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BC – Lab Report – Photosynthesis

Introduction

In 1771, Joseph Priestley discovered that a sprig of mint could change the air in an enclosed space. After having burnt a candle in a container until the air did not support further combustion, he placed the small plant in the container. He found that a few days later it was possible to reignite the candle (McEvoy). Later described as Photosynthesis, this process is vital for plants. When they absorb Carbon Dioxide, Water, and light energy, they produce Oxygen and Glucose (Bassham and Lambers). Eight years later, Jan Ingenhousz published a study he conducted. In the study he, expanding on Priestley's work, found out that light energy and green tissue are necessary for the reaction (Rogers). Later, Jean Senebier found out that the two gases which take part in the chemical reaction are Oxygen and Carbon Dioxide (Britannica).

Hypothesis

This discovery would lead me to think that if I augment the mass of Carbon Dioxide a green plant, which is illuminated, absorbs, the more oxygen it would emit. Most notably, I think this is because all studies mentioned before would indicate such results, plants that contain green tissue and are surrounded by light and Carbon Dioxide change the gas to Oxygen. In addition, this hypothesis is also supported by the law of conservation of mass, which defines that matter can neither be created nor destroyed (Britannica). The chemical equation for Photosynthesis is $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$. If the mass of Carbon Dioxide (CO_2) is doubled, this would mean the mass of Oxygen (O_2) would be doubled too because no matter can be destroyed. The rest of the Carbon Dioxide can be found in the Glucose ($C_6H_{12}O_6$). Because there is no other source of Hydrogen which can be found in the

Glucose, it would also be expected that more water is absorbed (This is a side effect I will not actively observe). This experiment wants to prove this hypothesis by answering the question: *How does changing the relative mass of Carbon Dioxide absorbed by a green plant influence the volume of oxygen it emits?* This question addresses Priestley's and Senebier's work by mentioning the idea of a change of gas in the plant's environment and by mentioning the discovered gases.

Variables

In biology, it is difficult to keep constant variables as constant as in physics because the science is dealing with organisms. For this reason, we planned to pay extra attention to these variables. Our goal was to keep the water temperature constant, this would be measured with a thermometer, we wanted to use identical water by only using distilled water. Distilled water is chemically pure water (Cambridge Dictionary). In addition, we planned to use the same beakers, which we wanted to wash out after every turn and refill with the same level of water by checking the markers on the side. By using the same spinach leaves, we hoped to guarantee the most stable results, although it is impossible to know for sure because plants are living beings. The plan to use the same lamp, with the same bulb, outlet, at a constant distance from the plant, and in the same dark room (sun orientation and blind quality) further allowed us to create a stable environment. In addition, we wanted to use the same pack of sodium bicarbonate to negate any impurities, which are impossible to remove. Lastly, we planned to use the same scale for weighing the powder. This would still allow a relative mass of carbon dioxide to water, in case the scale was inaccurate.

The independent variable, the variable we wanted to change, was the relative mass of Carbon Dioxide which three spinach leaves absorb. Sodium Bicarbonate ($NaHCO_3$) reacts to carbonic acid (H_2CO_3) and sodium hydroxide (NaOH) in water, carbonic acid in turn breaks down to water (H_2O) and Carbon Dioxide (CO_2). In other words, when dissolving Baking Soda (Other name for Sodium Bicarbonate) in water, Carbon Dioxide will be emitted for plants to absorb. (Northern Arizona University) By changing the mass, which would be measured using a scale, of the added Sodium Bicarbonate, we can directly change the mass of Carbon Dioxide in the water.

The Dependent variable, the variable we planned to note down and is dependent on the independent variable, was the number of bubbles emitted by the plant in one minute. For these measurements, we wanted to use a stopwatch, which would tell us the time the leaves had been in the water for and count the bubbles with our eyes. To help us count the bubbles and keep track of time, our plan was to film the entire experiment in Slo Motion. Not only would this allow us to go back and find out if we saw a bubble, but this would also help to have a clear demarcation at the one-minute mark, which would increase the accuracy of the experiment.

