Eton College King's Scholarship Examination 2018

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.*

Allow yourself about 12 minutes for each question.

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.

For examiners' use only.

1	2	3	4	5	TOTAL

Do not turn over until told to do so.

1. The rate (speed) of chemical reactions is often affected by changing the concentration of a reacting solution.

   (a) Suggest, in terms of the reacting particles, why you would expect an increase in the concentration of a solution to lead to an increase in the rate of the reaction.

_____

_____ **[1]**

In the reaction between hydrochloric acid and limestone, the rate is affected by the concentration of the acid. The higher the concentration of the acid, the faster the reaction.

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + H_2O + CO_2$$

In an experiment, some hydrochloric acid was placed in a conical flask. Small pieces of limestone were added, and the flask was placed on an electronic balance. Its mass was recorded at regular intervals.

   (b) Explain why the mass of the flask decreased as the reaction took place.

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_____ **[2]**

   (c) Suggest one other way of monitoring the progress of this reaction, other than by measuring the mass of the flask as it decreases.

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_____ **[1]**

   (d) After 5 minutes, the reaction had finished. Just by looking at the flask, and without taking any measurements, how would it be possible to know that the reaction had finished?

_____ **[1]**

   (e) Some pieces of limestone were still visible at the bottom of the solution in the flask after the reaction had finished. Explain why.

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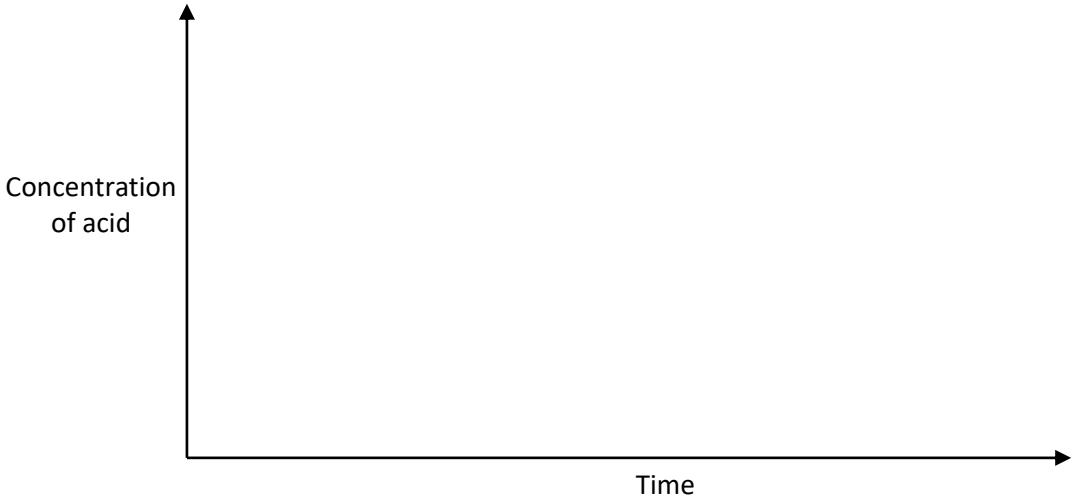
_____ **[1]**

(f) **Sketch** a graph (no scale is required on either axis) to show how the concentration of the acid in the flask changed over the course of the reaction.

[2]



(g) The flask and its contents from the experiment were then left for a week, and reweighed. Its mass was found to have decreased slightly. Explain why.

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_____ **[1]**

(h) A flask containing a solution of sodium hydroxide, which is an alkali, was also left in the laboratory for a week. Its mass was found to have increased slightly. Explain why.

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_____ **[2]**

Changing the concentration of one of the chemicals can sometimes have surprising effects on the rate of a reaction. This is because not all chemical reactions happen in a single step.

The reaction of nitrogen dioxide with carbon monoxide occurs in two steps as shown below. The reaction in step 1 is much slower than the reaction in step 2.

Step 1 (slow): $NO_2 + NO_2 \rightarrow NO_3 + NO$

Step 2 (fast): $NO_3 + CO \rightarrow NO_2 + CO_2$

(i) By combining the equations for step 1 and step 2, work out the equation for the **overall** reaction.

_____ **[1]**

(j) Increasing the concentration of nitrogen dioxide increases the rate of the reaction, but increasing the concentration of carbon monoxide has no effect on the rate. Use the information provided to suggest why.

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_____ **[2]**

2. The *solubility* of a substance is a measure of how much solute can be dissolved in a given amount of solvent. It often varies significantly with temperature.

