Biology Coursework: The effects of Carbon Dioxide (CO_2) on the rate of photosynthesis

Hypothesis:

As you increase the concentration of Carbon Dioxide, this results in an increase in the rate of photosynthesis.

Introduction and Background:

An overall and common equation for photosynthesis is:

$$6CO_2 + 6H_2O \xrightarrow[\text{in the presence of chlorophyll}]{\text{Light Energy}} C_6H_{12}O_6 + 6O_2$$

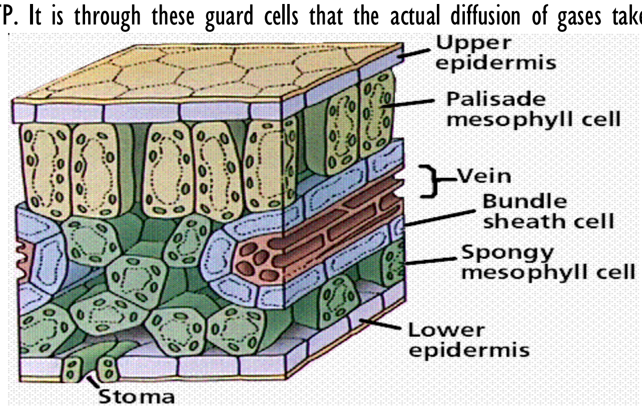
carbon dioxide + water → glucose + oxygen

(B1)

The process of photosynthesis transfers light energy into chemical potential energy of organic molecules. It is the fixation of carbon dioxide and its subsequent reduction to carbohydrate (glucose), using hydrogen from water.

Leaf structure (B1)

- The Palisade Mesophyll is the main site of photosynthesis. There are more chloroplasts here than there are in Spongy Mesophyll.
- Palisade cells show many adaptations of gaseous exchange.
  - Palisade cells are cylindrical shaped. They pack together with long narrow air spaces between them giving a large surface area of the contact between the cell and the air.
  - The cell walls of the palisade cells are thin. This way, the gas can diffuse through much easily.
- The Spongy Mesophyll is adapted for the exchange of carbon dioxide and oxygen.
  - The spongy Mesophyll has irregular packing of cells so that air can move around them. Thus giving a large surface area of moist cell wall for gaseous exchange.
  - This allows more CO_2 to enter and leave the leaf via specialised structures called Stomata. Oxygen produced during photosynthesis can only pass out of the leaf through the opened stomata.
- Stomata have guard cells. The opening and closing of guard cells is an active process and therefore requires ATP. It is through these guard cells that the actual diffusion of gases takes place.



Limiting Factors (B2)

- A limiting factor is the one factor, of many affecting a process, that is nearest its lowest value and hence is rate - limiting.
- Within the process of photosynthesis, there are many limiting factors. They are; light intensity, temperature and Carbon Dioxide Concentrations.
- Light Intensity may well be a limiting factor. If there is no sunlight, then the photolysis of water cannot occur without the light energy. But as intensities increase, so does the rate. However at high intensities, other limiting factors must be present. Such as, temperature or carbon dioxide supply.
- Temperature can also be a limiting factor. The enzymes that are involved in Photosynthesis, are directly affected by temperature. At higher temperatures, other limiting factors may be present such as light intensities and CO_2 concentrations.
- Carbon Dioxide concentrations can be limiting factors too. This is because of the supplies of CO_2 required in the Calvin Cycle. At higher CO_2 concentrations, other limiting factors such as temperature and light intensities may be present.

