RADLEY

Entrance Scholarships

SCIENCE

March 2012

Time allowed 2 hours

You may try the questions in any order.

No calculating aids may be used.

Show all working.

BIOLOGY **[25 marks]**

Read the following passage:

Life in the Ocean around Antarctica

The Southern Ocean has high levels of two key **nutrients**, phosphates and nitrates, often several times higher than in the other oceans. This and the continuous 24 hour daylight of the summer months provide the perfect conditions for phytoplankton blooms to flourish. In places, huge areas of the ocean turn green as the phytoplankton rush to **photosynthesise** before winter steals away the sun. But the **turbulence** that brings up the minerals also ensures that these green patches are widely separated and very unpredictable.

The next step up the food chain ladder is occupied by the animal plankton, or **zooplankton**. They come in an enormous variety of shapes and sizes but by far the most important are the shrimp-like crustaceans called krill. Just 5 centimetres long, krill can occur in swarms so dense and large that they turn the surface of the ocean red for kilometres. Like birds in a flock, the several thousands of individuals per square metre in a krill swarm show amazing **co-ordination**, swimming parallel to each other and altering course together. The total number of krill in the Southern Ocean is estimated to be a staggering 600 million million, making krill easily the most numerous creature on Earth. Based on this estimate, their total weight is 650 million tonnes, far greater than that of the world's human population.

The krill is the cornerstone of the Antarctic's ecology. Whales, seals, penguins and many other seabirds depend on it for their basic food. In the first half of this century it is thought that whales alone were taking 150 million tonnes of krill a year. In comparison, our annual world fish catch weighs 70 million tonnes. Since then, people have vastly reduced whale **populations**, which has left far more krill for other creatures. The massive increase in fur seal numbers and the steady climb in penguin populations in the last 20 years reflects the bounty now available. For the Wildlife of Antarctica, it is good news that our taste does not run to krill.

As winter approaches the krill disperse, most of them grazing beneath the increasing **pack ice**, and all the baleen whales except the minke head north. The six months they have spent feeding in Antarctic waters have built up their blubber and fat reserves for breeding. They will now draw on these in the winter months. Not surprisingly, when the summer comes and the whales return to the Antarctic, their blubber is thin and their condition poor.

From *Life in the Freezer* by Alastair Fothergill

Using information in the passage and your own knowledge, answer the following questions.

1. What is meant in the passage by the words indicated in bold as follows:

i. nutrients
ii. photosynthesise
iii. turbulence
iv. zooplankton
v. co-ordination
vi. populations
vii. pack ice [7]

2. Describe two characteristics of krill which mean they are classified as crustaceans. [2]

3. Backboned animals are called vertebrates and there are five main groups of vertebrates. Which three of these groups are represented by animals in the passage above? [3]

4. Phytoplankton photosynthesise. Why, apart from nutrient availability, is the Southern Ocean such a good place for them to do this? [2]

5. Write out two food chains, starting with phytoplankton in each case. [3]

6. The krill is the cornerstone of the Antarctic's ecology. Explain the effect on other animals of:

i. Humans reducing whale populations by hunting. [1]
ii. Humans deciding to eat krill in the future. [1]

7. Many whales move north in the winter.

i. What word do we use for seasonal animal movements like this? [1]
ii. Name two British animal species that move in this way. [2]

8. Krill live underneath the pack ice in Winter. Explain:

i. Why whales can't hunt them there. [1]
ii. What effect global warming would have on the krill. [2]

Total for Biology [25]

Chemistry [25 marks]

1.

When on secret operations members of the Special Boat Service use special scuba diving equipment called rebreathers. Rebreathers capture exhaled gas and remove any carbon dioxide made from breathing and recycle unused oxygen. This means no oxygen is wasted and no bubbles are formed which might give away an agent's position.
Carbon dioxide dissolves in the rebreather to form carbonic acid.

$$CO_2 + H_2O \rightarrow H_2CO_3$$
Eq. 1

This reacts with a concentrated solution of sodium hydroxide as follows:

$$H_2CO_3 + 2NaOH \rightarrow Na_2CO_3 + 2H_2O$$
Eq. 2

a. *Eq.2* is an example of what sort of reaction?