To measure the solubility of potassium permanganate at 80°C a small amount of water was placed in a boiling tube heated to the required temperature using a water bath. Potassium permanganate was added, a little at a time, until no more would dissolve. The undissolved solid was allowed to settle to the bottom of the tube and about half of the solution was carefully decanted into a pre-weighed evaporating basin. The mass of the basin and solution was recorded. The solution was heated to boil off the water, leaving dry potassium permanganate, and the mass of the basin and this salt was recorded.

(a) Suggest two reasons why heating the solution until all the water had boiled off, and only dry solid remained, might lead to an inaccurate result causing a value for the solubility which is too **low**.

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_____ **[2]**

(b) What term is used to describe a solution in which the maximum amount of solute has been dissolved?

_____ **[1]**

(c) It is difficult to decant some of the hot solution into the evaporating basin without pouring some of the undissolved solid out too. A pupil suggests filtering the hot solution into the basin, to catch any undissolved solid. Explain why this is not a suitable suggestion.

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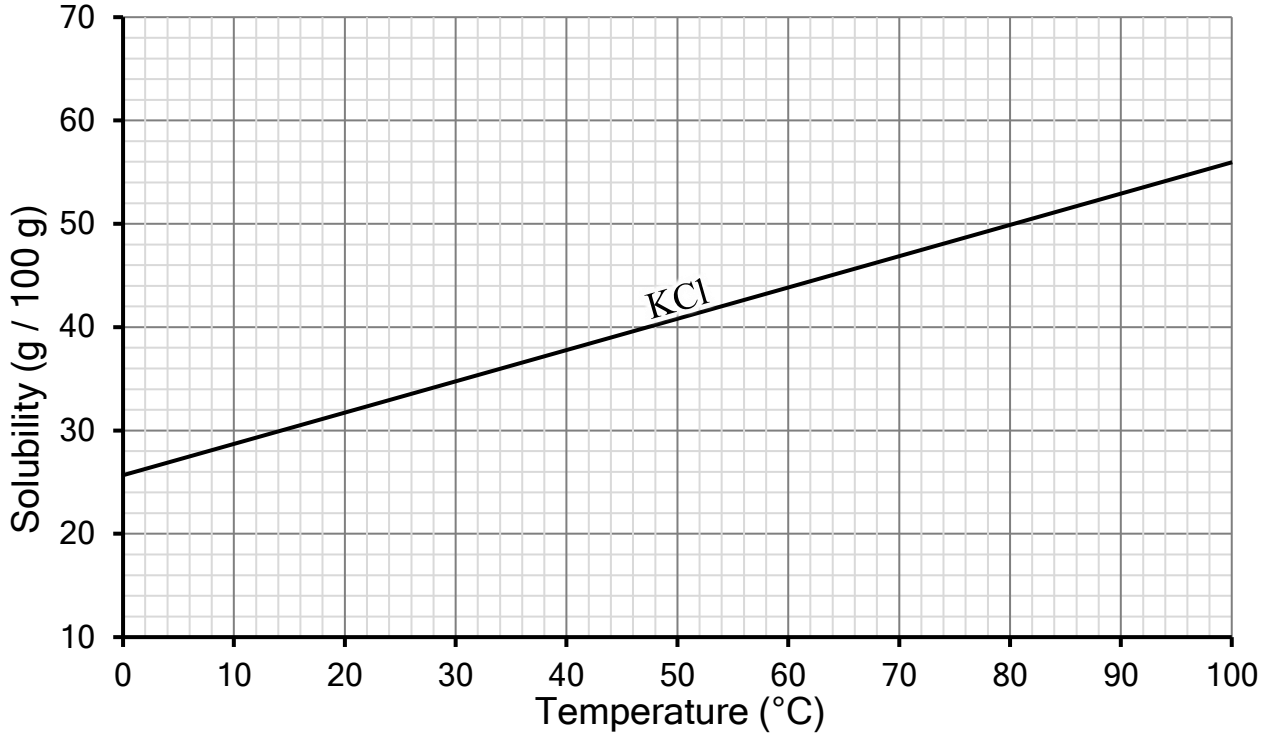
_____ **[2]**

The graph below shows the variation in solubility (g of solute per 100 g of water) against temperature for potassium chloride, KCl.



40 g of potassium chloride was added to 100 g of water at 20 °C, and the mixture was stirred.

(d) What mass of potassium chloride remained undissolved?

_____ **[1]**

(e) At what temperature would all of the potassium chloride dissolve?

