Science Investigation: Factors That Affect the Rate of Photosynthesis

Planning:

Preliminary Work → Plan A

Aim: The aim of our investigation is to find out how the factor, light intensity affects the rate of photosynthesis.

Prediction: ·I think that when the light source is closer to the plant, the rate of photosynthesis will be quicker. (Ref: 'Biology for You').

· I also think that the rate of photosynthesis will increase steadily until a certain point. (Ref: 'Biology for You').

Hypothesis: ·The rate of photosynthesis will be quicker when the light source is near because all plants have chlorophyll. Chlorophyll is like an enzyme. They capture sunlight for photosynthesis. All enzymes work best in warm temperature but not when hot. If the temperature is too hot, the enzyme will be destroyed and no longer able to photosynthesize.

· The rate of photosynthesis increases proportional to the light intensity until a certain point because it'll be the carbon dioxide level or temperature that is preventing the rate of photosynthesis. A plant relies mainly on carbon dioxide, temperature and light intensity. We have already provided the plant light intensity but not carbon dioxide and temperature. Since we have not provided the other two, the plant can only be able to photosynthesize to a certain point because carbon dioxide and temperature will become the limiting factors of the experiment. (Ref: GCSE Double Science Biology Revision Guide)

Controlling Variables: The variables that we need to control in this experiment are the amount and type of plant we are using, the temperature – room and beaker of water and solution, length of time oxygen is collected for, the position of the light censor, other light source in the room and the amount of sodium hydrogen carbonate ($NaHCO_3$) we are putting in the beaker.

-Amount of Plant: We need to control that we use the same amount of plant throughout the whole experiment and do not change it. Changing it to more or less can affect our experiment because the amount of chlorophyll changes the rate either faster or slower depending on how much you are using. Using more can help speed up the rate as there are more chlorophyll, using less can slow the rate as there are less chlorophyll to help photosynthesize. Therefore, when we change the plant, the amount of chlorophyll will also change.

-Type of Plant: We need to control that we use the same type of plant throughout the whole experiment. Changing the type of plant can alter our rate either faster or slower depending on the type of plant changed.

Therefore, we must not change the amount and type of plant during the entire experiment even if we are repeating tests.

-Temperature: Controlling the temperature is a very important variable because if the temperature is not constant and changing it can change the rate of our experiment and therefore, we will not have fair tests. If it is too hot, enzymes of chlorophyll will be destroyed and not able to photosynthesize. To ensure a fair test, we will need to control the temperature in the beaker of solution and water and the watt of the lamp. Changing

the watt of lamp can vary the temperature either higher or lower depending on the amount of watt you have changed to. This will lead to inaccuracy.
-Length of time oxygen is collected for: The time must be controlled so that the rate of photosynthesis will not be changed. If we changed the length of time often (exm: 2min to 5min to 1min), we would not be able to find out the rate since it is being varied often.
-Position of light censor: This is also an important variable because the different positions of the censor can give us different intensity, the closer it is the higher, the further away, the lower, therefore, the position must not be changed throughout the whole experiment.
-Other light sources: For our experiment to be accurate and fair, we must not have other kind of light sources in the area we are working in. If there are, it may also help with the rate of photosynthesis by giving the plant more light so it will photosynthesize more.
-Amount of $NaHCO_3$: The amount of $NaHCO_3$ can affect the rate greatly because the more of the solution you put in, the faster the rate will be. Therefore we must control and only give it a certain amount of $NaHCO_3$.

Experimental Variable(s): The variable that we will vary is the distance of the lamp.
Distance: We can vary the distance by moving it further and further away from the plant to see which is the best distance of light that photosynthesis works best in. Varying this variable can help us determine whether our prediction and hypothesis is right or wrong.

Control & Safety Aspects: To ensure a fair test, we must control all our variables mentioned and repeat each test at least 3 times. When repeating, we will take the three results and find it's average for precise results. By doing so can give us reliable results of this experiment. We also need to make sure that all the apparatus stays the same and not moved (except lamp, where we would be varying the distance). Doing this can ensure a fair test for this experiment.
Safety Aspects of this experiment are:
-When measuring the distance of where the lamp should be, make sure that the metre rule does not move, a suggestion is to tape down the metre rule. Also, when moving the lamp (lamp will be turned on at all times) be careful that you do not touch the cap because it'll be very hot after being turned on for a long period of time.
-When cutting plant with blade, be careful not to cut yourself because of the sharp blade.