Method

The materials planned to use during our experiment were the following:

- 1 400ml glass beaker
- Three spinach leaves
- 90g of pure Baking Soda
- 1 Spoon
- 7,5 litres of Distilled water
- 1 knife
- 1 cutting board
- 1 scale, accurate to 1/10 of a gram
- 1 stopwatch
- 1 funnel
- 1 glass test tube (50ml)
- 1 lamp
- 1 ruler
- 1 glass rod

The plan for the experiment was as follows:

1. Put the blinds down, turn off any light source in the room.

2. Fill 1 400 ml beaker with distilled water until it's full
3. Add 0g, 2g, 4g, 6g, or 8g of sodium bicarbonate to the water
   3.1 Do this by placing the full beaker on the scale, pressing tare, and adding the powder in small increments (using the spoon) until the specific mass.
4. Mix the solution thoroughly with a glass rod until everything is fully dissolved
5. Take three spinach leaves and cut off 5 mm of their stems with a knife on a cutting board
6. Add the leaves to the solution
7. Push them down with an upside-down funnel without any water splashing out of the beaker, push until the funnel touches the bottom is completely submerged
8. Fill a test tube with distilled water to the top
9. Place the tube upside down on the end of the funnel, with the least possible air entering and water exiting
10. Turn on a lamp at 15 cm (bulb) from the beaker
11. Turn on the slow-motion camera
12. Start the stopwatch and count the bubbles rising in the next minute, note down the data
13. At the end of the minute, empty the beaker and test tube and rinse them
14. Restart the experiment. Every mass of Sodium Bicarbonate is used three times. A total of 15 experiments.
15. Count the bubbles on the different footages. Change results if necessary.

There were last-minute changes, and this was the process of our experiment:

1. Put blinds down, turn off any light source
2. Fill 1 400ml beaker with tap water until it is full
3. Add 0, 1, 2, 3, or 4 heaping teaspoons of sodium bicarbonate to the water
4. Mix thoroughly with a pencil until everything is dissolved
5. Take three spinach leaves, soaked for one hour, and cut off 5 mm of their stems with a knife on the lab surface
6. Add the leaves to the solution

7. Push them down with an upside-down funnel without any water splashing out of the beaker, push until the funnel touches the bottom and is almost submerged
8. Fill a test tube with distilled water to the top
9. Place the tube upside down on the end of the funnel, with the least possible air entering and water exiting (we managed to keep the air part to less than 1 cm)
10. Turn on a lamp at 15 cm (bulb) from the beaker
11. Turn on the slow-motion camera
12. Start the stopwatch and count the bubbles rising in the next three minutes, note down the data for every minute separately.
13. At the end of the three minutes, empty the beaker and test tube and rinse them
14. Restart the experiment. Every number of spoons of Sodium Bicarbonate is used once. A total of 5 experiments.
15. Count the bubbles on the different footages. Change results if necessary.