_____ **[1]**

On further heating, the temperature of the solution reached 100 °C, and the water began to boil off. As the amount of water present therefore decreased, and the solution became more concentrated, solid crystals eventually began to form again.

(f) Calculate the mass of water which had boiled off when crystals first began to form. **Show your working**.

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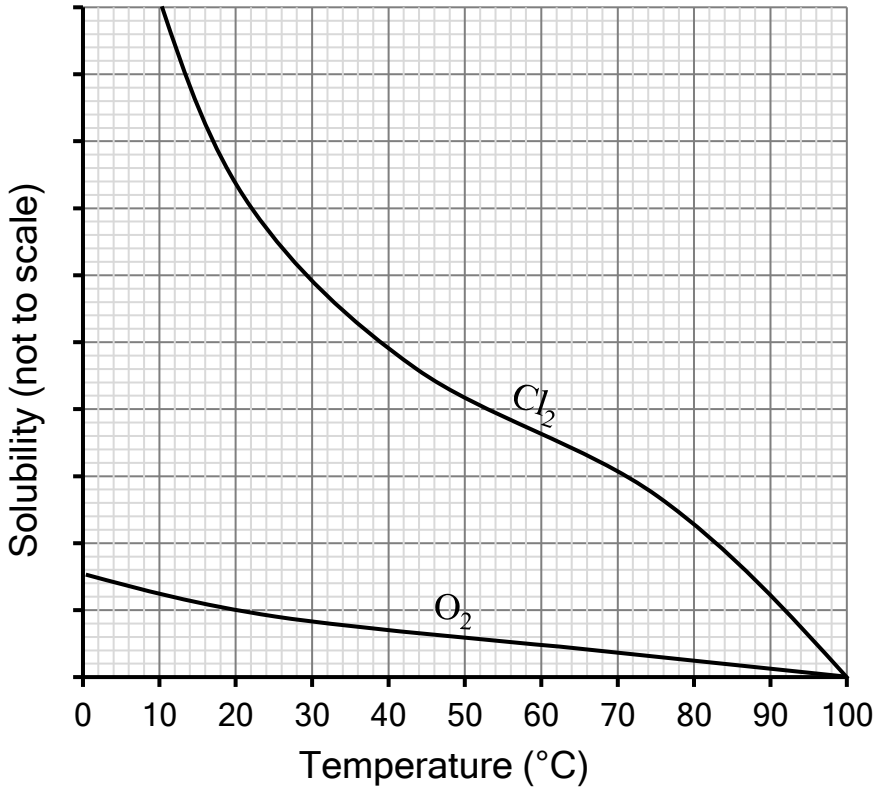
_____ **[3]**

The graph below shows the variation with temperature of the solubility of two gases.



(g) Use this information to explain why, when changing the water in a goldfish tank, the new water from the tap should be boiled beforehand, but after cooling must then be left to stand for 24 hours before putting the fish into it.

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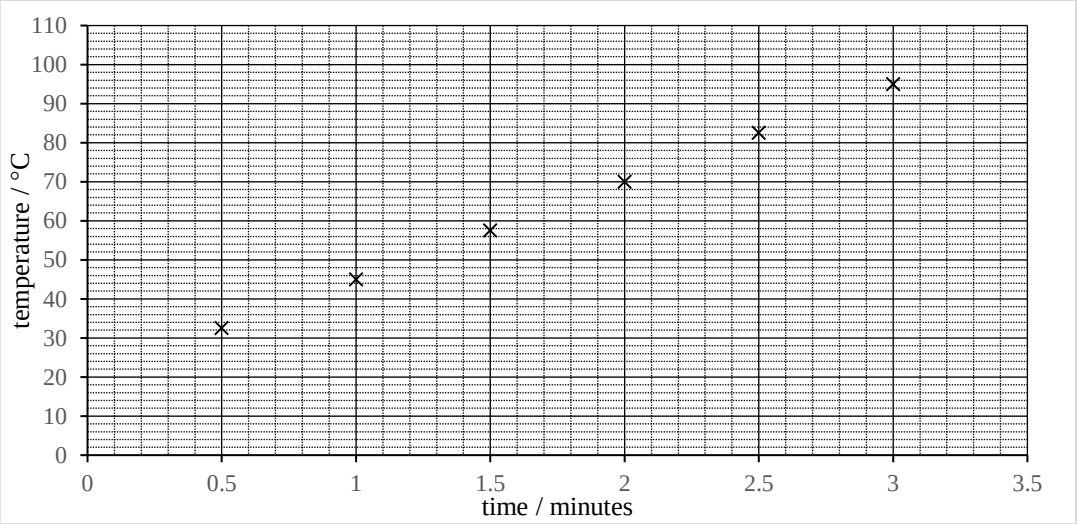
_____ **[4]**

3. A student pours a known volume of water into an insulating container. An immersion heater is placed in the water. The heater supplies energy to the water at a rate of 3000 J/s.

