Photosynthesis Investigation

Prediction

The equation for photosynthesis is:

$$\text{Water + Carbon Dioxide} \xrightarrow{\text{SUNLIGHT}} \text{Glucose + Oxygen}$$

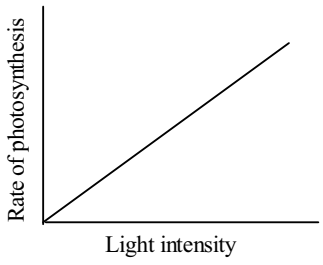
$$6H_2O\ (l) \quad 6CO_{2\ (g)} \xrightarrow{\text{CHLOROPHYLL}} C_6H_{12}O_6\ (aq)\ 6O_2$$

From this equation it is seen that sunlight is very important in the production of glucose. If all other products are available e.g. water and carbon dioxide in sufficient quantities then light can be used as a variable. If not enough of any reactant is present it will be a limiting factor. This means that no matter how much light is added no more glucose can be made.

In our experiment the plant i.e. elodea is placed in water and sodium hydrogen carbonate is added thereby preventing a limiting factor. This is because the water of course is plentiful and the sodium hydrogen carbonate provides the elodea with carbon dioxide. The only way that a limiting factor can be reached is if the temperature rises too high. To prevent this we placed a beaker in front of the light source, which absorbed the heat. The beaker also prevented an increase in temperature as the lamp was moved closer to the elodea. The introduction of the beaker stopped an additional factor entering the experiment. As a limiting factor is unlikely to occur I anticipate that there will be a positive correlation between the rate of photosynthesis and the light intensity. This means that as the light intensity doubles the rate of photosynthesis doubles also.

Plants are always respiring but during the light stage the carbon dioxide that should be released is used as for the production of starch by photosynthesis. During the dark stage though the carbon dioxide is released, as photosynthesis is not taking place, due to a lack of sunlight. When the plant respires it takes in oxygen and gets rid of carbon dioxide just like a human. While making food however the processed is reversed with carbon dioxide being absorbed and oxygen being given off. Also during the light stage a plant splits water ready for the dark stage so the plant is not dependent on the light stage.

In my experiment I will vary the light intensity by altering the distance between the plant and the light source. The effect of this will mean that the closer the light is to the plant the more rapid the production of oxygen. This is because chloroplasts containing chlorophyll are situated on the top layer of the leaf in the palisade cells. If the light is further away less cells can absorb the light and as the source is weaker it takes longer for the photosynthesis to work.



On the left is my prediction to how the rate of photosynthesis will relate to the light intensity. They are directly proportional meaning that for example, if the light intensity increase the rate of photosynthesis will also increase. Also if one is doubled the other doubles as well. The reason for this relationship is that during photosynthesis light is a key element. If all other aspects of photosynthesis (carbon dioxide, water chlorophyll) then light intensity is in control of the reaction. As the light intensity increases chlorophyll can trap enough light needed to form glucose quicker. Therefore the higher the light intensity the quicker that chlorophyll can trap sunlight so the rate of photosynthesis is quicker also. I have already taken part in preliminary tests to make sure I was comfortable with the experiment. My results, although they were not accurate or thorough, show a relationship as I have already stated forming. The Rate of photosynthesis was going up at a fairly similar rate to the Light intensity so I am confident that in the genuine experiment the results will be closer to the graph above and show a directly proportional line on the graph. "***Photosystem II is***

the membrane protein complex found in oxygenic photosynthetic organisms which harnesses light energy to split H_2O into O_2, protons and electrons. It drives the most oxidising reaction known to occur in nature and is responsible for the production of atmospheric oxygen, essential for aerobic life on this planet." Extract from the Imperial college of Science, technology and medicine. This photosystem two splits the water into oxygen, which is one of the most important stages during photosynthesis. I found this extract from the Imperial College website as it shows clearly the complicity of Photosynthesis and the stages that take place. As it says in the extract the light is harnessed by this membrane protein to split the water showing that the more light the more water is split.