Range of Measurements: The range of measurements that we will take for the length of time the oxygen being collected for will be one minute per distance when the plant has begun to photosynthesize at a constant speed. We will be taking a result for three times for accuracy. (For example: For a distance of 5mm, we will begin taking results when the plant starts photosynthesizing, therefore it'll have bubbles coming out of the stem at constant speed. We will take this for one minute then take restart and repeat this procedure two more times).

Apparatus:
Beaker: to hold water and $NaHCO_3$ solution, pondweed, funnel and test-tube.
Pondweed: to measure the rate of photosynthesis.
Funnel: to hold pondweed in place.
Test-tube: where oxygen will be collected.
$NaHCO_3$: to help saturate water with CO_2
Stopwatch: timing the rate of photosynthesis.
Metre Rule: to measure distance of lamp.
Bench Lamp: light source for photosynthesis.
Light Sensor: Measuring the light intensity.

Blade: to cut stem of pondweed.
Thermometer: making sure the temperature is constant.
Preliminary Method:

1) Get a beaker with a base that is large enough to fit a funnel. (About 500mL)
2) Find a pondweed with many leaves; take off all the excess leaves that maybe blocking the tip of the funnel. Cut off where there are most leaves. When cutting, use a blade and cut diagonally because you'll need a place that has active cells.
3) Measure 25mL of $NaHCO_3$ solution into beaker. Fill the rest of the beaker with water up to 500mL. Therefore, there should be 475mL of water in the beaker.
4) Put funnel with pondweed into the beaker.
5) Fill test-tube with water then tip upside down so that it is covering the tip of funnel. Do not fill the whole test-tube with water. You will not be able to collect any oxygen if the test-tube is full.
6) Measure your starting distance then place the bench lamp at measured distance. Make sure other sources of light in room are turned off.
7) Place the light censor as close to lamp as possible but not touching lamp.
8) Therefore, the apparatus should be set up as shown:

9) When the plant has a constant size and speed of bubbles, (sign of photosynthesis), start stopwatch and begin to count bubbles for one minute.
10) After first test, repeat step 9 twice for accurate results.
11) When finished with the first distance, move lamp (with it on) and repeat step 9 and 10. Note down all results when experiment is finished.

Obtaining Evidence → Observation/Results (A)

See 'page 3a and 3b' for tables and graphs.

Distance (mm)	Number of Bubbles (per minute)				Light Intensity (Lux)
	Test 1	Test 2	Test 3	Avg	
5	38	40	41	40	427
10	32	30	31	31	239
15	24	25	24	24	165
20	19	18	19	19	87
25	15	15	17	16	66

After obtaining our results, we have to realise that this funnel experiment is not reliable enough to obtain accurate results. Some of the problems we have come across in our preliminary work are: a) different sizes of bubbles
b) lost count of bubbles
c) bubbles getting stuck cause by tip of funnel
d) timing
e) water temperature

All of the problems above (except for problem 'e') can be resolved by doing a more accurate experiment, which we will call the 'syringe test'. This experiment that we are going to do can be more reliable and accurate. We will plan to choose and do this experiment for our actual work (final not preliminary) so that we can have fair tests and resolve our problems and find the rate of photosynthesis.
*Placing a panel to prevent heat can solve problem 'e'.

*Note: Our distance did not include 0cm because the closest possible distance is 2.5mm. This is because the beaker is rounded so we are unable to get the exact distance of 0mm.

Actual Work → Plan B

Aim: The aim of our investigation is to find out how the factor, light intensity affects the rate of photosynthesis.

Prediction: · I think that when the light source is closer to the plant, the rate of photosynthesis will be quicker. (Ref: 'Biology for You').
· I also think that the rate of photosynthesis will increase steadily until a certain point. (Ref: 'Biology for You').
· Another prediction is that the closer the lamp, the longer length the bubble will be.

