Aim: To investigate a factor that affects the rate of photosynthesis.

Introduction: A measured piece of pondweed will be cut and placed into a beaker containing measured amounts of water and sodium hydrogen carbonate. A lamp will be shined on to the pondweed and the amount of bubbles that are produced from the plant will be counted. The lamp will be adjusted to different distances from the plant to try and obtain differing results. The point of this experiment is to find out how light intensity affects the rate of photosynthesis. The equation for photosynthesis is:

$$6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$$

Carbon Dioxide + Water (light energy) Glucose + Oxygen

Light intensity will be the controlled variable looked at in this investigation. Increasing or decreasing the distance from the light source to the plant varies the light intensity.

Fixed Variables

Why the rate of photosynthesis increases or decreased from the amount of light energy absorbed is what is being investigated in this experiment. Pigments in the leaf such as chlorophyll absorb light energy. Chlorophyll easily absorbs blue light, in the 400-450 nm range, and also easily absorbs red light in the 650-700 nm range. Chlorophyll does not absorb green light or yellow light effectively but tends to reflect them, decreasing the amount of light absorbed and decreasing the rate of photosynthesis. The light colour can be fixed by using the same lamp throughout the experiment.

Enzymes are used in photosynthesis also. Therefore, increasing the temperature will increase enzyme reaction and the rate of photosynthesis until a certain point is reached when the enzymes stop working. The temperature can be kept somewhat a constant by performing the experiment in one session, when the air temperature shouldn't change enough to affect water temperature. A transparent glass block can also be placed in front of the lamp to prevent some of the heat from the lamp reaching the pondweed.

CO_2 concentration can affect the rate of photosynthesis since the more CO_2 in the air, the more CO_2 that can diffuse into the leaf. This variable can be fixed by adding a fixed amount of sodium hydrogen carbonate to the beaker and plant. Sodium hydrogen carbonate reacts with the water to release carbon dioxide. Any other products of the reaction are not accounted for, as they will not affect the results to such an extent that they are unreliable.

Water is required in the photosynthesis. When plants lack water, their stomata close to prevent any more water loss. Closing the stomata cells prevent CO_2 from diffusing into the leaf. Therefore water is linked to the carbon dioxide factor. Water can be kept a constant by measuring the amount of water in the experiment and keeping it the same.

Light, carbon dioxide, temperature, and chlorophyll are all limiting factors, meaning that even when there is more than enough of every other variable, the rate of photosynthesis can be limited by just one limiting factor, until there is enough of the limiting factor to increase the rate of photosynthesis further. Otherwise, the rate of photosynthesis can no longer increase.

Prediction

I predict that increasing the light intensity will increase the rate of photosynthesis. Light Intensity can be worked out by using $1/d^2$ when d= distance (from light source to plant). This is true to a certain point until another limiting factor affects the rate of photosynthesis.

I predict this because when chlorophyll absorbs light energy, the light energy cannot be immediately used for energy conversion. Instead the light energy is transferred to a special protein environment where energy conversion occurs. During this reaction, oxygen is produced as a by-product and it is the oxygen bubbles that are being measured in the experiment. The greater the light intensity, the more light energy that can be transferred and harnessed to fuel reaction in photosynthesis.

Light intensity is inversely proportional to the distance squared because the light energy spreads out as it travels further and further from its source. Light energy travels along the circumference of an expanding circle. When light energy is released from a point, the energy is dispersed equally along the circumference. But since the circle is expanding, the circumference increases and the same light energy is distributed along a greater surface.

Preliminary investigation

Before carrying out the real experiment, we carried out a preliminary investigation to see which factors we can improve to increase the effectiveness of the experiment. The most effective length of elodea was 10cm. This was because there is a larger surface area for photosynthesis to occur. The best light intensities were 5cm, 10cm, 15cm, 20cm and 25cm. This gave a wide range but not so wide that they would produce unreliable results. We also worked out that turning a measuring cylinder full of water upside down and put it over the top of the elodea in a beaker, better results were attained because less bubble escaped. Clipping the elodea to the bottom of the measuring cylinder helped to keep it from rising and therefore difficult to read the measurements.

Method

1) Set up the apparatus as shown (in the diagram on separate paper) but leaving out the pondweed, measuring cylinder, test tube, water, and the sodium hydrogen carbonate.
2) Fill the beaker with 200 cm3 of water and 50 cm3 of $NaHCO_3$.
3) Select 1 piece of pondweed roughly 5-10 cm long and cut off the stem.
4) Place the pondweed in the beaker

5) Place a water-filled measuring cylinder upside down and over the pondweed, and attach it with a paper clip (see diagram).
6) Place the ruler so that the beaker is aligned with 0cm.

7) Place the lamp directly in front of the plant so that it is 0 cm away from the beaker.

8) With the light shining on the plant, record the number of bubbles emitted in a 1 minute duration. Switch off the lamp and wait for another minute before taking another reading.
9) Take 3 readings at the current distance and move the lamp 5 cm further away from the plant.
10) Repeat steps 8 and 9 until 3 readings from at least 5 intervals of 5 cm have been taken.

11) Place results in a table and analyse the data

Results

Key: d=distance in metres

D2= the distance squared

d (m)	**d2 (m)**	**Bubbles per minute**			**Average**
		1	**2**	**3**	
0.05	400	36	40	28	38
0.1	100	35	24	22	27
0.15	44.1	15	16	17	16
0.2	25	7	5	6	6
0.25	16	2	3	1	2

After all our classroom research, we decided that the experiment was not giving us the desired results, as the classroom conditions were not ideal for this experiment. Instead our teacher provided us with accurate results to analyse and provide a conclusion.

Conclusion

The graph shows that as the light intensity increases, the amount of bubbles produced will also increase, just as I wrote in my prediction. The light is turned into energy by special proteins inside the plant. This is why oxygen is produced, as a by-product and how we determine the effects of light intensity, by counting the bubbles. As light energy travels along the circumference of an expanding circle, the further away the light is then the more surface for the energy to be distributed, so the light is 'less intense'. The table also shows 1 anomalous result at 0.1m, test 1. There is over 11 more bubbles than the other 2 results show, suggesting an error. This may be due to change in temperature, excess of carbon dioxide or even plain human error. A simple mistake could have been made when recording the result of that particular light intensity. If a graph were to be drawn of light intensity against bubbles per minute, the graph would level off at 330 light intensity approximately. This would be because another factor would affect the rate of photosynthesis. It could be either the functioning of chlorophyll, the temperature in the surroundings or the amount of carbon dioxide that the plant had supplied to it. We supplied the plant with enough $NaHC0_3$ to photosynthesise and we made our best efforts to keep the temperature constant. As we know, enzymes work best at around 40 Degrees Celsius so maybe we could have benefited by increasing the temperature. The CO_2 content probably would not have affected the results further as we put much $NaHCO_3$ into the water.

Evaluation

I think that the results we obtained were very reliable. There was only one anomaly showing that results were accurately recorded. I think that my method of carrying out the experiment was thorough but if I carried out this investigation again then I would carry out more preliminary work to ascertain why the results that our class gathered were unreliable and why our pondweed did not photosynthesise effectively, causing us to rely on secondary results.

To extend this investigation, I would look at other limiting factors of photosynthesis and try to understand the link between the all. I could also attempt to look at the effects of different colours in light and see which colours worked more effectively than others. To improve the experiment, I could of attempted to block out foreign light better, as this may have affected my results. I could also look at better ways of controlling the temperature, maybe by using a beaker of water, as this would absorb heat but also is transparent. I would have to analyse this carefully however, as water can refract light and this would take me further into the effects of different light and light colours.