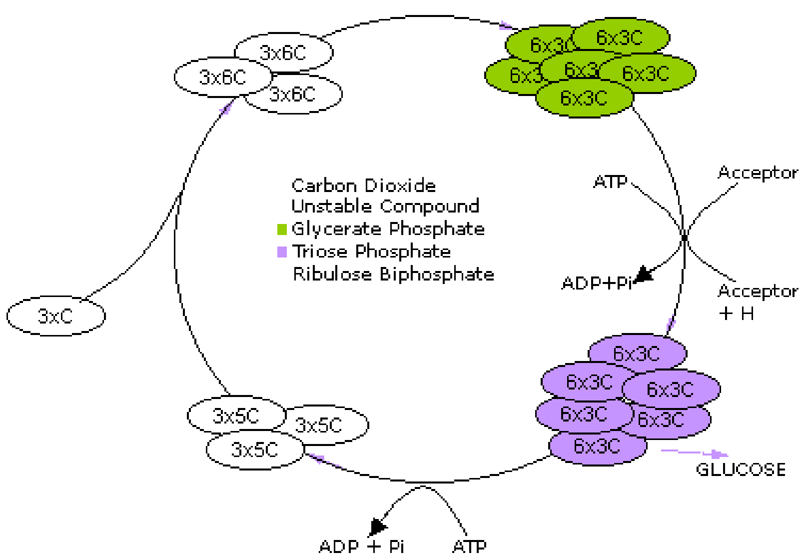
There are two types of reactions of photosynthesis:

- Light Dependant [The Hill Reaction]
- Light Independent [The Calvin Cycle]

The Calvin Cycle (B3)&(B4)

- This reaction is enzyme – driven
- It takes place in the Stroma of a Chloroplast
- It brings about the production of photosynthetic products. Such as, glucose, amino acids, lipids etc.

- The Calvin Cycle is the fixation a carbon dioxide.

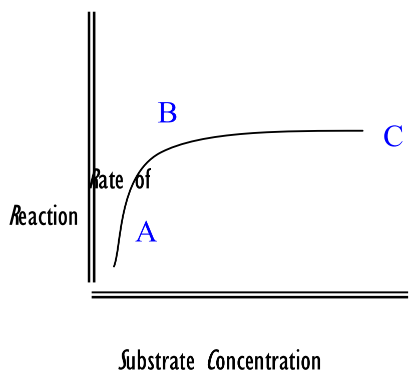


- Carbon from CO_2 enters the cycle combining with Ribulose Biphosphate (RuBP, a five-carbon sugar)
- The cycle enters an 'unstable intermediate', which means the compound formed is unstable and breaks down from its 6-carbon nature to a 3-carbon compound called Glycerate Phosphate (GP)
- Energy is used to break down GP into Triose Phosphate, whilst a hydrogen acceptor reduces the compound therefore requiring less energy.
- The end product of this is Triose Phosphate, a 3-carbon compound which, can be doubled to form glucose (used in respiration).
- When the remaining RuBP molecules meet with a carbon acceptor and turned into RuBP, the cycle is completed. The RuBP joins with the CO_2 molecules to re-begin the process.

Six CO_2 molecules are taken up by RuBP to be converted into one molecule of Glucose.
Therefore the cycle has to go around six times.
During this cycle, $6CO_2$, 6RuBP and 12 $NADPH_2$ are used.

Enzymes

- During the Calvin cycle, RuBP is carboxylated with CO_2 with the assistance of the enzyme Rubisco (also known as RuBP Carboxylase).
- However, if there is a high concentration of substrate, the rate of reaction would reach a plateau.
- Because all of the enzyme would be unavailable as they would be reacting with other substrates.



A: There is an increasing rate of reaction.
Substrate molecules are binding to active sites at a rapid rate.
Reason being, that there is a high probability than an enzyme's active site will collide with a substrate molecule.

B: The active sites are beginning to become unavailable. Many substrate molecules have and still are binding to the active sites.

C: There is too much substrate.
The enzymes are working at a maximum rate.
It is unable to handle the amount of substrate, as there are no more vacant active sites left. Other substrate molecules have occupied them all.

<u>Variables</u>

In this experiment, there are three constants and one variable. Therefore in order to keep this experiment a fair test, I am going to:

- Keep light intensity, temperature and time constant
- These are not the factors I want to investigate therefore I do not need to change them.
    - The lamp will be kept at the same power (60W), voltage and distance away from the beaker at all times. It will be kept 30cm away from the beaker.
    - The beaker will be kept at a constant temperature of 30 ^{0}C
    - Each test will take place for10 minutes.