   The student switches on the heater and records the water temperature every 30 seconds. She plots the graph shown below.



(a) What was the original temperature of the water (at 0.0 minutes)?

_____ **[2]**

(b) Predict the time at which the water will start to boil.

_____ **[1]**

(c) Suggest a value for the temperature of the water after 3.5 minutes.

_____ **[1]**

It takes 4200 J of energy to raise the temperature of 1 kg of water by 1°C.

(d) Given water has a density of 1 g/cm^3, determine the volume of water used by the student. **Show your working** clearly in the space below.

[5]

The student repeats the experiment using a container made from a better thermal conductor. The volume of water, initial water temperature and heating equipment are the same.

(e) Add a second line to the graph above to show how the temperature of the water is likely to vary during the second experiment. **[2]**

(f) Explain the shape of the line you have drawn.

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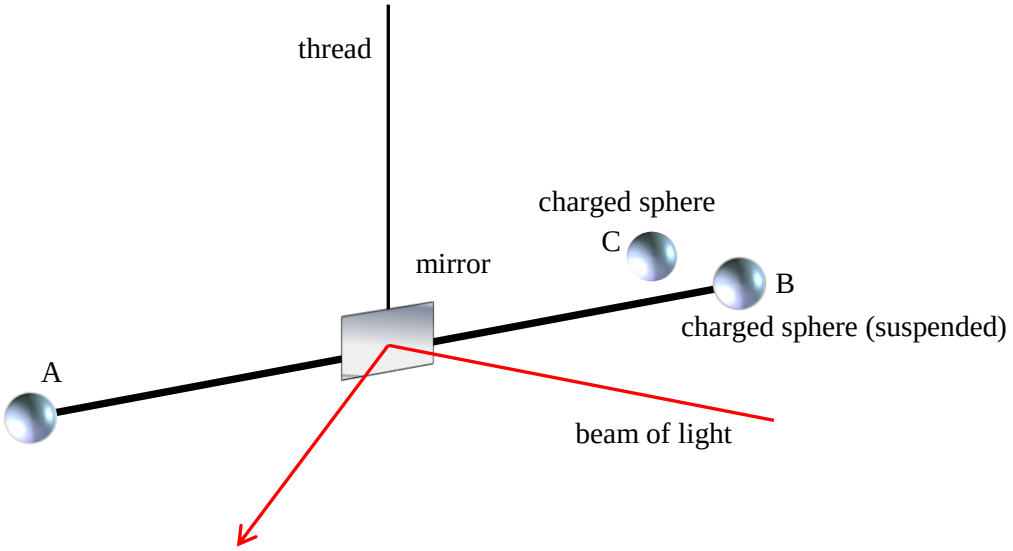
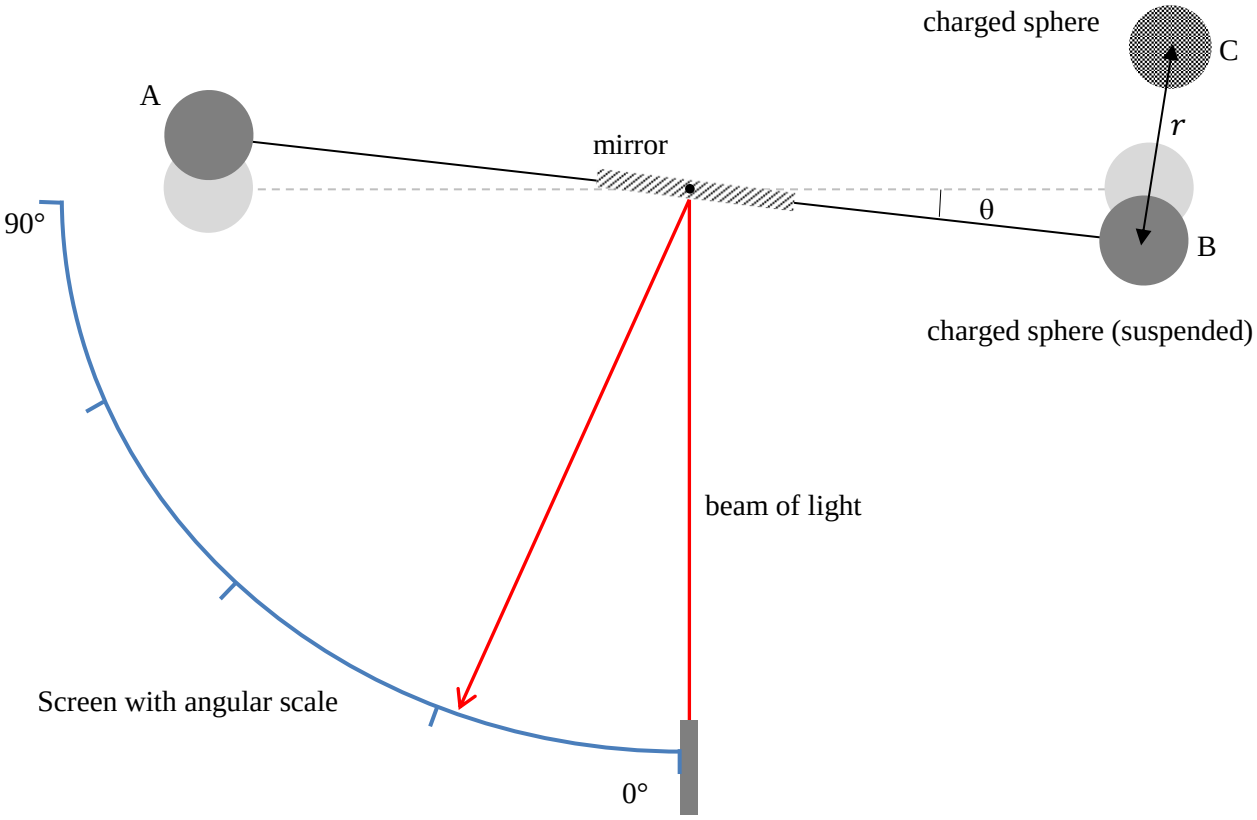
_____ **[3]**