Hypothesis: · The rate of photosynthesis will be quicker when the light source is near because all plants have chlorophyll. Chlorophyll is like an enzyme. They trap sunlight. These enzymes work best in warm temperature but not when hot. If the temperature is too hot, the enzyme may be destroyed and no longer able to photosynthesize.
· The rate of photosynthesis increases proportional to the light intensity until a certain point because it'll be the carbon dioxide level or temperature that is preventing the rate of photosynthesis. A plant relies mainly on carbon dioxide, temperature and light intensity. We have already provided the plant light intensity but not carbon dioxide and temperature. Since we have not provided the other two, the plant can only be able to photosynthesize to a certain point because carbon dioxide and temperature will become the limiting factors of the experiment.
· The length of the bubble will be longer when the lamp is closer because the rate of photosynthesis will be faster. They are related to one another because the more bubbles being produced, the larger the bubble will get when you pull them up into the capillary tube.

Controlling Variables: The variables that we need to control in this experiment are the amount and type of plant we are using, the temperature – room and beaker of water and solution, length of time oxygen is collected for, the position of the light censor, other light source in the room and the amount of sodium hydrogen carbonate ($NaHCO_3$) we are putting in the beaker.
-Amount of Plant: We need to control that we use the same amount of plant throughout the whole experiment and do not change it. Changing it to more or less can affect our experiment because the amount of chlorophyll changes the rate either faster or slower depending on how much you are using. Using more can help speed up the rate as there are more chlorophyll, using less can slow the rate as there are less chlorophyll to help photosynthesize.
-Type of Plant: We need to control that we use the same type of plant throughout the whole experiment. Changing the type of plant can alter our rate either faster or slower depending on the type of plant changed.

Therefore, we must not change the amount and type of plant during the entire experiment even if we are repeating tests.
-Temperature: Controlling the temperature is a very important variable because if the temperature is not constant and changing it can change the rate of our experiment and therefore, we will not have fair tests. If it is too hot, enzymes of chlorophyll will denature and not able to photosynthesize. We will need to control the temperature in the beaker of solution and water and the watt of the lamp. We mustn't change the watt. Changing the watt can vary the temperature, therefore a result of inaccuracy.

-Length of time oxygen is collected for: The time must be controlled so that the rate of photosynthesis will not be changed. If we changed the length of time often (exm: 2min to 5min to 1min), we would not be able to find out the rate since it is being varied often.
-Position of light censor: This is also an important variable because the different positions of the censor can give us different intensity, the closer it is the higher, the further away, the lower, therefore, the position must not be changed throughout the whole experiment.
-Other light sources: For our experiment to be accurate and fair, we must not have other kind of light sources in the area we are working in. If there are, it may also help with the rate of photosynthesis by giving the plant more heat so it will photosynthesize more.
-Amount of $NaHCO_3$: The amount of $NaHCO_3$ can affect the rate greatly because the more of the solution you put in, the faster the rate will be. Therefore we must control and only give it a certain amount of $NaHCO_3$.

Experimental Variable(s): The variable that we will vary is the distance of the lamp.
Distance: We can vary the distance by moving it further and further away from the plant to see which is the best distance of light that photosynthesis works best in. Varying this variable can help us determine whether our prediction and hypothesis is right or wrong.

Control & Safety Aspects: To ensure a fair test, we must control all our variables mentioned and repeat each test at least 3 times. When repeating, we will take the three results and find it's average for precise results. By doing so can give us reliable results of this experiment. Before beginning the experiment, we must make sure that the capillary tube does not contain any other air bubbles or else there won't be a fair test. We also need to make sure that all the apparatus stays the same and not moved (except lamp, where we would be varying the distance). Doing this can ensure a fair test for this experiment.
Safety Aspects of this experiment are:
-When measuring the distance of where the lamp should be, make sure that the metre rule does not move, a suggestion is to tape down the metre rule.
-When cutting plant with blade, be careful not to cut yourself because of the sharp blade.

Range of Measurements: The measurements we will be taking for this experiment are the length of the bubble, and how long we will collect the oxygen bubble for. When taking the measurement of the bubble, we will pull up the bubble up to the point at 0. For every one-minute, we will pull up the syringe and then measure the bubble. We will be pulling up a bubble per minute for 3 times for accurate results. After, we will change the distance.