- Change the CO_2 concentrations
- This is the factor that I want to investigate. I want to find out how different CO_2 concentrations affect the rate of photosynthesis.
    - Range of different concentrations

0.025 mol dm^{-3}, 0.05 mol dm^{-3}, 0.1 mol dm^{-3}, 0.2 mol dm^{-3}, 0.3 mol dm^{-3}, 0.4 mol dm^{-3}

<u>Apparatus</u>

The following apparatus is required in order to complete this experiment:

- Canadian Pondweed (Elodea)
- Distilled water (500cm^3)
- Thermometer
- Large Beaker
- Boiling tube
- Lamp (60W bulb)
- Clamp
- Stand
- Boss
- Capillary tubing
- Flared End of Capillary tube
- Plastic Tube
- Syringe (20cm^3)
- Sharp blade
- Board
- Photosynthometer
- Stopwatch
- Sodium Hydrogenate Carbonate ($NaHCO_3$) Solutions.
  [Concentrations: 0.05 mol dm^{-3}, 0.01 mol dm^{-3}, 0.1 mol dm^{-3}, 0.2 mol dm^{-3}, 0.3 mol dm^{-3}, 0.4 mol dm^{-3}]

<u>Diagram</u>

Practical Method

This is a step-by-step method of how to carry out the experiment:

1. Set out the apparatus as shown in the diagram
2. Fill the beaker with water and set the temperature to 30^0C.
3. Place a thermometer in the beaker.
4. Select a healthy piece of Elodea. It should be of approximately 5cm long and its stem should be cut off at an angle with a sharp blade under water.
5. Place the plant into the boiling tube and make sure the stem is facing the top.
6. Carefully remove the plunger from the syringe and fill the capillary tube and plastic tube with water.
7. Put the plunger back into the syringe and gently squeeze it through to remove any air bubbles that may be trapped.
8. Place the flared end of the capillary tube over the stem of the Elodea
9. Fill the boiling tube with made up solution of $NaHCO_3$ (concentration: 0.025 mol dm^{-3})
10. Allow 1 minute for the Elodea to equilibrate. It needs time to adapt to the conditions.
11. Switch on the lamp, which is 30cm away from the beaker.
12. Start the stopwatch
13. Photosynthesis has now begun
14. After 5 minutes, stop the stopwatch.
15. Then draw up the bubble with then syringe and measure the length on the capillary tube with the scale against it.
16. Now, the volume of this bubble will be worked out using this formula:

$$\pi r^2 h$$

(where 'h' is the length of the bubble)

17. Repeat steps 4 – 16 at least two more times in order to obtain more accurate results. Work out an average of the three readings.
18. Carry out the experiment with all different concentrations of $NaHCO_3$

[0.05 mol dm^{-3}, 0.1 mol dm^{-3} 0.2 mol dm^{-3}, 0.3 mol dm^{-3}, 0.4 mol dm^{-3}]

Justification

- The Elodea is left to equilibrate in the boiling tube filled with N, because it needs time to adapt to the conditions. I.e. adapting to the temperature of 30 °C
- A syringe is used in this experiment. This ensures precision as it is better than counti ng the oxygen bubbles. If you count the bubble, it is very easy to miscount them. Some bubbles may even be too small to see. Whereas when using the syringe, the total volume of oxygen is collected and it is easier to measure.
- Distilled water is used as it contains no impurities. E.g. No extra carbon dioxide.
- Cut the stem of the Elodea under water to prevent any air locks. This will ensure water enters the leaf without effecting photosynthesis.

Reliability

- To ensure reliability, it is important that this experiment is repeated at least three times. This will give you an average, making the results more accurate.
- Use the same species of Elodea for each experiment.

Precision

- The lamp should remain at a constant distance and have a constant intensity. I.e. 60W

Bibliography

BOOKS			
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Biology 2 B1	Mary Jones Jennifer Gregory	Cambridge University Press	17, 21, 23, 25, 26
A Level Biology B2	RW. D. Phillips T. J Chilton	Oxford University Press	69

WEBSITES
Site
www.biology4all.com B3
www.biology-online.org B4