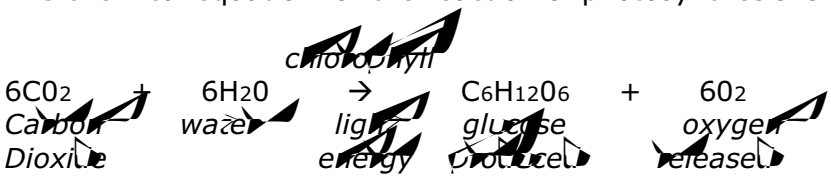
An Investigation into the Effect of Temperature on the Rate of Photosynthesis

Theory

The aim of my experiment is to determine how temperature affects the rate of photosynthesis of the aquatic plant Elodea.
Photosynthesis is a chemical reaction that takes place in the leaves of green plants building up food compounds from carbon dioxide and water, and using the energy from sunlight, which is absorbed by chlorophyll.
The chemical equation for the reaction of photosynthesis is: -



This reaction will take place in my experiment and the oxygen released will be measured using the technique of counting the number of oxygen bubbles released from the aquatic plant.
Catalysts speed up many chemical reactions without being used up or changed. Inside living organisms, chemical reactions take place all the time with a specific enzyme controlling every reaction. Enzymes are biological catalysts as they effect metabolic reactions.

In all chemical reactions one thing is changed into another thing. The substance at the start of the reaction is called the *substrate* and the substance produced by the reaction is called the *product.* As enzymes are unchanged in reactions, a small amount of enzyme can catalyse the conversion of a lot of substrate into a lot of product. In the case of this experiment the enzyme is chlorophyll, the substrate is the carbon dioxide dissolved in water. The product is the glucose produced, with oxygen released as bubbles.

From my knowledge of enzyme activity, I predict that the following will occur when I carry out this experiment.
Between the temperatures of 0-40 C as I increase the temperature, I expect the rate of photosynthesis to increase at a proportional rate to the temperature. This is because at a higher temperature the speed of the particles is also higher. Therefore there are more successful collisions and so the rate of reaction is increased. I think the optimum temperature for the photosynthesis to take place will be at around 37 C, as this is the temperature that enzymes work best in the human body. The optimum is likely to be at a similar temperature for the chlorophyll enzymes in this reaction.
I predict that the enzyme will be completely denatured at about 50 -60 C and the rate of reaction will be quite low at this point.

I have chosen temperature to be the variable I will change.
To execute this experiment well I must control the other variables.
I must keep carbon dioxide levels constant as they affect the levels of respiration. CO_2 is an essential substance in the photosynthesis reaction. I will keep the carbon dioxide levels constant by dissolving 1gram of hydrogen carbonate into the water, which will surround the aquatic plant during the experiment. This will maintain a good supply of carbon dioxide, and won't limit the plants potential to photosynthesise.

I must also keep light intensity constant throughout the experiment.
All plants need energy, in the form of light, to photosynthesise. When light energy falls on the chloroplasts in a leaf, the chlorophyll traps it. This energy is used for the chemical reactions, and therefore if the amount of energy (in the form of light intensity) is varied then the test would not be fair.

I have chosen to take three readings at each temperature, at intervals of 10 from 20-70 C. At 10 C, photosynthesis does not take occur to take a sufficient reading, and at 80 C the plant is denatured. I decided on this suitable range after preliminary work I carried out. Here is a results table of the small number of results I took in preliminary work.

Bubbles released per minute

Temp (C)	1st reading	2nd reading	3rd reading	Average
10	0	0	0	0
20	54	58	61	58
40	167	171	170	187
60	42	37	29	36
80	0	0	0	0

Apparatus

- Safety glasses
- 500ml of water
- Bunsen burner
- Tripod
- Heat mat
- Wire gauze
- Thermometer
- Clamp stand
- Boss clamp
- Stop-watch
- Lamp
- Ice cubes
- Beaker
- Glass rod
- Paper clip
- Aquatic plant

Plan

- Set up apparatus as shown.
  Cut a slanted slit through the top of the aquatic plant's stem. This allows bubbles to be released, and the slanted slit ensures a larger surface area for the bubbles to be released through.
  Attach the paper clip to the other end of the aquatic plant, holding it vertically underneath 500ml of a water solution containing 1g of HCL.
  Position the lamp 10cm from the beaker, being sure to maintain this for the duration of the experiment.
  Clamp the thermometer into place in a suitable position.
- Cause the water temperature to settle at 20 C, the first temperature at which a reading will be taken.
  Do this by heating the beaker with the Bunsen burner or by adding ice to the water.
- Time a minute on the stopwatch while counting the number of bubble released from the plant, through the stem.
- Take 3 readings at each temperature from 20 -70 C at intervals of 10.

Results

Bubbles released per minute

Temp(C)	1st reading	2nd reading	3rd reading	Average
20	81	89	94	88
30	170	171	177	173
40	189	184	186	186
50	172	179	(112)*	176
60	45	18	6	23
70	10	5	4	6

*Anomalous result – discounted.

Conclusion

My results show that photosynthesis increases as the temperature increases up to a certain point, after which photosynthesis declines rapidly and soon stops altogether. My graph shows the first average reading at 88 bubbles per minute. This was approximately half of the second reading recorded at 30 C. This shows that there was a small amount of photosynthesis taking place at 20 C, but a large increase in the rate of reaction between 20 C and 30 C. This is because when the temperature is increased the speed that the particles move is raised too. This equates to more collisions occurring, and the rate of reaction increasing. At a higher temperature, molecules move around faster, this causes more of them to have the needed activation energy to react and gives them more kinetic energy causing them to collide with the enzymes more often therefore speeding up the reaction. This is due to the collision theory - the rate of reaction depends on how often and how hard the reacting particles collide. At low temperatures, the particles are moving about slowly as they do not have much energy. They don't collide very often and when they do they rarely have the activation energy needed for the reaction to occur.

At the optimum temperature on my graph (40 C) the collision rate is very high, but at this point the enzymes start to denature. This results in a small drop in photosynthesis rate at 50 C, as the high collision rate compensates for the denaturing enzymes. Between 50 C and 60 C the enzymes denature to a further, so that photosynthesis can no longer take place sufficiently.

My prediction that the optimum temperature for photosynthesis would be around 37 C is confirmed, and that the rate of photosynthesis increases at a proportional rate to the temperature. I also corrected predicted that photosynthesis would slow down noticeably at 50-60 C, due to the chlorophyll enzymes being denatured.

Evaluation

To a large extent my experiment went to plan, although looking back I have become aware of some drawbacks in the method. Firstly, accuracy of measuring bubbles was very hard to achieve. I encountered difficulty counting oxygen bubbles, as they were released so fast from the plant and they were so small. The size of bubbles could also have changed during the experiment, which made me question the reliability and accuracy of the experiment. If performing the experiment again, I would employ another method for measuring the amount of oxygen released, for instance, collecting the volume of oxygen. I performed the observation 3 times at each temperature, in order to over come this problem and I think this was a suitable amount of times to repeat each test.

However, I did obtain one anomalous result in my third reading at 50 C, which suggests that the enzymes in the chlorophyll were denaturing after the second observation at this temperature. It would have been better to perform the experiment three separate times, instead of taking three observations at each temperature.

To obtain a smoother graph it would be desirable to take readings at shorter intervals of temperature change. The light intensity could vary if the experiment was repeated on 3 separate occasions to gain refined reliability.

One relevant variable that was not accounted for was pH. This should be kept constant as it affects the shape of enzymes altering the rate at which they convert substrate to product.