4. In 1785, Charles Augustin de Coulomb published the results of his experiments to measure the force between two identical electrically charged objects. He used a 'torsion balance', a diagram of which is given below.





Two identical metal spheres (A and B) are mounted on an electrically insulated bar that is suspended from a thread. Sphere B is given an electrical charge. A third sphere, C, is charged and brought near to B. The repulsion between the two charged spheres causes the bar to rotate and twist the thread. The twist of the thread creates an opposing moment and the bar comes to rest with the charged spheres separated by a distance r. The angle of twist, θ, is measured by reflecting a beam of light off a mirror (mounted on the bar) on to a scale marked in degrees.

The moment τ created by the twist of the thread is proportional to the angle of twist, given by the formula

$$\tau = k\theta$$

where θ is the angle of twist in degrees and $k = 1.5 \times 10^{-5}$ Nm per degree.

(a) Explain why it is important that the bar is made from an insulating material.

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_____ **[2]**

(b) Explain why there is an uncharged sphere (A) on the opposite end of the rod to the charged sphere (B).

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_____ **[1]**

The reading on the scale is 6 degrees, the bar is 30 cm long, and the distance between the spheres when they come to rest is $r = 1.0$ cm. You may assume that the line between the centres of spheres B and C is perpendicular to the insulated rod.

(c) Calculate τ.

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_____ **[3]**

(d) Calculate the force between the spheres.

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_____ **[2]**

Coulomb discovered that the force between the spheres was proportional to the inverse of the square of the distance between them, i.e. $F \propto {}^{1}/_{r^2}$.

(e) If sphere C was moved such that spheres B and C came to rest at $r = 0.5$ cm, what would the reading be on the scale?

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_____ **[2]**

Henry Cavendish performed a very similar experiment around the same time, but he was using uncharged spheres and was attempting to measure the gravitational attraction between the masses.

(f) Do you think that Coulomb should have corrected for the gravitational attraction between the spheres? Give a reason for your answer.

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_____ **[2]**

(g) Without changing any of the equipment used, what simple change could be made to make the apparatus more sensitive? Explain your answer.

