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# Poorly Pondweed

## Questions

1) How does light intensity affect the rate of photosynthesis?
2) How does temperature affect the rate of photosynthesis?

$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \text{glucose} + \text{oxygen}$$

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

## Prediction

I predict that the more intense the light, the higher the rate of photosynthesis. To photosynthesise, plants need light. It provides the energy for the process to happen. Chlorophyll is an enzyme and it speeds up the reaction. If a plant does not get enough of either of these things, photosynthesis will not happen as quickly, if at all. Therefore, I predict that when the light is not very intense we will not see so many bubbles being produced. This is because the plant will not have so much energy (derived from light) to activate photosynthesis. All reactions require a certain activation energy, and if this is not reached the reaction will occur more slowly.

I think that as we move the lamp away (and therefore reduce the light intensity) from the elodea pondweed the number of bubbles produced will decrease steadily. For instance, say at 10cm distance 50 bubbles are counted, it is likely that at 20cm distance 25 bubbles will be counted, as the lamp is twice the distance away. This means the rate of photosynthesis is halved. I think that if we move the lamp any further away than 50cm no bubbles at all will be produced because there will simply not be enough light for photosynthesis to work.

I predict that for temperature, it will not be a case of an increase in $x$ = an increase in $y$. I predict that there will be a peak where photosynthesis happens the quickest at around 40-50°C. Chlorophyll is an enzyme, therefore it requires some heat to work, but if it is overheated it stops working. Enzymes work rather like a lock and key. It is important that they are a very specific shape for their purpose (in this case chlorophyll joins carbon dioxide and water together to form glucose). If a key is heated too much, it melts and becomes denatured. It will no longer fit the lock it was designed for. This is why enzymes start to work less well at high temperatures.

I think that at the lower temperatures (i.e. 0-20°C) we will not see many bubbles being produced. This is because enzymes need energy to work, which they get form heat (as well as light). So when the temperature is quite low the chlorophyll does not have much energy, therefore the rate of photosynthesis will be low. As the temperature increases, I predict that the rate of photosynthesis will increase (more bubbles will be produced). This is because more heat energy is being provided to the chlorophyll, meaning that photosynthesis can happen more quickly. However, I think that when the temperature reaches 50°C and above, the rate of photosynthesis will decrease, because the chlorophyll will become denatured, and unable to activate photosynthesis as well. Eventually I predict that no bubbles at all will be produced,

say around 100°C. So we should see a pattern where the rate increases dramatically between 0-50°C, but then it should decrease dramatically from 50 -100°C.

# Plan

# Apparatus

- desk lamp
- Elodea pondweed x 2
- boiling tube x 2
- paperclip x 2
- 250ml glass beaker x 2
- test tube rack
- thermometer
- sodium hydrogen carbonate solution
- stopwatch
- ice
- tongs
- metre stick
- black A4 paper
- sellotape
- scissors
- 1ml pipette

# Safety

- Take care of the light bulb, which may get very hot.
- As you will be using electricity (for the light bulb) and water at the same time, special care must be taken.
- As a precaution try not to drop any water onto the beaker in the light intensity investigation as it will be hot and may crack.

# Method

**Preliminary work…**

Take two green, healthy pieces of pondweed, with lots of leaves on, and about 8-10cm long (you are taking two so as to find which one photosynthesises the best, and therefore produces the most amount of bubbles). Cut the ends of them diagonally, and strip part of the stem of leaves. This is simply so we can see the bubbles as they come out of the stem. Attach a paperclip to the bottom end of each piece of pondweed (the part with leaves on). This acts as a weight so the pondweed does not float above the surface of the water. Next, put each piece of pondweed in a boiling tube, and fill them with water until the top of the pondweed is well covered, but make sure there is still enough room for some sodium hydrogen carbonate.

Add about 3 pipettes of sodium hydrogen carbonate solution to each boiling tube. This is to provide carbon dioxide to the plant as it is vital in photosynthesis. With scissors, cut the end of each piece of pondweed diagonally *while it is still under the water*. It is important that you do this while submerged in water because you are removing any air locks in the xylem tubes of the plant, which would prevent oxygen bubbles from escaping. This would lead to anomalous results.

Half-fill a glass beaker with water, and leave the boiling tubes containing the pondweed there for approximately one minute. Check them to see which is producing bubbles the most rapidly. This is the one you will use for both the experiments.

You must do the light intensity investigation first, because we do not want the pondweed to be damaged after being in high temperatures. This is also why you will do the lower temperatures first in the temperature investigation.

