Photosynthesis
Planning

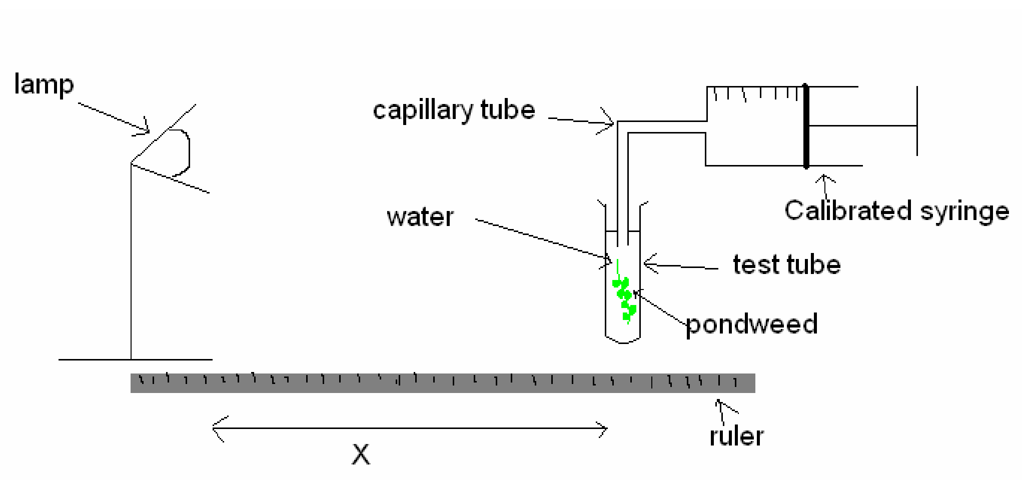
Photosynthesis is the building up of sugars using carbon dioxide and water as the raw materials. The energy for the process comes from light and a green pigment called chlorophyll allows the plant to transfer the energy from light to sugar. The chemical equation for this process is:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 + \text{energy}$$

↑
(Light & Chlorophyll needed)

Plants can only photosynthesise during the day, as light is needed. The rate at which a plant photosynthesises depends on the conditions in which it is kept, in particular the light intensity, the amount of carbon dioxide available, the temperature and the amount of water available. In general the best conditions for photosynthesis are found in areas with long hours of sunshine, warmth and high rainfall.

In this investigation, I will assess how light intensity affects the rate at which photosynthesis occurs. The rate of photosynthesis can be calculated by measuring the amount of oxygen produced by the plant over a set period of time, the greater the volume of oxygen produced the greater the rate of photosynthesis. An experiment can be set up to measure the amount of oxygen as follows:



Apparatus: - lamp, ruler, calibrated syringe, capillary tube, test tube, pondweed.

Method: -

1. Set up the apparatus and fill the syringe, capillary tube and test tube with water.
2. Cut the stem of the pondweed so that the bubbles of oxygen produced during photosynthesis can escape the plant and place it, upside-down, in the test tube.

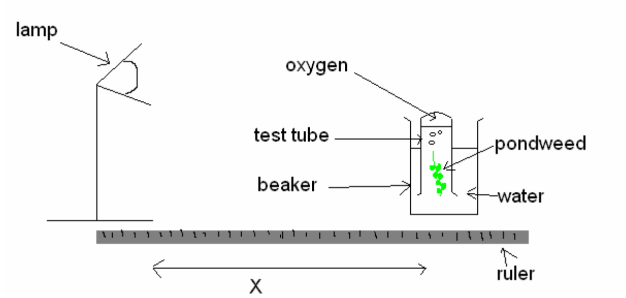
3. Starting with the maximum value of x, allow the plant to photosynthesise for 5 minutes noting the amount of oxygen that has been produced every minute.
4. When 5 minutes have passed, note the final reading then increase x by 5cm. Leave the plant to adjust to the new light conditions for 5 minutes.
5. Reset the apparatus and repeat the experiment for the new value of x.
6. If a result appears to be anomalous, repeat the experiment for that value of x.