[1]

b. What is the pH of a concentrated solution of sodium hydroxide?

[1]

c. Is carbonic acid a strong acid or a weak acid?

[1]

d. What colour would universal indicator go in the presence of carbonic acid?

[1]

e. At school, what is the test for carbon dioxide gas?

[2]

f. Apart from possibly causing global warming, what environmentally damaging effect might atmospheric carbon dioxide emissions have?

[1]

Question 1 total marks [7]

2.

Hydrogen peroxide solution contains hydrogen peroxide, H_2O_2, dissolved in water. When hydrogen peroxide is exposed to bright sunlight it slowly decomposes into water and oxygen.

a. Balance the equation for the decomposition of hydrogen peroxide:

$$H_2O_2 \xrightarrow{Sunlight} \ldots\ldots\ldots + \frac{1}{2}O_2$$

[1]

b. What is the test for oxygen gas?

[2]

A catalyst is a substance that speeds up a chemical reaction but is unchanged at the end of a reaction. Potassium iodide solution can be added to hydrogen peroxide solution and will act as a catalyst in the decomposition reaction above.

Look at the Chemistry Insert sheet provided. *Fig.1* graphs the formation of oxygen gas with time for three 100 millilitre solutions of hydrogen peroxide, using the catalyst. Curve A is a 6% solution of hydrogen peroxide at 30ºC; curve B is a 6% solution at 70 ºC.

c. What has happened to the hydrogen peroxide in all three graphs by 500s?

[1]

d. Curve C is also at 30 ºC, what is the % concentration of the solution?

[1]

e. For curve A, describe how the rate of formation of oxygen gas changes over the course of the reaction.

[2]

f. *Fig.1* shows that increasing which two factors speeds up a chemical reaction (do not include catalyst)?

[2]

Time / s	Vol. Oxygen / ml
0	0
100	70
200	127
300	130
400	214
500	247

Table 1

Table 1 displays data for a similar 6% solution, but at 10 ºC.

g. Plot the points in *Table 1* on *Fig. 1*.

[2]

h. Circle the anomalous point.

[1]

i. Draw a curve of best fit through the right points and label it D.

[1]

j. Given enough time, what will be the final volume of oxygen gas produced by D?

[1]

Fig. 2 shows curve A again, and curve E. Curve E is a similar 6% solution at 30 ºC but uses a different catalyst: the biological enzyme, *catalase*.

k. Which catalyst causes a faster rate to begin with?

[1]

l. Apart from at the start and at the end, after how many seconds has the catalase solution produced the same amount of oxygen as the solution using the non-biological catalyst at 30 ºC?

[1]

m. *Fig. 2* also shows curve F. Curve F is a 6% solution again using the biological enzyme catalase, but this time at 70 ºC. Although at a higher temperature, why is the reaction so unexpectedly slow?

[2]

Question 2 total marks [18]

Name: Prep School:

