Photosynthesis Investigation

Analysis

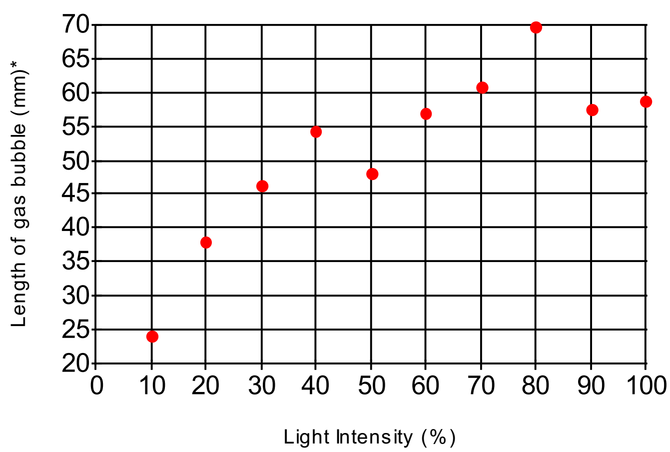
Below is the data table showing my results from the investigation, I have also added an adjoining column and calculated the mean average (total of items B number of items) of the five trials at each level of light intensity:

Light Intensity (%)	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Average
10	22	23	27	27	21	24
20	38	44	35	40	33	38
30	44	42	45	52	49	46.4
40	52	56	57	57	49	54.2
50	49	22	61	55	54	48.2
60	59	54	62	55	55	57
70	45	64	50	74	71	60.8
80	61	60	67	102	58	69.6
90	44	62	55	67	60	57.6
100	60	58	63	62	51	58.8

I believe that there are a few anomalous results in the above table and I have decided not to include them in my experiment as I believe they are inaccurate and might distort my conclusion. In the table below I have highlighted any anomalous data that I will remove. I have also drawn a graph of the averages, calculated above, to assist me in identifying inaccurate data.

Light Intensity (%)	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
10	22	23	27	27	21
20	38	44	35	40	33
30	44	42	45	52	49
40	52	56	57	57	49
50	49	22	61	55	54
60	59	54	62	55	55
70	45	64	50	74	71
80	61	60	67	102	58
90	44	62	55	67	60
100	60	58	63	62	51

Average - with anomalous data



I have circled the data I believe is anomalous, as it does not follow the line of best fit.

* = length of bubble of gas (mainly oxygen) in capillary tube after 10mins using 10g of Elodea.

Any anomalous data I successfully identified, by studying the table of results and by observing irregularities in the trend of my averages on the graph, has been omitted and not included in calculating my new averages.

I have decided to plot the light intensity (%) against the volume of the gas (mainly oxygen) bubble produced per 10mins per 10g of Elodea (mm^3). In order to work out the volume of the gas bubble I will use the formula:

$$V = \pi r^2 \times l$$

V = volume of gas (mainly oxygen) bubble (mm^3)
r = the radius of the capillary tube, 0.5mm
l = the length of the bubble (mm)

Below is a table containing the new, more accurate averages of the gas bubble length and the gas bubble volumes.

Average (mm)	V = PI r² x l	V = PI r² x l
24	18.8495559	18.8
38	29.8451302	29.8
46.4	36.4424748	36.4
54.2	42.5685805	42.6
54.75	43.0005494	43
57	44.7676953	44.8
60.8	47.7522083	47.8
61.5	48.301987	48.3
57.6	45.2389342	45.2
58.8	46.181412	46.2

Graph (see attached sheet)

From the graph you can see that I have drawn my line of best fit through the origin (0,0). I have done this deliberately because I already know that without light energy, a plant cannot photosynthesise. "Photosynthesis takes place in the chloroplasts… tiny, membrane-bound bodies containing millions of molecules of the green, light-trapping pigment chlorophyll. The chlorophyll traps energy from…[the] light and transforms it into chemical energy…[and] oxygen is released…" (Dorling Kindersley Encyclopedia of Science – ©1997). This suggests that the graph does not steadily increase before reaching a plateau but actually curves.