Safety

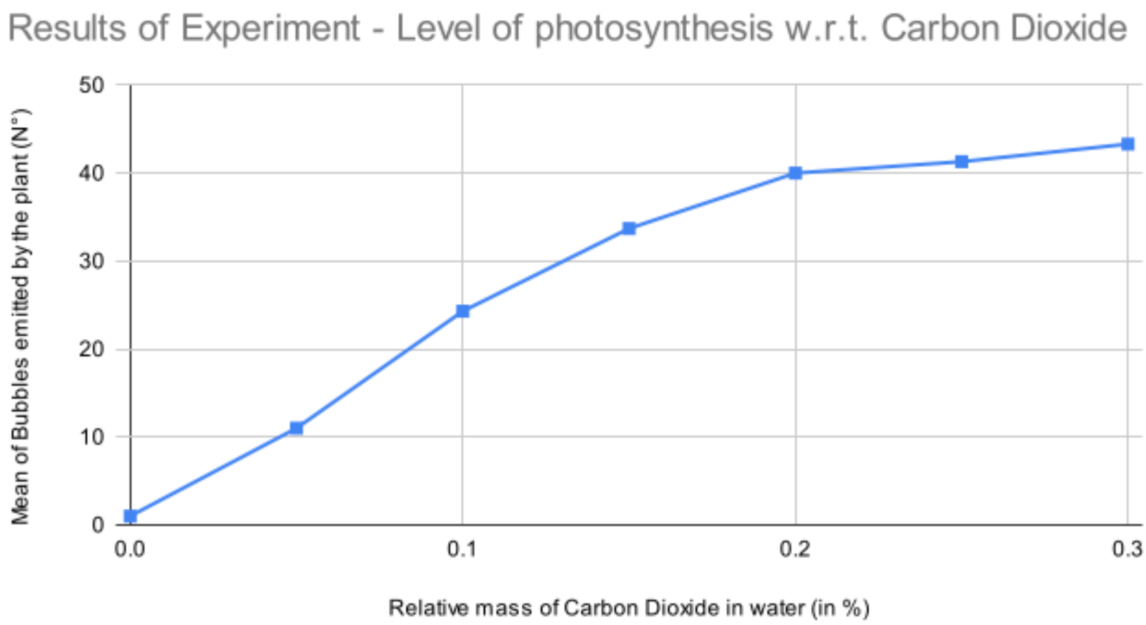
A laboratory, especially a biology laboratory, comes with risks. Handling liquids, working with acids, the risk of unwanted reactions, or the risk of slipping and tripping. It is important to be especially cautious when in a lab, for this reason, there are safety precautions we actively followed. Most importantly, every one of us put on lab coats before we came in contact with any material. At the end of the experiment, after we cleaned up, we took them off again to prevent any further risk outside the lab or with our school equipment. During the experiment, any unnecessary objects were put away into our bags and the one notebook and pencil were placed one double table (ca. 1,5 m) away from the beaker with water. There were no coats nor bags in our lab. In addition, although we did not have team members with long hair, we would have required them to tie their hair up. We also paid attention to the distances we had to walk, trying to mitigate any risk of splashing water from the beaker and slipping. Lastly, all cutting was made on a cutting board, and we always took extra care that every limb was at a safe distance and that we did not use momentum on the knife.

Results

This section is using data collected from the simulation at "https://lookangejss/biology/ejss_model_photosynthesis/photosynthesis_Simulation.xhtml"

Results of Experiment - Level of photosynthesis w.r.t. Carbon Dioxide

Relative mass of Carbon Dioxide in water (in %)	Number of bubbles emitted in Experiment 1	Number of bubbles emitted in Experiment 2	Number of bubbles emitted in Experiment 3	Mean of Bubbles emitted by the plant (N°)
0.00	2	0	1	1
0.05	11	10	12	11
0.1	27	24	22	24.3
0.15	35	33	33	33.7
0.2	39	41	40	40
0.25	39	42	43	41.3
0.3	44	43	43	43.3



The results are apparent. With no outliers or abnormalities, it seems the data is logical and can be analysed correctly. The graph shows a flattening curve, when the relative mass of Carbon Dioxide in the water increases, so does the number of emitted bubbles. The curve starts with 1 emitted bubble from the plant, with no Carbon Dioxide in the water. At 0.05% of Carbon Dioxide in the water we see a difference of 10 bubbles, 11 bubbles are emitted in the minute (on average). The next jump is the biggest with a difference of approx. 13 bubbles, to an average of 24.3 bubbles emitted in 1 minute with 0.1% of Carbon Dioxide in the water. From then on, the curve flattens rapidly, at 0.15% Carbon Dioxide an average of 33.7 bubbles were emitted. This creates a difference of 9.4 bubbles. At 0.2% the average number of bubbles grows by only 6.3 to 40 and the next steps are even smaller. At 0.25% the jump is of 1.3, this is the smallest difference of emitted bubbles. At 0.3% Carbon Dioxide in the water, the difference grows back to 2 for an average of 43.3 bubbles emitted in one minute. In general, the graph indicates that the level of photosynthesis and the relative mass of carbon dioxide in the water correlate, although the correlation is not linear.