Chemistry Insert

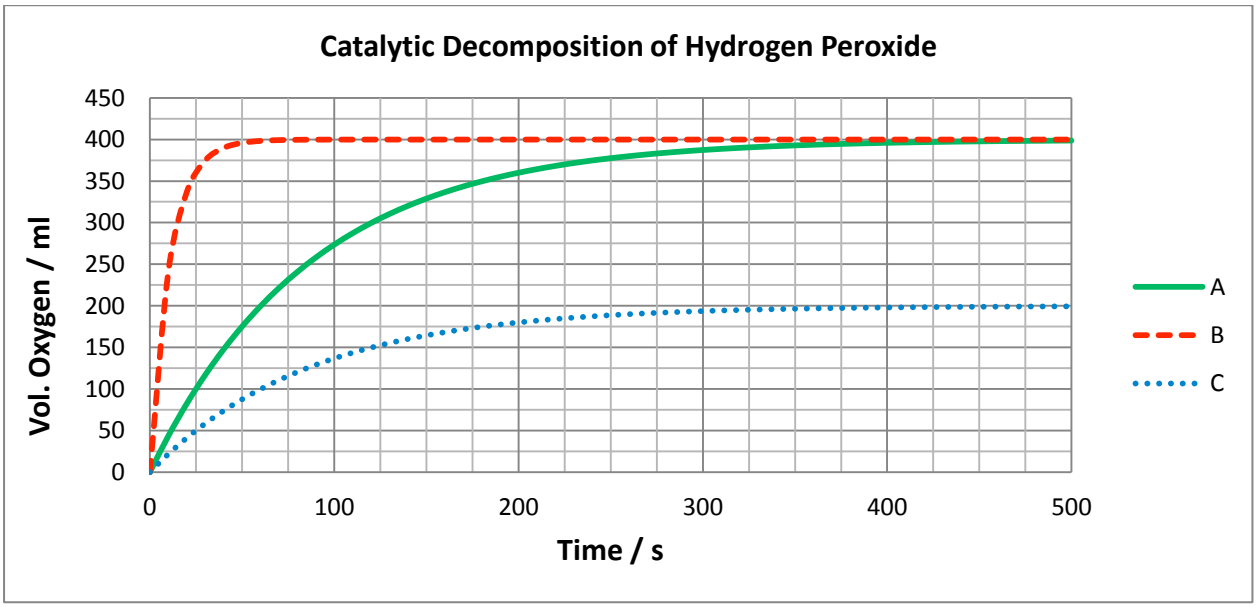


Fig. 1

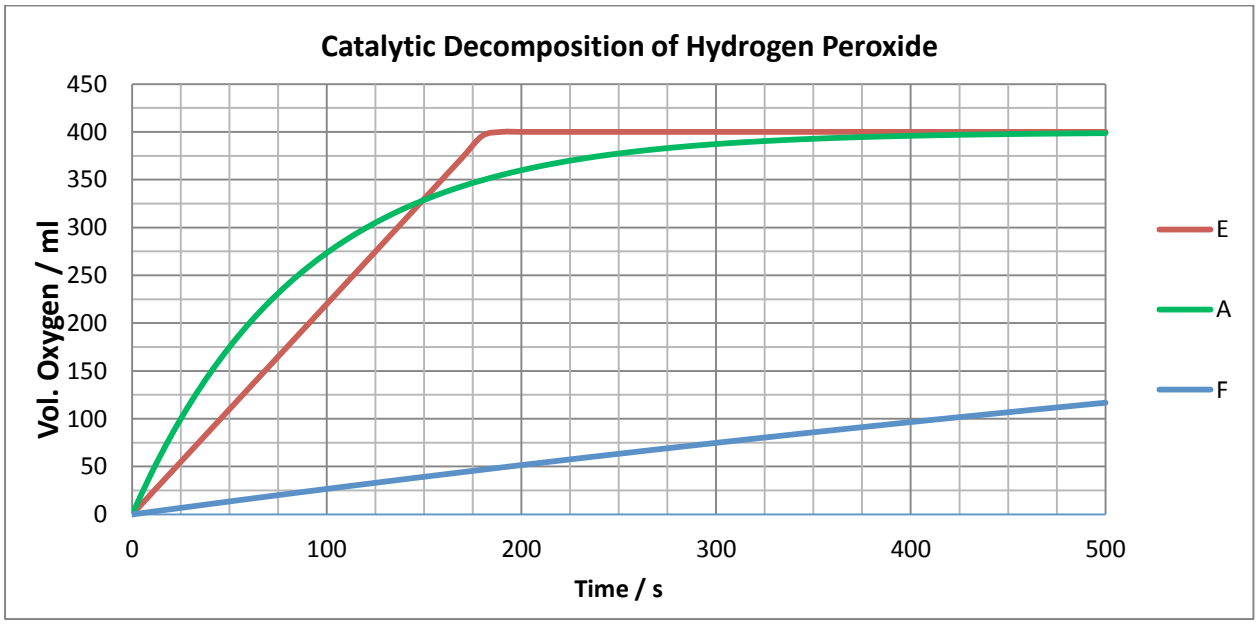


Fig. 2

PHYSICS SCHOLARSHIP 2012

CALCULATORS ARE NOT TO BE USED

MOST OF THE MARKS IN THIS QUESTION ARE FOR SHOWING HOW WELL YOU CAN THINK. THE FINAL ANSWERS ARE LESS IMPORTANT THAN SHOWING THAT YOU CAN THINK AND WORK LOGICALLY.