Factors

It is very difficult to keep the experiment free from any outside factors. Changes in temperature by as much as two or more degrees can affect the whole experiment e.g. draughts or another heat source. For example if the experiment is set up by a window and the sun comes out from behind a cloud then the plant receives extra heat and light. Also if the experiment is spread over two days, then the temperature is likely to be different. To compensate for this I will place a thermometer in the beaker and check that this does not rise above or fall below a one-degree boundary on either side of the room temperature at the beginning of the experiment. Also the experiment will be carried out away from the glare of all windows to ensure that no other changes will affect the results. Different pieces of pondweed have different masses and length. Each time we change the light intensity I will use the same piece of pondweed so the length and mass is always the same. If the pondweed were longer it would have more palisade cells and so more chloroplasts and if the mass was bigger then more starch would be used up.

Variables

The variables, which can affect the rate of photosynthesis are temperature, mass, length and volume of pondweed and the colour of the light source. These variables can however be controlled during the experiment and subsequently changed if required to determine what effect each one has on the rate of photosynthesis. Temperature can change easily and the reason it affects the rate of photosynthesis is that when cells are hotter they have more energy and therefore move around quicker. Enzymes change the starch into proteins and many other foods when needed and this is done much quicker when they are hotter also.

The mass and length affect the rate of photosynthesis for similar reasons, the bigger the mass the more can be stored in other cells and the longer the plant the more chloroplasts it has so more food is made. The volume of pondweed affects the rate of photosynthesis as a long thin plant has much more surface area than a short thick one so there are more chloroplasts. The chloroplasts are found on the upper layer of a leaf in the palisade cells Therefore the more cells there are the more chloroplasts there are. The volume of water matters also as water is vital in the production of starch so it will cause a limiting factor if not enough is present. In our experiment this will not matter as we are using pondweed with lots of water.
Colour is a good variable also as some colours produce more starch than others. For example green light is the same colour as a plant so it is reflected away and produces nothing. Red and blue however are very good colours as they are furthest from green so have a good wavelength. Lastly changes affect results a lot as they prevent a fair test. If for example the temperature changes during the experiment it can ruin the results.

Method:

- Find a piece of pondweed or elodea and accurately measure its volume, mass and length.
- Get out the apparatus, which consist of a beaker, a test tube, a light, a clamp stand and a meter rule.
- Place the pondweed into the water filled test tube and add sodium hydrogen carbonate. Then put a capillary tube in the test tube.
- Mark on the capillary tube a line where the air bubble starts and set the test tube upside down using a clamp stand.
- Fill the beaker with 50ml of water and place it between the light and the test tube.
- Start the stopwatch and turn on the light.
- For the next 10 minutes take a reading every minute of how far the bubble has gone using the meter rule.
- Repeat this experiment for other lengths, five in total, 50cm, 40cm, 30cm, 20cm, 10cm.

The reason why this experiment works is that during photosynthesis oxygen is given off which due to the elodea being under water pushes the water down and so the air bubble down also. This works well as no extra oxygen or carbon dioxide interferes and it is the only way of finding out how much starch is present. Iodine can only tell me if it is present but in an experiment like this that means nothing.

When taking results I will measure to the nearest millimetre so it is accurate but not so much that it is more of a guess. I will also use five lengths so a clear picture can be drawn as the affect of the light intensity and I will repeat the whole experiment to make sure it is a fair test.

ANALYSIS

From the Elodea experiment I have found out that there is indeed a direct proportion between the rate of photosynthesis and Light intensity. Also there is an inverse proportion between the rate of photosynthesis and the distance of the elodea from the light source. This shows that the closer a plant is to light the higher the light intensity and the higher the rate of photosynthesis.