It is vital that the only variable in this experiment is x. All other possible variables must be kept the same for each test. Below is a list of possible variables and how they will be controlled:

- *The pH of the water and the minerals present in the water*. The pH of the water must be the same for each test. This can be done by using an indicator or litmus paper. Also the presence of some minerals can inhibit photosynthesis and therefore, de-ionised water which does not contain minerals must be used in order to perform an accurate experiment.
- *The water temperature*. This must be constant for every test. It can be checked before each experiment commences using a thermometer.
- *The pondweed*. The same piece of pondweed must be used for each test. This is because a different piece may have more or less leaves and as the leaf is the organ of photosynthesis, it will photosynthesise at a different rate, thus introducing another variable.
- *The time for the plant to adjust to the new light conditions.* This will be set at 5 minutes. This must be constant because if in one test, the plant is only given 2.5 minutes to adjust and in another it is given 5 minutes the one given 2.5 minutes will not be as well adjusted and thus the results will not as accurate.
- *The room temperature.* This must be constant for each test as a change in room temperature could cause a change in water temperature from one test to the next. It can be checked before each experiment commences using a thermometer.
- *The ambient light.* The ambient light in the room must remain constant for each test. If it fluctuates, this may cause inaccuracies. It is therefore necessary to perform the experiment under constant artificial light or in the dark (the only source of light being the lamp). Natural light cannot be used as its intensity is prone to fluctuations (e.g. If the sun goes behind a cloud).
- *The apparatus.* The same apparatus must be used for each test. This eliminates another source of error. For example if a syringe was inaccurately calibrated but it was used for all the tests it would not matter. If however it were replaced after the first test with a more accurate syringe, a fair test would not have been achieved.
- *The time each experiment is allowed to run for.* This must be kept the same for all the tests as if it is not, the whole experiment will be fundamentally flawed. Each test will run for 5 minutes, as this will provide a fair test.
- *The orientation of the pondweed within the test tube.* The pondweed must be upside-down within the test tube for each test. This is so that the bubbles of oxygen that are released can pass into the capillary tube without obstruction.
- *The point from which x is measured.* This must be kept the same in order to use accurate x values. If one test uses an x value measured from the left

hand side of the test tube and another uses an x value measured from the right, a fair test will not have taken place.

The above variables which must be controlled became apparent as a result of the preliminary work. This entailed a crude version of the above experiment which was set up as shown below.



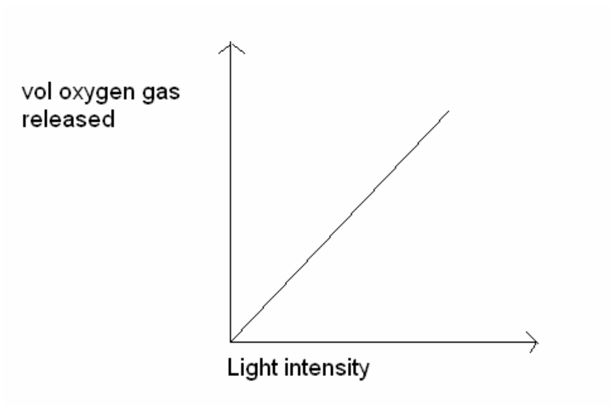
The rate of photosynthesis was not measured by the amount of oxygen released over a set period of time but by the relative size of the bubbles of oxygen released by the plant. This was found to be a very inaccurate method and thus helped to create the better, more accurate method that will be used in the actual experiment.

The preliminary work also helped to decide the range of values for x. The lamp was moved back until the bubbles of oxygen released were very small and barely visible. This (80cm) was taken to be the maximum value of x. When deciding upon the minimum value of x it was important to consider the fact that enzymes are vital for photosynthesis and as the lamp generates heat it cannot be so close to the plant that the enzymes are denatured. Thus the minimum value for x was set at 15cm. In addition, the preliminary work showed that it took longer for the bubbles to get smaller when the light intensity decreased than it did for them to get bigger when it increased. Thus it was decided to start with the maximum value of x so that the plant does not need too long to adjust to new light conditions.

The results for this experiment will be collected in the table below.