Discussion

The experiment proves that the more carbon dioxide is in a plant's environment, the more oxygen it will emit. This can be seen on the graph, where the higher the percentage of carbon dioxide, the more bubbles the plant emits. Every point has a higher number of bubbles than the last one. This is because of the already mentioned, law of conservation of mass. If we double the reactants of the reaction, double the energy is needed but also double the product comes out. The interesting part of the graph is the curve. We see that every difference in number of bubbles emitted gets smaller and smaller. This is because of the idea behind a chemical reaction. If we increase the relative mass of carbon dioxide, we would expect more of the product to come out. This is correct, except for the fact that we do not increase the energy added to the chemical reaction. In other words, there isn't enough stimulation for the particles to start the reaction. If we increase the (light) energy, the photosynthesis levels will grow until there is a lack of carbon dioxide. This goes to a point where the limiting factor is the absorption of light by the chloroplasts (Gadd). Temperature can also be limiting, the higher the temperature, the faster the reaction, since the molecules are more active. On the other hand, at one point, temperature becomes too high and slows the reaction. In short, there will always be a limiting factor, especially in nature, which does not allow higher rates of photosynthesis. (BBC Bitesize)

Evaluation

My hypothesis was generally correct. I had correctly predicted the idea that, with the more Carbon Dioxide the plant absorbs, the more Oxygen it will produce. The graph represents my prediction well. The important factor I didn't account for in my hypothesis was the idea of a curve, a maximum at which the photosynthesis level doesn't rise any further, although the Carbon Dioxide still rises. If we read my hypothesis, we would assume the photosynthesis would have a linear correlation to the mass of Carbon Dioxide absorbed. If this hypothesis were entirely correct, we would see a perfectly straight graph starting at 0,0, which isn't the case. This leads to my next point, I assumed I would use distilled water in a perfect environment. In other words, there is no way the plant can absorb Carbon Dioxide if there is no Sodium Bicarbonate in the water. This would mean no Oxygen is emitted because the gas is mandatory for the reaction to happen. This world is not perfect, which means even if I do not intend the plant to absorb Carbon Dioxide, it will very likely still do, and therefore react with the water and light energy. In short, my Hypothesis was incomplete, but the general idea could be seen in the results.

The experiment did not give any results, this indicates that something went fundamentally wrong. It is difficult to find out what went wrong exactly, but there are a few variables which were impossible to predict, and therefore could have influenced the results. First, and most importantly, we always used the same Spinach leaves. If the leaves were infected or the organisms did not feel the need to do photosynthesis because they had too much glucose stored up (ARC), no Photosynthesis would happen, and no bubbles would be emitted. To solve this problem next time, it would be better to exchange the leaves after a few tries, in case it is not possible to observe a reaction. Second, it would have been better to wait for the Sodium Bicarbonate to react with the water. There is no way to find out when the reaction has started, and it is over because CO_2 Gas dissolves in water (FAO), but if we wait for some time, we can assume the reaction has happened or is about to start. This would allow the plant to absorb the CO_2 and perform Photosynthesis. Not only were there variables impossible to predict, but lack of experience made it difficult to estimate some variables, like the amount of light we should expose the plant to. To the naked eye, it seemed that there was a lot of light coming to the leaves with a light bulb at 15 cm from the beaker. It would have been better, the moment we realised nothing happened, to advance the lamp until the plant started performing photosynthesis. This is because, like every chemical reaction, photosynthesis requires energy for the reactants to start reacting and light is the most accessible energy source for a plant (Wakim and Grewal). It would have been necessary to restart the experiment since we changed multiple variables, and there is no guarantee this would have worked, but it would have been worth a try. Lastly, because of time restrictions, we decided to keep the leaves in the solution for three minutes at a time, by counting all the bubbles and dividing by three, we would get an immediate average of emitted bubbles per minute. This technique was very useful since there was no need to rinse and repeat as often as for the original plan. On the other hand, the plant could have absorbed all available carbon dioxide without us knowing, and still continuing the experiment. This would mean the plant wouldn't continue performing photosynthesis, since one of the reactants in the chemical reaction would be missing. In other words, it would have been better to follow the original plan, although in our case the problem was time, not laziness.