Plant's distance from light (cm)	**10**	**20**	**30**	**40**	**50**
Amount Of Oxygen Produced (Cm)	**0.5**	**0.7**	**0.3**	**0.1**	**less than 0.1**
	0.8	**1**	**0.5**	**0.2**	**0.1**
	1.5	**1.8**	**0.7**	**0.4**	**0.1**
	2	**2.1**	**1**	**0.6**	**0.2**
	2.6	**2.6**	**1.2**	**0.7**	**0.3**
	3.1	**3**	**1.6**	**0.8**	**0.4**
	3.5	**3.3**	**1.9**	**0.9**	**0.4**
	4	**3.5**	**2.1**	**1**	**0.5**
	4.6	**3.8**	**2.4**	**1.1**	**0.5**
Total amount of oxygen produced (cm)	**5.3**	**4.1**	**2.7**	**1.3**	**0.6**
Average rate of photosynthesis (cm/min)	**0.53**	**0.41**	**0.27**	**0.13**	**0.06**
Volume of oxygen produced (cm^3)	**0.6**	**0.52**	**0.34**	**0.16**	**0.075**

Volume = $\prod x\ r^2 x\ h$
R = radius of capillary tube = 0.2
H = Total amount of oxygen produced

The results above are those that I found from my experiment. Due to events beyond my control the results from my experiment appear lower and are less accurate. To compensate I have found results from an identical experiment carried out by some other students at a school. Their results are more useful to analyse as they took many results and must not have had problems equalling mine during their experiment.

Their results:

Light Intensity arb. units	Distance of lamp to weed	Set 1	Set 2	Set 3	Set 4	Set 5	Set 6	Set 7	Set 8	Set 9
16	10	25	26	26	28	25	27	26	19	26
8	14	24	24	25	13	22	15	24	8	22
4	20	19	18	18	12	18	7	20	7	11
2	28	16	13	15	11	7	5	14	5	9
1	40	10	9	13	6	2	3	11	3	5

These results reflect the same trend as my results but they are more accurate as they are more results. All the sets of results except set 8 are very similar in their readings. Set 8 has very low readings, which may be due to the position of the apparatus. The apparatus may have been set up in a dark corner but more likely there may not have been any Sodium hydrogen carbonate added causing a limiting factor. As the Sodium hydrogen carbonate was not added their wasn't enough carbon dioxide to keep photosynthesis getting any quicker. Set 5 has fairly inaccurate also as between the distances of 20cm and 28cm there is a dramatic difference. This may be due to a change in temperature half way through the experiment. The sun may have re appeared causing extra heat and maybe extra temperature as well. Sets 1, 2, 3 and 7 are all very similar and show the most accurate results. These four experiments would have been completed with no weather changes, mistakes or any faults. The rest of the results are all unique with very different readings, so are less useful to use in deciding if the Light Intensity does indeed affect the rate of reaction. Only set 8 will have had a limiting factor as the rest of the results start at least with a fairly high reading.

The graph comparing the rate of photosynthesis with Light intensity shows a steady directly proportional line with the line of best fit lying close to all of the points. The graph definitely shows that there is a direct relationship between the Light intensity and the rate of photosynthesis. Therefore this shows that the higher the light intensity the higher the rate of photosynthesis also. To confirm that the two are directly proportional I can multiply the light intensity by two and see if the rate of photosynthesis is doubled also.

Light Intensity 1arb. Unit = 62 x 2 = 124
Light intensity 2arb. Units = 95
This shows that there is a bit of a difference between the two values. The results indicate that there is a relationship between the light intensity and the rate of photosynthesis. The reasons why the relationship is not closer is that the rate of photosynthesis does not change as much from one light intensity to the next. It is still directly proportional though because during photosynthesis once a plant has all the factors needed for the chemical reaction to take place the reaction can be processed at a faster rate. When the light is more intensive the chloroplast can absorb sufficient amount needed for photosynthesis to take place quicker. As in the experiment all the factors of photosynthesis needed was present and the chloroplasts did indeed absorb the light faster which then sped up the whole reaction. The light is so important as without out it the chloroplasts could not absorb it and turn it into starch using carbon dioxide and water. The distance from light compared with the rate of photosynthesis graph is inversely. As the distance increases the light intensity reduces so it will have the opposite affect to the light intensity against Rate of photosynthesis graph.

