ **[1]**

ii. Complete the table below with the appropriate gas(es): **[3]**

	Net movement into leaf	Net movement out of leaf
Daylight		
Darkness		

iii. Suggest why rainforests are often described as '*the lungs of the planet*'.

_____

_____

_____ **[2]**

(b) Atmospheric carbon dioxide concentrations are measured in parts per million (ppm). The graph below shows how these have fluctuated for the past 800,000 years based on ice core data.

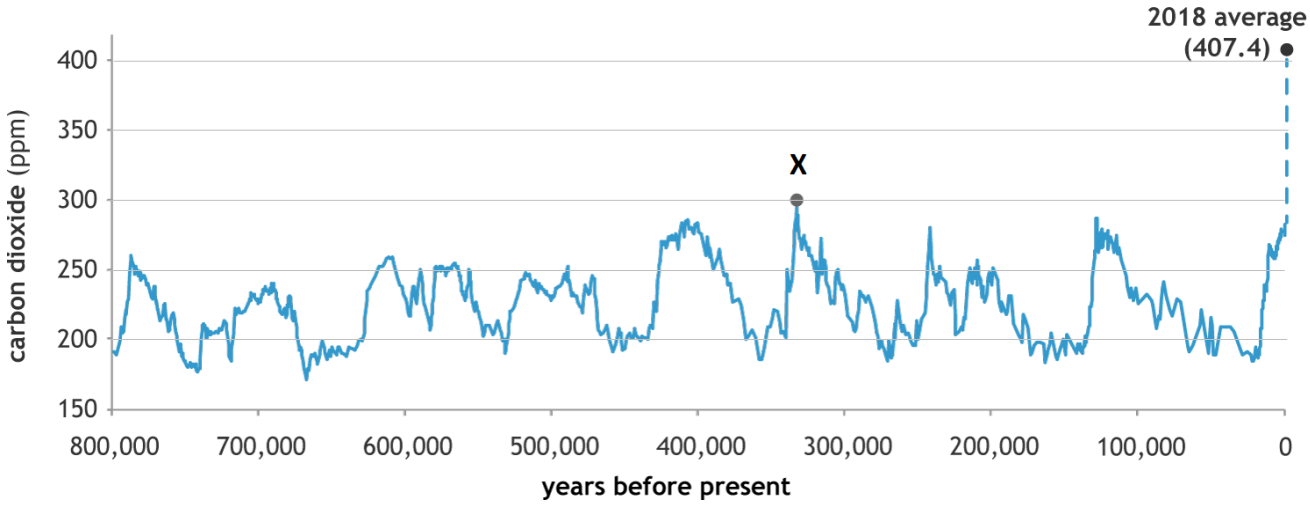


Figure 2. Image modified from NOAA Climate.gov (2019).

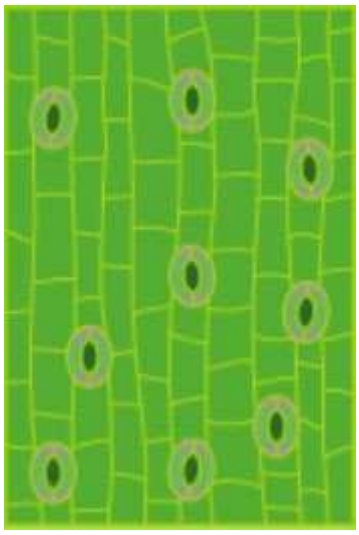
i. Use the graph above to calculate the percentage (%) change in atmospheric carbon dioxide concentration between point **X** and **2018**.

_____

_____ **[1]**

The stomata on the underside of living and fossil leaves can be seen under a microscope. The diagrams below depict two samples of leaf of the same species viewed under the microscope. The number of stomata per unit area is known as the stomatal density.

Sample A taken from time period **X**.



Sample B taken in 2018.

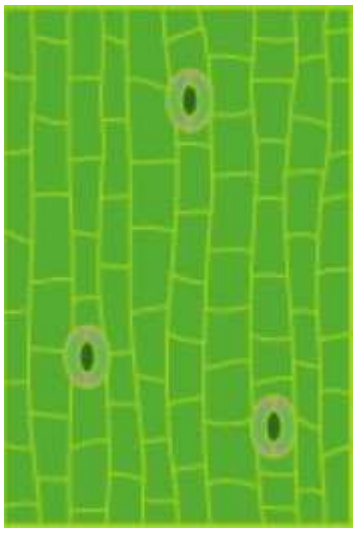


Figure 3. Image modified from evolution.berkeley.edu. (2019)

ii. Compare the stomatal density of leaf sample A with the stomatal density of leaf sample B.