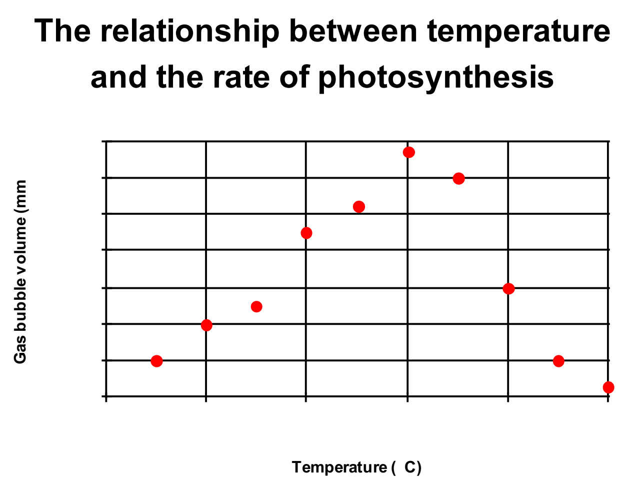
As I predicted, my graph shows that as the light intensity is increased so does the rate of photosynthesis, proved by the increase in the rate of the gas bubble volume. I can closely follow the progress of the chemical reaction by observing how the products appear. The increase in the rate of oxygen production strongly implies that the rate at which photosynthesis occurs is also increased. I believe that if the light falling on each part of the leaf is more intense, then more energy is being provided for the reaction, and subsequently the rate at which it takes place is also increased.

I also predicted that as the light intensity doubled, the rate of photosynthesis would also double, as there would be twice as much energy available to drive the reaction. There would also be twice as many carbon dioxide molecules reacting with water molecules, forming twice as many glucose molecules and producing twice as many oxygen molecules, in the given time limit. I predicted that my graph would clearly show that the rate of photosynthesis is directly proportional to the light intensity, by a positive correlation. Although there two are interrelated they are not directly proportional to each other, as the best-fit line on my graph is curved and not linear. I have observed from my graph that as the light intensity continues to increase the rate of photosynthesis does not, proven by the change in the increase of the gas bubble volume. The best-fit line, representing the rate of photosynthesis, reaches a plateau as it levels out. My graph indicates that this 'plateau' is reached when the light intensity is 70%, after then there is no increase in the rate of photosynthesis.

I believe that this plateau is connected to many factors required for photosynthesis, in particular, light, carbon dioxide and temperature. I think that the sudden change in the trend of my results, when the rate alters from increasing to constant, is because another factor, such as carbon dioxide or temperature, becomes the limiting factor, preventing the rate of photosynthesis from increasing further.

As you can see from my graph, when the light intensity is at 40% or above, there is a slight fluctuation in my results. I believe this is due to a fault that I perhaps overlooked in the experiment.

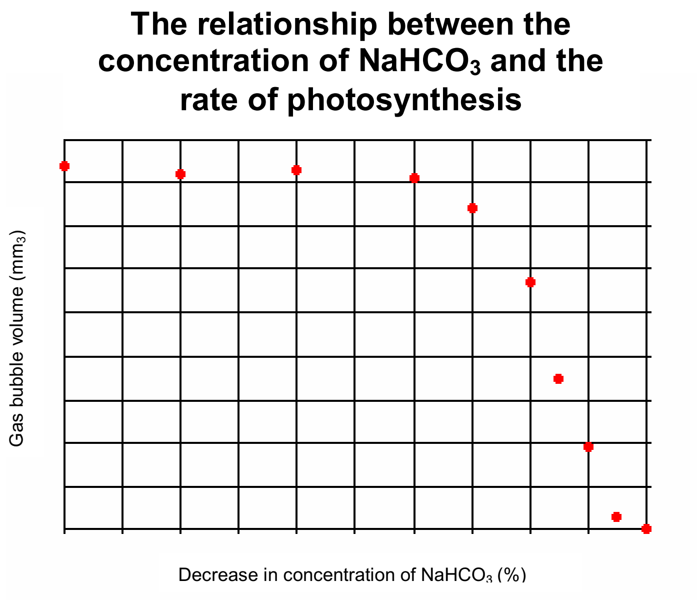
When I began the investigation I recorded the temperature of the water, the plant was submerged in, at 20°C. After the end of the experiment I tested the water again, this time recording it at 24°C. Although the increase was a mere 4°C and seems quite insignificant, and 24°C is below the optimum temperature for enzymes, I believe that these could be possible reasons for fluctuations in my results. I think that the water temperature increased due to heat energy produced by the light source, in this case the bench lamp. Below is a graph briefly indicating the affect the alteration of temperature has on the gas bubble volume.



I believe that because enzymes control photosynthesis reactions, the temperature affects the rate of photosynthesis. As the light intensity increases and subsequently the temperature, the rate of photosynthesis also increases. This is because the reactant particles have a higher level of kinetic energy and therefore there are more collisions per second. Below I have drawn two diagrams clearly illustrating how an increase in temperature increases the rate of photosynthesis:

I also think that the concentration of carbon dioxide could have affected my results and might be the answer to the fluctuation in my results. The solution that the Elodea was submerged in was enriched with sodium hydrogen carbonate ($NaHCO_3$), 0.3%. This compound increases the availability of carbon dioxide. I believe that it is possible that nearing the end of my investigation there was a reduction in the concentration of this compound, decreasing the availability of carbon dioxide. I also believe that the amount of carbon dioxide present in the water would be reduced, as the Elodea would be absorbing it.