Apparatus:
Beaker: to hold water and $NaHCO_3$ solution, pondweed, and funnel.
Pondweed: to measure the rate of photosynthesis.
Funnel: to hold pondweed in place.
Capillary Tube: to measure the length of the bubble
$NaHCO_3$: to help saturate the water with CO_2.
Clamp Stand: to keep syringe in place and not swaying around.
Syringe: to pull up the bubble
Rubber tubing: to connect capillary tube and syringe and to hold funnel (where bubble being collected).
Stopwatch: timing the rate of photosynthesis.
Metre Rule: to measure distance of lamp.
Bench Lamp: light source for photosynthesis.
Light Sensor: Measuring the light intensity.

Blade: to cut stem of pondweed.
Thermometer: making sure the temperature is constant.

Method:

1) Fill a beaker with 475mL with water and then 25mL with $NaHCO_3$.
2) Set up the clamp stand holding the syringe at top connecting rubber tubing to the capillary tube below (note that another rubber tubing at the other end of capillary tube is connected to a funnel). Make sure that capillary tube does not contain any air bubbles.
3) Find a pondweed with many leaves; take off all the excess leaves that maybe blocking the tip of the funnel. Cut off where there are most leaves. When cutting, use a blade and cut diagonally because you'll need a place that has active cells.
4) Put pondweed under funnel and place the whole apparatus (clamp, syringe, capillary tube etc.) into the beaker of water.
5) Place little water into syringe.
6) Measure your starting distance then place the bench lamp at measured distance.
7) Place the light censor as close to lamp as possible but not touching lamp.
8) Let plant get use to the brightness of lamp before starting experiment.
9) Therefore, the apparatus should be set up as shown:

10) Start stopwatch, after one minute; pull up syringe and measure length of bubble (in mL). Note down result. Repeat procedure 2 more times for fair test.
11) After repeating, set your next distance, (exm: 10mm), then repeat step 10.
12) Finish the rest of your experiment with steps 10 & 11 until you have finished your measurements (exm: 5mm, 10mm, 15mm, etc.).

Obtaining Evidence → Observation/Results B

See 'page 6a and 6b' for tables and graphs.

Distance (mm)	Length of Bubble (mL) per minute				Light Intensity
	Test 1	Test 2	Test 3	Average	
5	0.07	0.06	0.07	0.07	421
10	0.04	0.03	0.04	0.04	237
15	0.03	0.02	0.03	0.03	128
20	0.02	0.02	0.02	0.02	96
25	0.01	0.01	0.01	0.01	75

Comparing our results to our preliminary work, we are able to see that these results are more reliable because when repeating the tests, the length of bubble does not change much and are very near to one another whereas the previous experiment, while counting the bubbles, the range overall was not as accurate. There may have been more anomalies in our preliminary work than our actual. Though this experiment was more accurate and reliable, we still had some problems that encountered us.

a) While pulling up the syringe, we had also pulled up air bubbles and not the actual bubbles collected by photosynthesis.
b) A rise in temperature throughout the experiment though it was slight.

Therefore, we will analyze, draw conclusions and evaluate Plan B (Syringe Test).
*Note: Our distance did not include 0cm because the closest possible distance is 2.5mm. This is because the beaker is rounded so we are unable to get the exact distance of 0mm.
Analysing Evidence & Drawing Conclusions → Plan B

Our results to both our preliminary and actual work can be shown on a line graph (see pages 3a and 6a).
Patterns that are seen in the results are:
·As the light intensity decreases or distance increases, the length of the bubble decreases.
·As distance increases, the light intensity decreases.
·As distance decreases, so does the length of bubbles.

Yes, my results do support my predictions I had made earlier.
·As the distance is further away, the length of bubble decreased, therefore the larger the bubble, the quicker because the more bubbles being collected by photosynthesis, the longer the bubble will be.
·The rate of photosynthesis has increased steadily because our results state clearly that all our results are pretty similar, therefore, this means that the rate of photosynthesis had reached it's maximum rate because the length of bubble varied slightly.
·Our results state clearly that as distance of lamp increases, our length of bubbles decreases and the closer the distance of lamp, the larger length of bubble.