_____

_____ **[1]**

iii. Using information from the graph in **Figure 2**, suggest explanations for the difference in stomatal density between Sample A and Sample B.

[3]

iv. Suggest why having fewer stomata might be an advantage to a plant during drought conditions.

[2]

v. Suggest why conclusions drawn from the differences observed in these samples might not be valid.

[1]

4. This question is about a series of chemical reactions.

(a) Write a word equation for the reaction of magnesium with sulfuric acid.

_____ **[1]**

A student reacted some magnesium with sulfuric acid, making sure that the magnesium was in excess. He measured the time taken for the reaction to finish, and found that the reaction finished after 120 seconds.

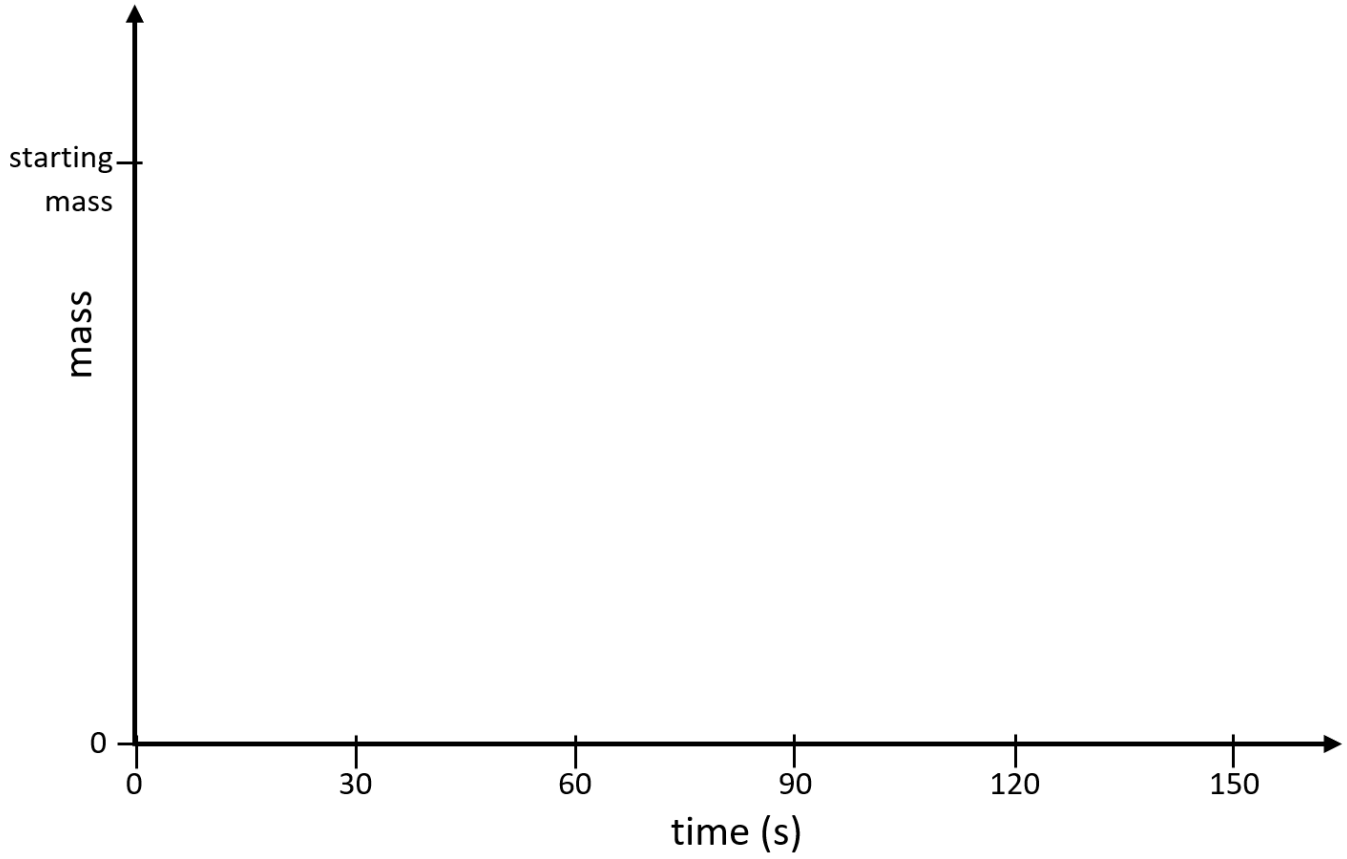
(b) Give one observation that would show that the reaction had finished.

