Biology GCSE Coursework

“An investigation of the effects of the quantity of light on the rate of photosynthesis in Elodea”

Planning

I am going to investigate the effect of the quantity of light on the rate at which a piece of Elodea photosynthesises.

The term photosynthesis means making food in the light. It is the basis of all food chains and webs, because green plants are able to use sunlight as an energy source. Green plants are called primary producers, and the food they make from simple inorganic substances is passed through the eco system. Plants take in two raw materials, water from the soil, and CO_2 from the air, and along with minerals, produce all the organic molecules they require. Plants are therefore said to be autotrophic (self-feeding), where as animals are heterotrophic (they eat food). Photosynthesis can be summarised by a simple equation:

$$\mathbf{6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(l) + 6O_2}$$

The glucose is soluble and turned to insoluble starch for storage, hence we test for starch to show photosynthesis has taken place.

From the above equation, we can see the factors that affect photosynthesis:

- Light – quantity and quality (colour)
- Temperature – needs to be at an optimum for the plant enzymes
- CO_2 – the amount of (not usually limiting, but in excess)
- H_2O – amount of (not usually limiting, but in excess)

- Chlorophyll – amount of (not usually limiting but in excess)

Thus, we can see from the above, that photosynthesis is controlled by several determining factors. Because of this, photosynthesis must follow **Blackman's Law:**

Blackman's Law states that in a process where there are many variables or factors controlling the rate of reaction (such as in photosynthesis), it is the factor which is in least supply, which governs the overall rate of the process.

Light

Here is a graph showing how the light intensity affects the rate of reaction in photosynthesis:

At first, as the light intensity increases, so does the rate of photosynthesis. However, at a particular point, the light intensity can still increase, but the rate of photosynthesis will not. The leaves have more light than they need, but another factor is preventing them from photosynthesising any faster.

Temperature

Here is a diagram showing how temperature affects the rate of reaction in photosynthesis:

This is a typical enzyme graph, showing that photosynthesis requires and uses enzymes. The enzymes reach an optimum temperature (usually about 20-30°C), and the rate of reaction will steadily increase to this point. However, as the temperature increases above the optimum, the enzymes begin to get destroyed in a process called denaturation, until they become completely denatured. This is not illustrating Blackman's Law.

CO_2

Here is a graph showing how the amount of CO_2 (released by $NaHCO_3$ ions) affects the rate of reaction in photosynthesis:

This graph is very similar to the light graph, and illustrates Blackman's Law in the same way.

In order for my investigation to be a fair test, I will need to control or vary all variables in a consistent manner.

Light: I will vary the light intensity. I will do this by varying the distance from the light source (a lamp) to the elodea. The relationship between distance from light and light intensity is $1/d^2$ – I will work out the light intensity by using this equation on the distances I use. My preliminary work showed that distances of 5, 15, 25, 35, 45, 55, and 65cm from the elodea, gave a good spread of results (distances further away from the elodea were not worth experimenting on, as the elodea photosynthesised at a very slow rate, or not at all. I know this from preliminary series of experiments).

Temperature: I will not be heating the water in which I will place the elodea, as this will keep the temperature (fairly) constant. My preliminary experiments showed that using this method, the temperature only varied by 2 or 3°C at the most – and this small amount does not impact the results.

CO_2: I will be placing the elodea in a test tube filled with a solution of 0.1% $Na^+HCO_3^-$ (and the test tube will be placed in a water bath at a constant temperature). The $Na^+HCO_3^-$ ions will release CO_2 for photosynthesis. The CO_2 will always be in excess, and my preliminary work showed that this solution worked well, and will not affect the photosynthesising of the elodea. It is by this method that I will control the amount of CO_2, keep it constant, and always in excess.

Chlorophyll: I will control the amount of chlorophyll, by using the same elodea all the way through my experiment. My preliminary experiments showed that an elodea 10cm in size photosynthesises at an ideal rate, and would be the best length for my experiment.s

Water: I will keep the test tube in the same amount of water throughout the experiment, to ensure that H_20 levels are kept constant.

Taking all this into account, I predict that the closer the lamp is to the elodea, the faster the elodea will photosynthesise. However, normally as the light intensity increases, so does the rate of reaction, but only up to a certain point, when another factor becomes limiting. In this case however, I have taken steps to try and ensure that this doesn't happen: the temperature will be at an optimum (approximately 25°C), the amount of CO_2 will be in excess, as will the water and chlorophyll – which should make the light intensity the factor in least supply. According to Blackman's Law (which photosynthesis follows) this will make the light intensity the overall governing factor, meaning that only it will determine the overall rate of reaction.

To carry out my experiment, I will need the following apparatus:

- Thermometer – to measure the temperature
- Bench lamp – to supply light for photosynthesis
- Beaker – to put water and test tube in
- Test tube – to put $Na^+HCO_3^-$ solution and elodea in
- Elodea
- Supporting clamp and stand – to hold test tube in place
- Metre ruler – to measure distance form lamp to elodea
- Stop watch – to time the elodea photosynthesising
- 0.1% $Na^+HCO_3^-$ solution – to release CO_2 for photosynthesis
- Knife – to cut piece of elodea of requisite length (10cm)
- Board – to place elodea on while cutting
- Blu-tac – if elodea floats in solution, a small piece of blu-tac may be stuck to the end of the plant, so that it will be weighed down to the bottom of the test tube.

I will arrange the apparatus as follows:

Here is how I will conduct the experiment:

I will cut a piece of elodea 10cm in length – as my preliminary experiment showed this to be the ideal length – and place it in a test tube in a solution of 0.1% $Na^+HCO_3^-$, so that CO_2 will be released and always be in excess for photosynthesis. This test tube will be placed in a beaker, in a water bath. The water will not be heated, so that the temperature will be constant throughout the experiment at room temperature. Room temperature (22-25°C) is also the optimum temperature for the plant enzymes - meaning they will be working at the optimum rate, and will not become denatured, as the temperature will never rise more than 2 or 3°C above the optimum temperature. The test tube will then be fixed in place by a clamp and stand. I will then leave the elodea for a five-minute "settling-in" period, where the elodea will adapt to the conditions. Then, I will place the lamp 5cm away from the elodea, and begin timing. I will be recording the number of O_2 bubbles given off by the elodea every minute – this is the rate of photosynthesis. For every distance, I will record the number of O_2 given off every minute, and repeat the procedure 3 times. I will then take the average of the 3 readings. This is to be able to accommodate any anomalous results that may crop up. The entire procedure will be repeated at distances of 15, 25, 35, 45, 55, and 65cm. These distances should provide me with sufficient readings for a suitable graph in my analysis.