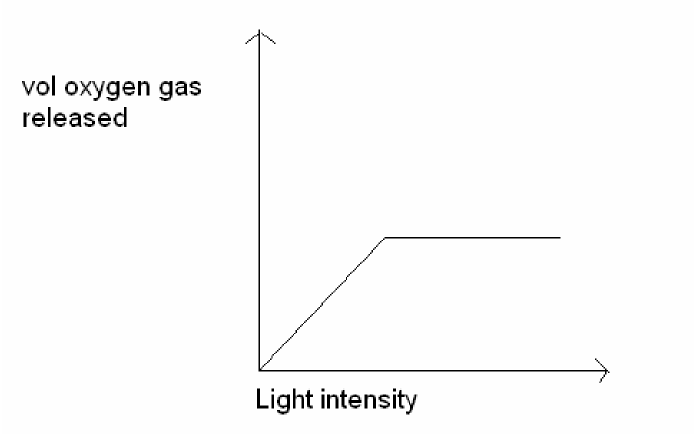
	Amount of oxygen gas released (cm^3)					
x (cm)	0 mins	1 min	2 mins	3 mins	4 mins	5mins
15						
20						
25						
30						
35						
40						
45						
50						
55						
60						
65						
70						
75						
80						

Prediction: -
I predict that because plants photosynthesise at a greater rate in greater light intensity, if a fair test is performed, the increase in light intensity (decrease in x) will be directly proportional to increase in the volume of oxygen gas released. If a graph of x vs. volume of gas released is plotted, I predict it will have the following shape:



If this is the case, and the graph produced is a straight line, it will be possible to calculate a formula for the volume of gas produced in terms of x. This can be done by using the general case of $y=mx+c$ (m=gradient of straight line, c=intercept on the y axis). In this case, y is the volume of gas produced.

The above may be true for my range of values (15-80cm) however, if a much wider range of values were used the graph would probably have a different shape:



The graph becomes a straight line in which the gradient = 0 towards the end because there is a limiting factor. This means that the plant will not photosynthesise at a greater rate even if the light intensity is increased further. This is because there is not enough of one of the other factors which affect photosynthesis (heat, water, carbon dioxide) to sustain a higher rate of photosynthesis. It is unlikely to be heat or water as the pondweed is in water and is next to a lamp which provides heat. Therefore, the limiting factor is probably the level of carbon dioxide and this could be tested by raising the concentration of carbon dioxide in the atmosphere surrounding the plant.

Obtaining

The experiment was carried out and the following results were obtained:

Light Intensity	Size of oxygen bubble (mm) (1st attempt)	(2nd attempt)	Average
10	5	5	5
20	10	10	10
30	15.5	15.5	15.5
40	20.5	20.5	20.5
50	26.5	26.5	26.5
60	31.5	31.5	31.5
70	36.5	36.5	36.5
80	41	41	41
90	47	46.5	46.75
100	51	52	51.5

Analysing

The results of the experiment clearly show that as the light source moves closer to the plant, the size of the oxygen bubble increases.

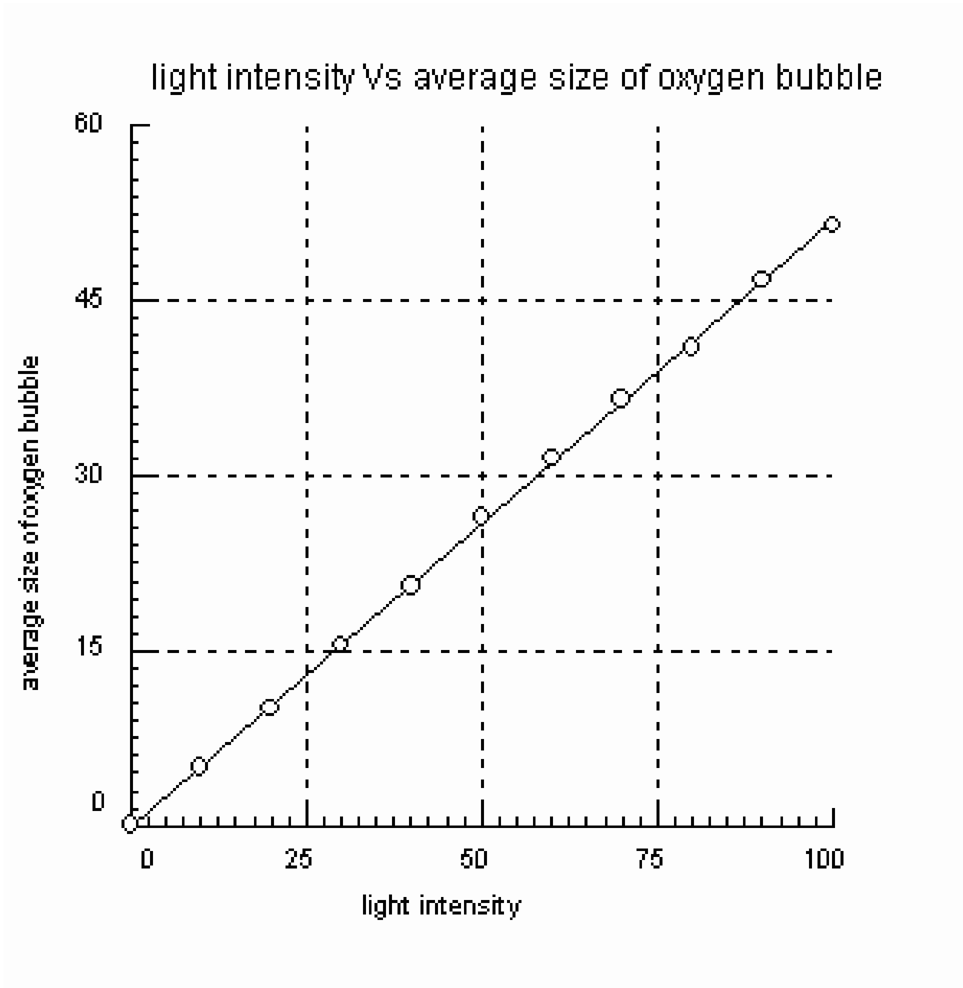
Light Intensity	Size of oxygen bubble (mm) (1st attempt)	(2nd attempt)	Average
10	5	5	5
20	10	10	10
30	15.5	15.5	15.5
40	20.5	20.5	20.5
50	26.5	26.5	26.5
60	31.5	31.5	31.5
70	36.5	36.5	36.5
80	41	41	41
90	47	46.5	46.75
100	51	52	51.5