_____ **[1]**

The above reaction was performed again, with exactly the same conditions and amounts of chemicals, but this time in a beaker on top of a balance.

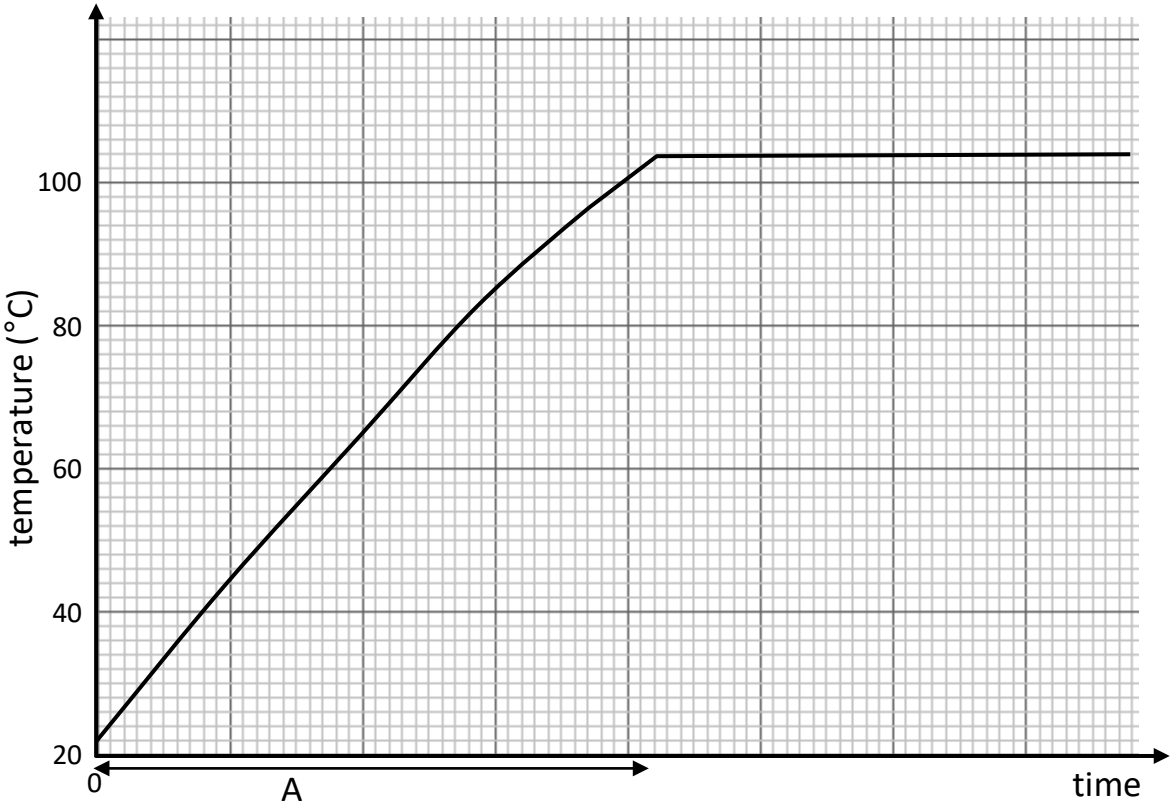
(c) Sketch on the axes below the shape of the graph for the mass measured by the balance against time, from the beginning of the reaction to 150 seconds.

The starting mass at time = 0 seconds has been marked for you.



[3]

The resulting mixture was first filtered, then the solution obtained was heated with a Bunsen burner. As it was heated the temperature was recorded and plotted on the graph below.



(d) Explain why the mixture was filtered.

_____ **[1]**

(e) **Name** the change of state which was occurring during time period A.

_____ **[1]**

(f) Explain why the graph levels off at 104 °C.

_____

_____

_____ **[2]**

The student finished off the experiment, and produced a sample of dry magnesium sulfate crystals.

These crystals were heated very strongly, causing them to decompose into magnesium oxide, sulfur dioxide gas, and oxygen gas. The equation for this reaction is:

$$MgSO_4 \longrightarrow MgO + SO_2 + \tfrac{1}{2}O_2$$

Atoms of different elements have different masses. These masses are recorded on the Periodic Table. The masses are recorded relative to each other – so, for example, a sulfur atom (mass 32) has twice the mass of an oxygen atom (mass 16), and a magnesium atom (mass 24) is 1.5 times the mass of an oxygen atom.