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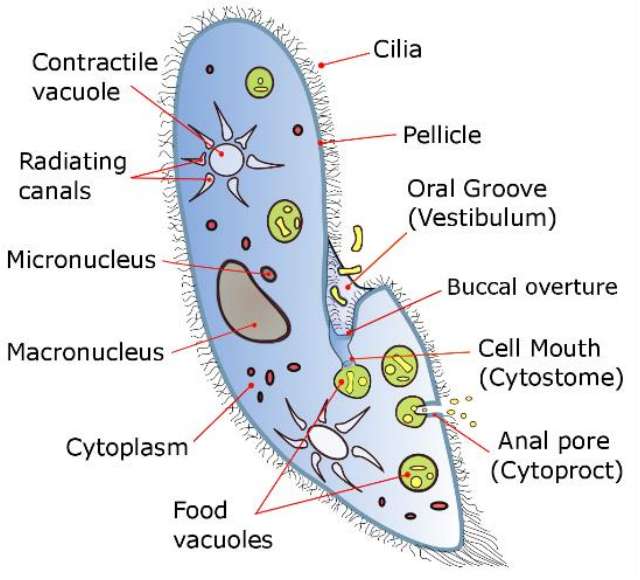
_____ **[2]**

5. The diagram below shows a unicellular organism from the genus *Paramecium*. It is typically found in freshwater environments (ponds for example).



(From https://en.wikipedia.org/wiki/Paramecium#/media/File:Paramecium_diagram.png)

(a) Suggest a function of the cilia found on the surface of the organism.

_____ **[1]**

There are several different species of *Paramecium*. Two which are commonly found in stagnant water are *Paramecium aurelia* (*P. aurelia*) and *Paramecium caudatum (P. caudatum).*

(b) Suggest why they are classified as different species.

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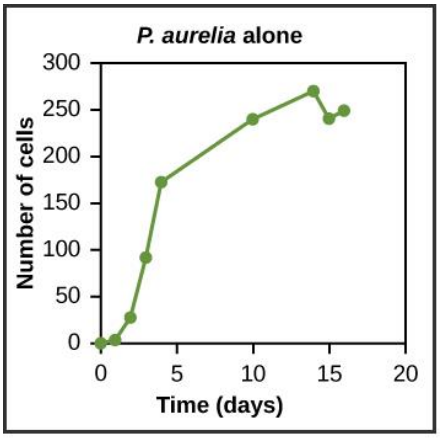
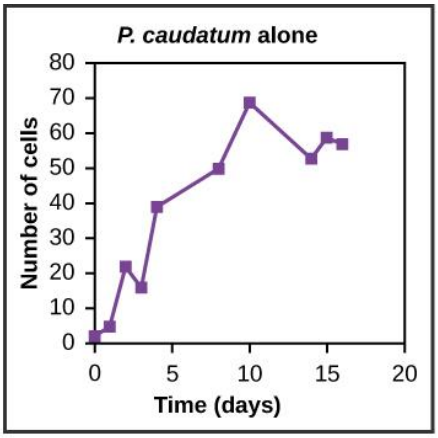
_____ **[2]**

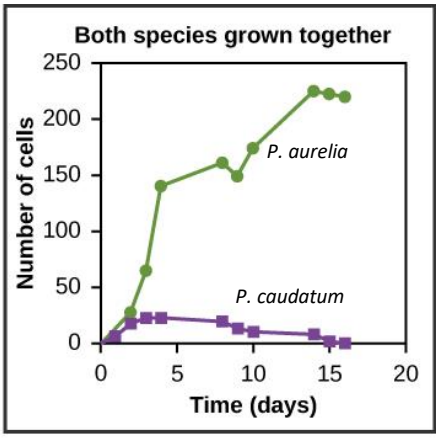
Paramecium reproduce asexually by binary fission, which allows rapid population growth in ideal conditions. To investigate population growth in these two different *Paramecium* species, a biologist prepared three separate identical containers, and added a single *P. aurelia* to the first, a single *P. caudatum* to the second, and one of each of the two species of *Paramecium* to the third container. She then recorded how the populations changed over a period of 16 days. The graphs overleaf show the results of the experiment.



Graph 1



Graph 2



Graph 3

(*Graphs taken from https://cnx.org/contents/s8Hh0oOc@9.10:pMtcae56@2/Community-Ecology*)

(c) Suggest what 'ideal conditions' might be for *Paramecium*.

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_____ **[2]**

(d) The number of cells shown in the graphs is an estimated value. How do you think the biologist estimated the number of cells?

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_____ **[3]**

(e) Explain the population growth curve for *P.aurelia* (graph 1) up to day 15.

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_____ **[3]**

(f) Suggest reasons for the results obtained when both species of *Paramecium* were cultured together (graph 3).

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_____ **[3]**

[End of paper]