As the light source moves closer to the plant, the light intensity increases. As this happens, the oxygen bubble increases in size meaning that more oxygen gas is being produced. This shows that the plant is photosynthesising at a greater rate.

A graph (graph 1) can be plotted of light intensity Vs average size of oxygen bubble. The graph produced is a straight line and therefore the general case of $Y = MX + C$ can be used to find a relationship between light intensity and the size of the oxygen bubble:

Y = size of oxygen bubble,

X = light intensity,
M = gradient of straight line on graph of light intensity Vs average size of oxygen bubble = 0.51
C = the value at which the straight line crosses the vertical (y) axis = 0.
Thus:
Y = 0.51X

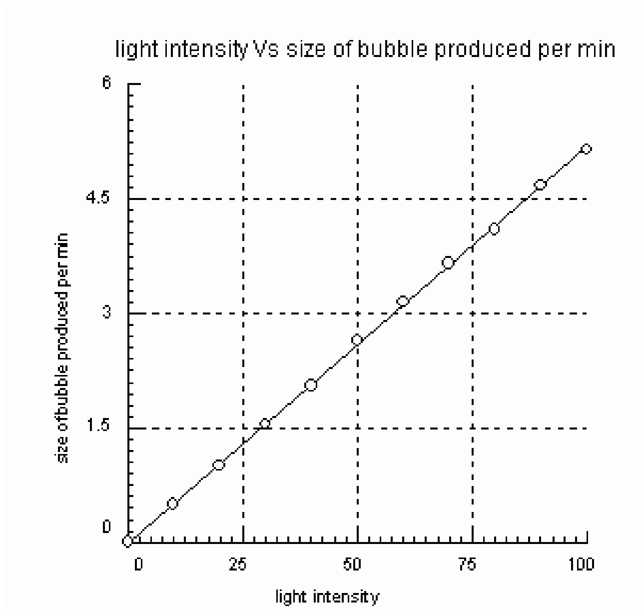


This means that, in general, the length of the oxygen bubble (in mm) is equal to the light intensity multiplied by 0.51. For example if the light intensity were equal to 32, the length of the bubble would be equal to (0.51 x 32) which is equal to 16.32mm. This can be checked by drawing a line on the graph from the point on the x axis where light intensity = 32 and then drawing another to a point on the y axis from where the first line touches the straight line.

As the only variable for each experiment was the distance between the light source and the plant (light intensity), all other possible variables were kept constant. This means that the time each experiment ran for was the same (10 mins). Thus a value for the rate at which the plant photosynthesises at a certain light intensity can be calculated. By dividing the size of the oxygen bubble after 10 mins by 10, a value for the amount of oxygen produced per minute can be calculated. This is shown in the following table.