(g) Given this data, predict the mass of magnesium oxide remaining after 30g of magnesium sulfate is decomposed completely. Show your working.

[3]

(h) The gas from the above reaction is bubbled through a solution of universal indicator in distilled water. The indicator turns red.

Explain fully why this change occurs.

_____

_____

_____ **[2]**

5. A scientist is taken to the top of Mount Everest (an altitude of nearly 9 km above sea level) early one morning, to do some experiments.

He hasn't had time for breakfast, so the first thing he does is boil an egg. He likes his egg hard boiled, and knows that it usually takes exactly 6 minutes and one teaspoon of salt in the water to get his egg hard boiled. He boils some water, puts in the salt, places the egg in and leaves it for exactly 6 minutes, all just as he does at home.

One of his colleagues has suggested that when very high above sea level, where the air pressure is lower, molecules of water require less energy to escape from a liquid to form a gas.

(a) State the observation that he makes when he cracks open the egg, and explain why this shows that his colleague was correct.

_____

_____

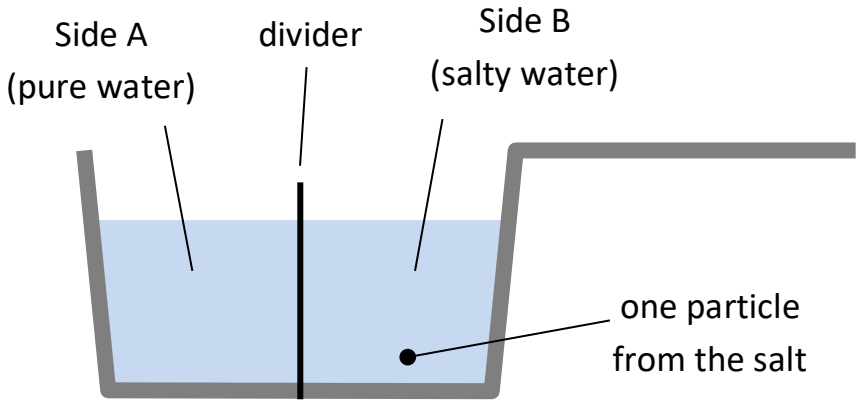
_____ **[2]**

(b) Suggest why molecules of water require less energy to escape from the liquid state at that altitude.

_____ **[1]**

The saucepan is of an unusual design. It is made of iron, and is divided into two sections by a removable, plastic, water-tight divider.

At the same time as boiling his egg, he has been heating pure water on the other side of the pan, to make coffee. However, as his egg is no good, he decides to skip the coffee as well, and leaves the saucepan to one side. The diagram below shows his saucepan at this point:



He removes the divider from the pan once it is cool.

(c) Name the process which then occurs as a result of removing the divider.

_____ **[1]**

(d) Imagine one particle from the salt can be labelled and tracked. This has been done in the diagram. Once the divider has been removed, and the process in part (c) is complete, where is that particle most likely to be found? **Underline** the correct answer. **[1]**

On the left side (A) in the above diagram

One the right side (B) in the above diagram

Exactly in the middle

Equally likely to be found in any location

The scientist then pours away the water, replaces the divider, and heats up two solutions that he has bought with him – one in each side of the pan. The solutions are silver nitrate and zinc nitrate.

He is surprised to find a hole appearing in his saucepan under one of the solutions.

(e) State under which solution the hole appears.

_____ **[1]**

(f) Explain why the hole appears on that side and not the other.

_____

_____

_____

_____ **[3]**

The scientist decides to leave some hot water for the next person to climb to the summit. He rinses out the undamaged side of his pan, uses it to melt some snow, and continues to heat until the water boils. He fills an insulating flask (made from stainless steel, so it won't rust) to the brim with the hot water, screws the lid on very tightly, and leaves it next to the summit. Unfortunately, the flask is only found 3 months later, and is of no use to the mountaineer who finds it.

(g) Explain all the reasons why the flask and its contents are of no use to the mountaineer.

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_____

_____ **[3]**

The scientist uses a small camping stove to heat his breakfast and his experiments. He notices that the flame is a different colour when he uses it at the top of Mount Everest, compared with what he observes when he uses it on his holidays at the seaside.

(h) Describe the difference in the flame colours, and explain this observation.

_____

_____

_____

_____ **[2]**