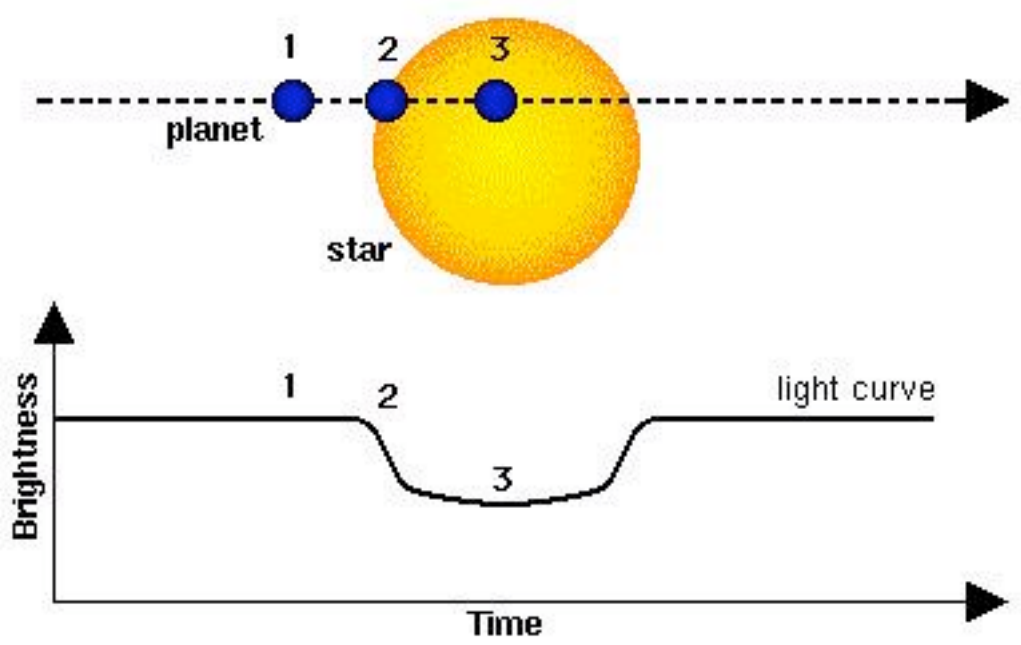
You must show your working out at all stages and clearly state any assumptions that you are making.

Where you can, use powers of ten to show very big or very small numbers. For example 1,000,000 = 1.0×10^6