Below is a graph depicting the affect of a reduction in the concentration of $NaHCO_3$ has on the gas bubble volume, as well as the rate of photosynthesis:



Below I have drawn two diagrams clearly illustrating how a decrease in carbon dioxide would decrease the rate of photosynthesis:

I believe that in my investigation the insignificant fluctuation in my results is due to an increase in the temperature of the solution and a decrease in the concentration of $NaHCO_3$.

Evaluation

I have evaluated my method in order to comment on how meaningful my results are. I have also clearly stated how I would amend any limitations I encountered, as well as any flaws in my conclusion.

I think I planned my investigation well and made my method as successful as possible. I also believe it is a suitable experiment and provided me with a correct set of data. I believe that after I had removed the anomalous data, my results were reliable enough to draw a conclusion from.

I omitted two anomalous figures from my data, as I believed them to be unreliable and to have occurred by error. I believe that if I had not removed them from my results then they would have affected my graph and distorted my conclusion, making it an untrue and incorrect interpretation. I think that the anomalies in my results were caused by human error, either in the form of a miscalculation, misreading or mistaken recording of the data. I believe that the anomalies are due to human error because there is a significant difference between the anomalous and correct data and I do not think that temperature and the concentration of carbon dioxide would alter the results to this degree.

Below I have estimated how accurate my results were:

I believe I could improve the reliability of my results by ensuring the investigation was conducted in complete darkness. In my experiment, although I have plotted the graph at the origin (0,0), I do not think I can dismiss the suggestion that the Elodea was photosynthesizing when there was 0% light intensity. This is because the experiment was carried out in a darkened room and it was impossible to eradicate all light and I know that in dim light a plant can photosynthesize slowly.

Although I believe my experiment was a reasonably fair test, I believe it could be improved. In my analysis I have commented on possible factors, causing fluctuation in my results, e.g. decrease in carbon dioxide levels and increase in temperature. Although, I believe both of these factors were, to a certain extent, working against and off setting each other, I still believe I could dramatically reduce the effects these factors have on my results.

I could reduce the affects of temperature by placing a sheet of clear perspex between the Elodea and the bench lamp. This will eradicate heat energy whilst still allowing light energy to penetrate through. Alternatively, I could place the glass test tube containing the solution and the Elodea in a filled water beaker. The water bath would ensure that the temperature was more likely to remain constant.

I could reduce the affect the concentration of $NaHCO_3$ has on the rate of photosynthesis by using a new test tube of solution for each trial. I could also use a new piece of Elodea, ensuring that the weigh was the same.

The formula I used to calculate the volume of the gas bubble could be improved. I used a formula typical for calculating the volume of a cylinder, whereas the gas bubble is in fact rounded at each end, meaning the volume is actually smaller then the figures I calculated. However, I think that this is somewhat irrelevant, as the formula provided me with adequate volumes with I was able to plot against the levels light intensity, giving me a rough indication of the rate of photosynthesis, if not an entirely precise one.

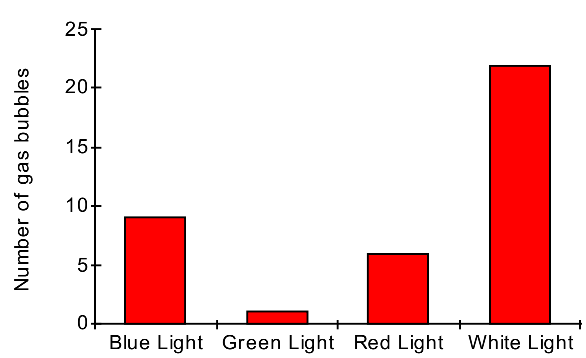
I believe that five trials were sufficient and I do not think that by increasing the number of experiments would significantly change the accuracy of the results.

If I were repeating this experiment, I would like to investigate the relationship between low light levels and the rate of photosynthesis.

I believe that there are additional investigations I could conduct to provide supplementary evidence supporting theories regarding the rate of photosynthesis. I would like to investigate the relationship between the wavelength of light and the rate of photosynthesis. I would use the same method but keep the light intensity constant and instead, place a blue, green or red coloured translucent filter in front of the bench lamp. I would plot the various coloured filters against the number of gas bubbles produced, as well as their volume.

By using a computer simulation programme, "Multimedia Science School", I have discovered the following:

Relationship between light wavelength and the rate of photosynthesis



I would like to investigate this further, see whether it is correct and calculate the percentage of difference between each colour of light.