Light intensity	Total size of oxygen bubble	Size of oxygen bubble produced per min (mm) (RATE OF OXYGEN PRODUCTION/min)
10	5	0.5
20	10	1
30	15.5	1.55
40	20.5	2.05
50	26.5	2.65
60	31.5	3.15
70	36.5	3.65
80	41	4.1
90	46.75	4.675
100	51.5	5.15

A graph of the above can be plotted (light intensity Vs size of bubble produced per min) (graph 2). The straight line produced proves that the increase in the rate of photosynthesis is directly proportional to the increase in light intensity. Also, it is found by again using the general case of Y = MX + C and the same method as before that the size of oxygen bubble produced per minute is equal to the light intensity multiplied by 0.051.



The above is slightly deceptive. If the light intensity were increased further, there would come a point at which the increase in the rate of photosynthesis would no longer be directly proportional to the increase in light intensity. This is the point where a limiting factor would be introduced. This is because there is not enough of one of the other factors which affect photosynthesis (heat, water, carbon dioxide) to sustain a higher rate of photosynthesis. It is unlikely to be heat or water as the pondweed is in water and is next to a lamp which provides heat. Therefore, the limiting factor is probably the level of carbon dioxide. The rate of increase in the rate of photosynthesis would decrease and would eventually become 0 as there would not be sufficient carbon dioxide for the rate of photosynthesis to increase any further.

It has been found that as the light intensity increases, the rate of photosynthesis increases. This is because light intensity is one of the four factors which govern the rate at which photosynthesis occurs. The other factors are the abundance of the raw materials carbon dioxide and water and the temperature. The light provides the energy for the process. Thus, if there is more light there is more energy available and photosynthesis can occur at a greater rate.

$$6CO_2 + 6H_2O \underset{\text{(Light \& Chlorophyll needed)}}{\xrightarrow{\uparrow}} C_6H_{12}O_6 + 6O_2 + \text{energy}$$

As the chemical equation for photosynthesis shows, a green pigment called chlorophyll is needed for the process. This substance allows the energy from light to be converted into sugar. The chlorophyll only uses two wavelengths (colours) from the spectrum of white light, red and blue. An increase in light intensity causes an increase in the levels of the two required light wavelengths and thus photosynthesis can occur at a greater rate.

In my prediction, I stated that I thought that an increase in the rate of photosynthesis would be directly proportional to the increase in light intensity. Although this may not be entirely correct due to limiting factors (as mentioned above), for the range of light intensities featured in my experiment it was the case and my prediction was correct. The limiting factor did not affect the experiment, as the light intensity did not increase enough to make the plant require more carbon dioxide than was available. The shape of my predicted graph of light intensity Vs amount of oxygen produced was correct. In my opinion, my conclusions show that my prediction was accurate.

Evaluating

The experiment performed to asses how light intensity affects the rate at which plants photosynthesise was adequate to allow accurate conclusions to be drawn. The results taken can be considered accurate. None of my results were particularly anomalous showing that the experiment had been performed to a good degree of accuracy. The results which were slightly anomalous (i.e. line of best fit on results graph did not pass through them) were very close to the best-fit line and basically within the general trend and thus did not affect the accuracy of the conclusions. These anomalies are evident on the rate of photosynthesis graph which has been reproduced with the slight anomalies circled.

The computer simulation of the experiment has its limitations. The only variables that it allows to be regulated are light intensity, temperature and level of carbon dioxide. It does not allow other possible variables to be controlled. Possible variables such as ambient light, ambient temperature and water pH level cannot be controlled. It is not known whether these variables were controlled when the actual experiment was carried out to get the data for the computer simulation and therefore it can be said that the discrepancies in the experiment may have caused the slightly anomalous results. For example, a change in ambient temperature from one experiment to another would cause inaccurate results.

Further experiments could be performed to asses whether all plants photosynthesise at the same rate. This could be achieved by repeating the experiment with plants other than the Canadian pondweed used in this experiment. Also, different light sources could be used to investigate how different types of light affect the rate of photosynthesis. This could be achieved by using sources of light other than the lamp used in this experiment such as coloured lights. The limiting factors such as level of carbon dioxide and temperature could also be investigated to see how they affect the rate of photosynthesis. If these factors were investigated, light intensity would become a constant and 2 experiments would be performed, one with level of carbon dioxide as the variable and one with temperature as the variable.