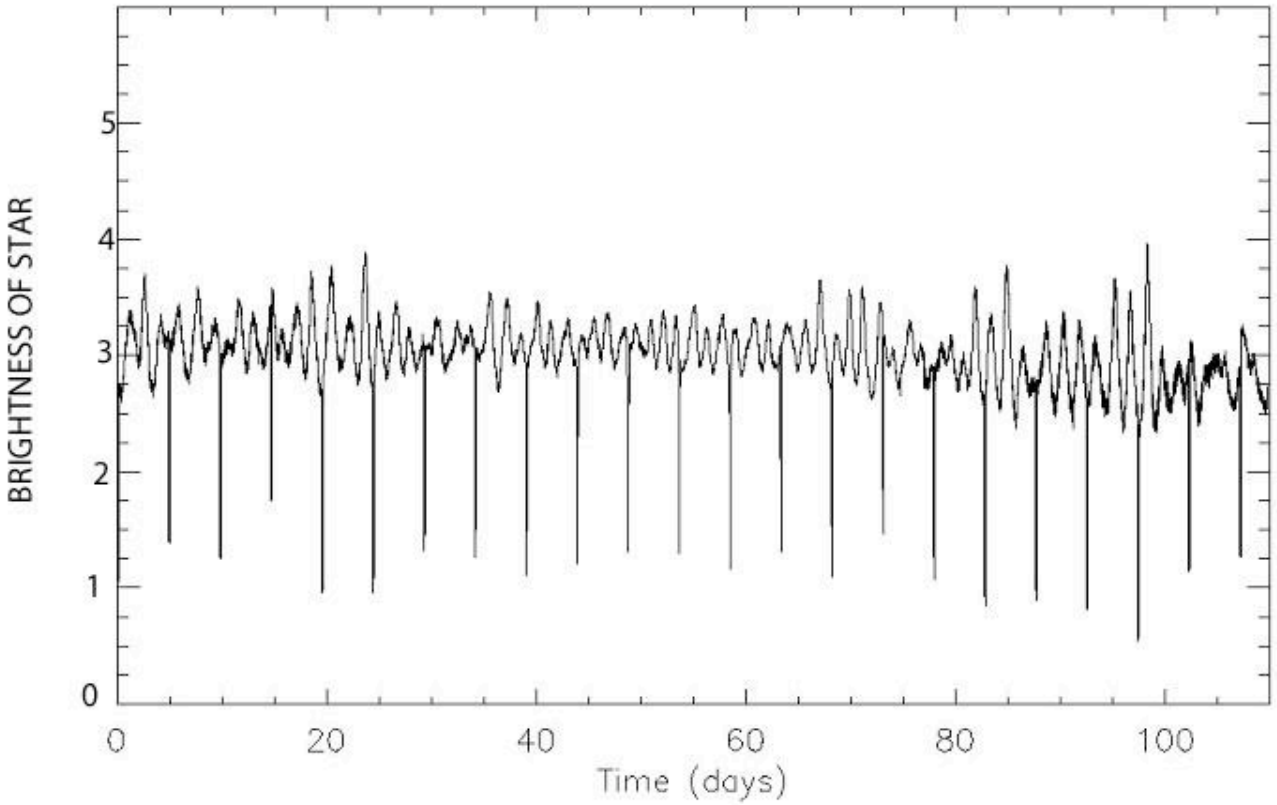
EXOPLANETS

All the planets in our solar system orbit the sun, our local star. This question is about the search for planets orbiting other stars in the Milky Way. Such planets are known as exoplanets.

One way in which such planets are detected is by looking at the stars they orbit. When the planet passes in front of the star it blocks some of the light and causes the brightness of the star to dip for a short time as shown below in the diagram.



The graph below is a light curve for a real star, with the dips in brightness being seen as sharp downward spikes.



1. Using the graph, answer the following questions:

   a. How long does it take for the planet to complete 10 orbits of the star? (2 marks)

   b. Use your answer to part (a) to calculate the time for one orbit. (1 mark)

   c. Do you think that the planet in this question is closer to its star than the Earth is to the sun, or further away from its star than the Earth is to the sun? Explain your answer (2 marks)

2. Using the graph again, answer the following questions:

   a. Estimate as a percentage (%) the amount of light blocked when the planet passes in front of the star. (2 marks)

   b. Can you deduce anything about the size of the planet from your answer to part (a)? (2 marks)

3. One of the most recent exoplanets to be discovered is called Gliese 581c. It is known as a 'super Earth' because it has a mass that is not too much larger than the mass of the Earth.

How many times heavier than the Earth is Gliese 581c? (2 marks)

The mass of the Earth is 6×10^{24} Kg

The mass of Gliese 581c is 3.6×10^{25} Kg

4. Gliese 581c is a distance of 20 light years from Earth. Calculate the distance to Gliese 581c in metres. (2 marks)

1 Light Year = the distance travelled by light in 1 year

Speed of light = 3×10^{8} m/s

1 year = 3×10^{7} seconds

5. Rockets travelling to the moon reach speeds of 12 kilometres per second.

a. Using powers of ten, write down 12 kilometres per second as a speed in metres per second (1 mark)

b. Calculate how long it would take to reach Gliese 581c at a speed of 12 kilometres per second. Give your answer in years. (5 marks)

c. Given your answer to (b), discuss what the problems would be for humans trying to travel to Gliese 581c (3 marks)

6. In the Milky Way there are approximately one hundred billion stars. So measuring the light from each one to see if there is a planet orbiting would take a long time.

One billion = one thousand million

If we could check one hundred stars per month, how long would it take to check every star in the Milky Way? (3 marks)