Both my results and the other student's results reflect my prediction, they show that the Light intensity of light affects the Rate of Photosynthesis. The affect is a direct proportional increase of the rate of photosynthesis as the Light intensity increases. The distance is inversely proportional to the Rate of photosynthesis, as the further away the light is the longer it takes for it to reach the plant. Therefore the light is less strong so the rate of photosynthesis is less also. The results don't fully support my prediction though as I thought that the Light intensity and Rate of photosynthesis would be more closely linked. I thought that if you doubled the light intensity the rate of photosynthesis would double also but this is not the case. The results are fairly close to my prediction but the factors are not quite as related as I thought.

Evaluation

From the other students results there is one set that is totally out of place. Set 8 is far below the rest of the readings and due to it the averages were pulled down. Although the other sets of results aren't overly similar they are much more so than set 8, which is nearly half of the other results. Also in set 5 there is too big a difference between light intensity 2 and 4 arb. Units. Due to this the other sets of results were affected also as again the averages were brought down.

Using my results though I have averaged the total amount of oxygen produced by the number of minute we measured it for, so that I have an average rate of photosynthesis. This is different to the students' results, as they have just measured how much oxygen is produced and left it there. The procedure I used to complete the experiment worked well and no limiting factors came into contention. To begin with I received promising and accurate results and was pleased with the hassle free procedure but soon everything changed when our power failed. I found the procedure very suitable to the task in hand as it was quick and easy to set up so more results could be researched in the time available. There was only one problem with the procedure and that was the heat shield made by filling a beaker with water. The problem was that to get the beaker to a height where the light and capillary tube could align with was difficult. For example, for 10 cm the capillary tube had to be on top of the table and not dangling over the edge causing it to be fastened very high up the clamp stand. Due to this the light had to be lifted also causing a 30cm gap between the beaker and the alignment of elodea and light. To solve the problem we managed to find enough books to pile up and so get the beaker in the right place. The only problem with this is it made the experiment more unsafe, although it was not overly unsafe as the books were A4 size and not piled up to high but still one of my group had to hold the books safely at all times. This meant that we had fewer hands to set everything else up.

To improve the reliability of the results more tests could have been done but there was limited time so this became a problem. The worst problem was that the power was wrong so that it kept switching off causing the results to be worthless as the light was switching on and off every few minutes. This caused my final results to be not as reliable as they would have been. Luckily some other students had more reliable results, so I could use them to guarantee that Light Intensity affected the Rate of Photosynthesis, as I had thought. My results still do reflect my prediction but on their own they are substandard evidence. The student's results reflect nearly everything I predicted although I thought that the two factors would be more closely related.

From my graphs the margins of errors can be seen which show that the students result on the Light intensity graph are very small and all the points are very near to the line of best fit. The distance graph however uses my results and has some larger margin of errors showing that the results are less accurate. My expected graph is fairly similar to the outcome but as I have already said it does not reflect the forty-five degree gradient causing a definite direct proportional graph. In my prediction I thought that the line of best fit would show that as one value is double the other doubles also but really this is not the case.

If I were to redo the experiment there would be some major and minor changes that I would make. Firstly I would hope that the electricity would not keep cutting out so I could carry out the experiment easier and more accurately. Also I would make sure I checked the thermometer more as in the last experiment it was not checked as often as it should have. Maybe instead of using a thermometer a temperature probe could be used to guarantee the temperature did not get too high or low. This way it would be easier and would make sure that the temperature was checked and not be down to me while I handle everything else. I would try and find a better way of preventing the heat from reaching the elodea, as the beaker was effective. I may use a heatproof screen which would let only light through. This way it would be easier to set up and more safe at more elevated heights. Also while marking the air bubble on the capillary tube the mark was thick which could have slightly affected the results. I could use a pen with a thinner nib or mark it using string or wire. Also I could have tried to control the background light more efficiently by covering the whole experiment perhaps. If a black bag was tied around the light and elodea it would make sure that the experiment was a total fair test with no extra light. Also to test if this proportion worked for all plants I could try and set up an experiment using another plant.