Conclusions: In conclusions, the rate of photosynthesis increases as light intensity increases but only up to a certain point because there are other limiting factors that are limiting the rate. A plant relies on many factors, but the three main factors are light, amount of carbon dioxide and temperature. Our rate only reaches a certain point because we have only given one of the three points towards it. We have only given the light factor but we still have the carbon dioxide and temperature as limiting factors. Carbon dioxide becomes a limiting factor because we had only given little $NaHCO_3$ solution and the temperature becomes a limiting factor because we are using a panel, which keeps the water temperature constant. This is because light can only give a plant a certain amount and cannot rely all on the light. It'll also need carbon dioxide and temperature we can help increase rate of photosynthesis.
As light is closer to the plant, rate of photosynthesis increases because the closer the light, the more light the plant will absorb. Rate of photosynthesis increases because inside the plant, there are chlorophyll. Chlorophylls are like enzymes. They capture sunlight. They work best in a warm temperature but not hot because enzymes may be destroyed. Since these enzymes work best in warm temperature, the rate of photosynthesis will be faster as light is closer to pondweed because the enzymes will have a closer distance absorbing the light whereas if it is further away, it'll have a longer distance to absorb. The lengths of bubbles are longer when the lamp is closer because it has a faster rate of photosynthesis. Since it is faster, more bubbles will be collected. The more bubbles there are, the longer it'll be when you pull up the syringe.

Evaluating your Evidence → Plan B

Applications: •Improvements: ·I think that we can improve our practical work by changing to the 'Syringe Test', as we have already done. Changing to this test would be more accurate and reliable because we would not have any problems that we have encountered earlier (counting the bubbles or losing count of the bubbles, different sizes of bubbles and the timing). Improvements we can make towards our 'Syringe Test' are ·We

can work in an area where there is the lamp as the only source of light. Therefore, the area we are working in is a dark room with only either one or two bench lamps so that our experiment can be fair and accurate without any other lights distracting the rate of photosynthesis except the lamps, which are the source of light. ·Instead of having the light censor leaning against the beaker, we can have it taped so it stays in one place because when we are changing the distance of the lamp, we might have moved the censor but did not notice. Also, the light censor does not have a flat base so it may be a good idea to have the light censor taped to the beaker. This way, we can have accurate results of the light intensity.

·We can improve on our accuracy of our results by repeating our experiment at least three times for more accuracy. For example, we may take up to ten results then find the average, and then we will have accurate results because of the repeated tests. ·If we were to do this in groups or partners, we can set up two of the same apparatus and then compare the results we get to see if they are similar or not. Therefore, if we do the experiment exactly the same with both apparatus, we should have very similar results.

Other improvements can be made to the reliability of our results. Are they reliable enough to support a firm conclusion? When repeating tests, would we get the same results again? When finish with our preliminary work, compare these results with the ones you did on the actual day. Are they similar or were they rather vague? If they were pretty similar to one another than you can be sure that both of your actual experiment is reliable. If they have results that are rather different from one another then maybe the experiment should be re-done to get more reliable and accurate results.

•Results: I think that there are few results that do not fit the general pattern. There were few anomalies (see graphs for marked anomalies) that did not fit the general pattern. I don't think that the results are good enough to draw firm conclusions because the pattern on the graph should be more on a curve. The line may not be as curved because it may be the possibility that the light censor had been slightly moved. Therefore, this problem can result to one of our improvements as stated above (having the light censor being taped to the beaker).

•Further Work and Investigation: Further investigations can be varying other factors of the rate of photosynthesis, such as both light intensity and light quality at the same time or the amount of carbon dioxide (in this case, it is $NaHCO_3$) being put into the beaker.

·For light quality and light intensity, we can investigate this by repeating the method above then change the colour of panel being put in front of the light. Therefore, our experiment would be exactly the same as the one we did with the clear panel but instead of stopping afterwards, we start again but with a different colour panel (exm: red). After doing a few colours, we are able to find out which type of light is most used in photosynthesis.

·We can investigate the amount of carbon dioxide by varying the amount of carbon dioxide being put in instead of the distance of lamp. For example, for starters we keep a distance of 5cm and start with 25mL of $NaHCO_3$ and 475mL of water and then test rate of photosynthesis. After repeating at least three times, we can a new solution to 50mL of $NaHCO_3$ and 450mL of water, but we continue to have a distance of 5cm. We test the rate of photosynthesis again. Then after, we continue this experiment until we have reached a desired measurement. Varying the amount of carbon dioxide can help us find out how much it speeds up the experiment and how much is needed for best results.