**For the light intensity investigation…**
Set up the apparatus as shown in the diagram on the following page.

Make sure the black paper is attached to the beaker so that only the front of it is exposed to the light. This is to ensure that the plant takes in only the light from its own lamp. This is why you must also make sure all the main lights in the room are turned off.

Put the water bath with the boiling tube with the best piece of pondweed in on the test tube rack. This is just so it is as close to the level of the light as possible. Put the lamp 10cm away from the water bath. Allow 2 minutes adjustment time for the pondweed so it can get used to its new environment. Otherwise the plant will not produce oxygen at a steady rate. Then, start the stopwatch, and begin counting bubbles. After one minute, stop the stopwatch and note down how many bu bbles were counted. Repeat this paragraph 3 times.

Place the lamp 20cm away from the water bath. Leave the pondweed for 2 minutes, as adjustment time for it to get used to its new environment. Otherwise the plant will not produce oxygen at a steady rate. T hen, start the stopwatch and begin counting bubbles. After one minute, stop the stopwatch and note down how many bubbles were counted. Repeat this paragraph three times.

Repeat the previous paragraph except for 30, 40 and 50 cm away from the water bath. This should give reliable results, because of repeated readings and the range of 10-50cm in intervals of 10cm.

If the pondweed stops bubbling at any time during the experiment, this may be due to an air lock in the xylem tubes of the plant. In this case you need to cut the end of the pondweed with no leaves on while it is still under the water. This should stop the air from blocking up the xylem tubes of the plant. The other problem may be that the plant has used up all the carbon dioxide form the sodium hydr ogen carbonate solution. In this case you need to add two or three 1ml pipettes of the solution to the water the pondweed is in.

**For the temperature investigation…**

Set up the apparatus as shown in the diagram below.

Ensure that the black paper is attached to the water bath so that only a small area at the front of the beaker is exposed to the light. Using the previous investigation, find the distance in which the pondweed produced the greatest amount of bubbles. This is the distance you will use throughout the whole temperature investigation, because then we will have more reliable results. There is no need to move the lamp at any time during the experiment.

Put some ice in the water bath, along with the thermometer. When the temperature has reached between 0-10°C, leave the pondweed for 2 minutes to adjust to its new environment. Otherwise, the plant will not produce bubbles at a steady rate. Then, start the stopwatch and count the bubbles produced. After one minute, stop the stopwatch and note down how many bubbles were counted (it does not matter if no bubbles were produced, just write down 0). Repeat this paragraph 3 times.

Take some of the ice out of the water bath, but do not remove the thermometer. When the temperature is between 11 -20°C, leave the pondweed for 2 minutes to adjust to its new environment. Then, start the stopwatch and start counting the oxygen bubbles. After one minute note down how many bubbles have been produced. Repeat this paragraph 3 times.

Repeat the previous paragraph for 21-30°C, 31-40°C and 41-50°C, adding ice or warm water from the tap as necessary. If the temperature goes above or below the temperature needed, then add ice or warm water accordingly.

If the pondweed stops bubbling at any time during the experiment, it may be due to an air lock in the xylem tubes of the plant. In this case you need to cut the end of the pondweed with no leaves on while it is still under the water. This should stop the air from blocking up the xylem tubes of the plant. The other problem may be that the plant has used up all the carbon dioxide form the sodium hydrogen carbonate solution. In this case you need to add two or three 1ml pipettes of the solution to the water the pondweed is in.

# Variables

**For the light intensity investi gation…**

- the dependant variable is light intensity
- the independent variable is the rate of photosynthesis
- the controlled variables are 1) the power of the light bulb
  2) the piece of pondweed
  3) adjustment time
  4) temperature
- the range is 10-100cm in intervals of 10cm
- number of readings – 3 for reliability

**For the temperature investigation…**

- the dependant variable is temperature
- the independent variable is the rate of photosynthesis
- the controlled variabl es are 1) the power of the light bulb
  2) the piece of pondweed
  3) adjustment time
  4) the distance the lamp is from the water bath
- the range is 0-50°C in intervals of 10°C
- number of readings – 3 for accuracy

# Results

**For the light intensity investigation…**

| Distance from lamp (m) | Number of oxygen bubbles produced in 1 minute | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | Average |
| 0.1 | 25 | 26 | 25 | 25 |
| 0.2 | 22 | 19 | 19 | 20 |
| 0.3 | 11 | 13 | 13 | 12 |
| 0.4 | 9 | 7 | 7 | 8 |
| 0.5 | 4 | 3 | 3 | 3 |