Not only was our method problematic, but we also had issues with our data collection. In the case that we had been able to count the bubbles coming out of the plant, there still would have been concerns with accuracy. This is because we decided to count the bubbles rising from the plant stems instead of measuring the volume of the gas. This was due to the difficulties we had turning the test tube around without any air coming inside. In addition, the top of such a tube is rounded, in other words, the volume calculation was a lot more difficult since we would have used a ruler to measure the length of the gas part and calculate the volume from there. The bubbles could have had different volumes, making the data unreliable and adding another variable. Lastly, we also do not know if the content of those bubbles are pure oxygen and if there isn't a slight percentage of carbon dioxide, entering the bubble from the water on the way up.

Conclusion

In conclusion, photosynthesis is a chemical reaction happening inside green plants when light energy makes carbon dioxide and water react into glucose and oxygen. This means, in theory you would expect, the more carbon dioxide is absorbed, the more oxygen is released. This is correct, although not infinitely, because of limiting factors like light intensity, carbon dioxide concentration and temperature. In other words, the answer to the research question *How does changing the relative mass of Carbon Dioxide absorbed by a green plant influence the volume of oxygen it emits?* could be formulated as: The more Carbon Dioxide a plant absorbs, the more oxygen it will emit. This happens until a specific factor limits higher rates of Photosynthesis. The experiment went wrong because of multiple variables, a lack of results is proof. Lastly, the data we would have collected would not have been very reliable because we counted bubbles instead of the volume of oxygen.

Works Cited:

ARC. “Too Much Sugar Doesn’t Put the Brakes on Turbocharged Crops.” ScienceDaily, 11 Nov. 2019, www.sciencedaily.com/releases/2019/11/191111100935.htm.

Bassham, James Alan and Lambers, Hans. "photosynthesis". Encyclopedia Britannica, 4 Dec. 2022, https://www.britannica.com/science/photosynthesis. Accessed 13 May 2023.

Britannica, The Editors of Encyclopaedia. "conservation of mass". Encyclopedia Britannica, 19 Jul. 2011, https://www.britannica.com/science/conservation-of-mass. Accessed 15 May 2023.

Britannica, The Editors of Encyclopaedia. "Jan Ingenhousz". Encyclopedia Britannica, 4 Dec. 2022, https://www.britannica.com/biography/Jan-Ingenhousz. Accessed 13 May 2023.

Britannica, The Editors of Encyclopaedia. "Jean Senebier". Encyclopedia Britannica, 2 May. 2023, https://www.britannica.com/biography/Jean-Senebier. Accessed 15 May 2023.

Cambridge Dictionary. “Distilled Water.” Cambridge Dictionary, 2023, dictionary.cambridge.org/dictionary/english/distilled-water.

Food and Agriculture Organization of the United Nations. “6. Carbon Dioxide.” CHEMICAL FEATURES OF WATER, 2023, www.fao.org/3/ac183e/AC183E06.htm.

Gadd, K. “Rate of Photosynthesis: Limiting Factors - RSC Education.” RSC Education, 2023, edu.rsc.org/download?ac=12620.

Grewal, Mandeep, and Suzanne Wakim. “3.9: Energy in Chemical Reactions.” Biology LibreTexts, 20 July 2022, bio.libretexts.org/Bookshelves/Human*Biology/Human*Biology*(Wakim*and*Grewal)/03%3A*Chemistry*of*Life/3.09%3A*Energy*in*Chemical*Reactions.

McEvoy, John G.. "Joseph Priestley". Encyclopedia Britannica, 9 Mar. 2023, https://www.britannica.com/biography/Joseph-Priestley. Accessed 13 May 2023.

North Arizona University. Photosynthesis, 2023, www2.nau.edu/lrm22/lessons/photosynthesis/photosynthesis.html.

Rogers, Kara. "What did Jan Ingenhousz discover about photosynthesis?". Encyclopedia Britannica, 12 Nov. 2019, https://www.britannica.com/story/what-did-jan-ingenhousz-discover-about-photosynthesis. Accessed 13 May 2023.