**For the temperature investigation…**

| Temp. range (°C) | Actual temp. (°C) | Number of oxygen bubbles produced in 1 minute | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | Average |
| 0-10 | 4 | 0 | 0 | 0 | 0 |
| 11-20 | 15 | 1 | 0 | 1 | 1 |
| 21-30 | 24 | 8 | 9 | 6 | 8 |
| 31-40 | 36 | 10 | 13 | 11 | 11 |
| 41-50 | 45 | 15 | 14 | 15 | 15 |

# Graphs

# Conclusion

I conclude that the greater the light intensity, the q uicker the rate of reaction. For photosynthesis, plants require light and chlorophyll to make the reaction happen. They are not constituents of glucose but are still vital. So, when the lamp was further away from the pondweed the plant was unable to photos ynthesis as well as when the lamp was right up close to the pondweed. When the lamp was 50cm away, an average of just 3 bubbles was produced, compared to an average of 25 for 10cm away. As the lamp was moved further away, the light intensity increased, the refore the rate of photosynthesis increased. The pondweed had more light energy for photosynthesis and was therefore able to produce more oxygen bubbles in one minute.

Looking at the light intensity graph, you can see a trend. It shows that the rate of photosynthesis and light intensity are proportional to each other. This is because there is a straight line of best fit going down as the distance increases (when the distance is increasing this is the equivalent of the light intensity decreasing).

In my prediction I said that for double the distance there would be half the amount of bubbles, but this did not happen between 10cm and 20cm. 10cm away from the lamp the pondweed produced an average of 25 oxygen bubbles. At 20cm the plant produced 20, and this is n ot even close to half of 25. However, 40cm away from the lamp, an average of 8 bubbles was produced by the pondweed, which is a little under half of the 20 bubbles at 20cm. So there was some truth in that prediction. Perhaps my results were slightly anomal ous.

I also conclude that temperature affects the rate of photosynthesis in that there is a peak around 40 -50°C. At the lower temperatures the plant was unable to produce many bubbles, if at all. Unfortunately due to time restrictions we were unable to go up to 100°C, but I have made an estimate of what would have happened on the temperature graph. It would have decreased until eventually the pondweed was not producing any bubbles at all.

Chlorophyll is used to make photosynthesis happen in plants. It is an enzyme, and all enzymes need some heat to activate them. This is why at the lower temperatures the rate of photosynthesis was so low. As the temperature increased, so did the rate of photosynthesis. At around 40 -50°C was a peak. This was when the rate of photosynthesis was the highest. After that, it decreased. You might expect the trend to be that the higher the temperature, the higher the rate of photosynthesis, but this is not the case. Enzymes work rather like a lock and key. They are specifically designed for one purpose – in the case of chlorophyll it is to activate photosynthesis. If a key is heated up, it will melt and become denatured and can never be restored to its original shape. This is how enzymes work. When the temperature is over 50°C, the enzymes are damaged and no longer fit the “lock” they were designed for. This is what causes the peak.

On the graph you can see this trend of a peak (although the second half of the graph is an estimate). It is a lot clearer than looking at the results tabl e. It supports my prediction, unlike for the light intensity investigation, although they do not support what I said about the peak, as I have only been able to estimate.

# Evaluation

I think that the procedure used was quite suitable, as we managed to achi eve fairly reliable results. However, when dealing with living things the results can never be that accurate, because living things do not work at a constant rate. So we cannot know if the plant was working at a high or a low rate or somewhere in between w hen we did the experiment. I think it might have been working at a low rate judging by the fact that the most bubbles produced in the whole experiment was 25. This is nowhere

near as high as I expected. However, at least the results were not completely anomalous and I was able to draw reasonable conclusions from them.

There is not really any way in which we could improve this procedure, because living things are so unreliable. However, we could take results over a period of several weeks for more accuracy. This way we would catch the pondweed at times when it was working at a high level and at times when it was working at a low level.

Another thing that was not very suitable was the way of measuring the rate of reaction. Counting the bubbles got very boring and I could easily have miscounted, leading to anomalous results. A better way would be to find some way of collecting the oxygen bubbles in a capillary tube and measuring how far along the oxygen goes. We would have to fill the capillary tube with water a nd seal the top, and attach the tube to the pondweed. Although fiddly this would be more reliable.

There were no anomalous results, but if there were there are many reasons why it could be. For a start, I could have miscounted the bubbles. Also, the pondweed might not have been bubbling properly due to an air lock that I did not notice. Similarly, there might not have been enough sodium hydrogen carbonate solution, which provides carbon dioxide for the plant. Also, there is the possibility that the piece of pondweed used was damaged – for example perhaps it had been heated up too much and the chlorophyll had become denatured. Because there were no anomalies, this supports my prediction in that they were reliable.