

Factors affecting the rate of photosynthesis

Investigate and describe the effects of varying light intensity, carbon dioxide concentration and temperature on the rate of photosynthesis

For Cambridge IGCSE Biology 0610 (and 0970, which has the same content). Teacher answers start on a new page.

Name

Date

Aim

To investigate how light intensity, carbon dioxide concentration and temperature affect the rate of photosynthesis of an aquatic plant, by counting the bubbles of oxygen released.

Background

In **photosynthesis** plants take in carbon dioxide and water and, using light energy, make glucose and release oxygen. The **rate of photosynthesis** can be measured by the rate at which an aquatic plant such as *Elodea* gives off bubbles of oxygen.

The rate depends on **light intensity**, **carbon dioxide concentration** and **temperature**. Light gives the energy for the reaction, carbon dioxide is a raw material, and the reaction is controlled by enzymes. If one of these factors is in short supply it is the **limiting factor** and limits the rate.

Only one factor is changed at a time and the others are kept constant. Light intensity is changed by moving the lamp, carbon dioxide concentration by using different concentrations of sodium hydrogencarbonate solution, and temperature by using a water bath.

Hypothesis

As light intensity or carbon dioxide concentration increases, the rate of photosynthesis increases until another factor becomes limiting, because more light energy or more raw material is available. As temperature increases the rate rises to an optimum (about 30 to 40 °C) and then falls, because photosynthesis is controlled by enzymes.

Variables

Independent	Light intensity (distance of the lamp from the plant); in the extension investigations, concentration of sodium hydrogencarbonate or temperature
Dependent	Rate of photosynthesis, measured as the number of bubbles of oxygen released in one minute
Control	• Same piece of <i>Elodea</i>, with the same length of stem • Concentration (1%) and volume (250 cm³) of sodium hydrogencarbonate solution, when light is investigated • Temperature of the water, using a larger beaker of water around the plant as a heat shield and checking it with a thermometer • Time for the plant to adjust at each distance (2 minutes) and time for counting (1 minute) • Light intensity, when carbon dioxide or temperature is investigated

Equipment

- Fresh healthy Elodea (pondweed), about 10 cm long, with a freshly cut stem, and a paper clip to weigh it down
- 250 cm³ beaker for the plant and a larger beaker (600 cm³) of water as a heat shield
- Sodium hydrogencarbonate solution, 1% (a source of carbon dioxide)
- Lamp, preferably an LED lamp
- Metre rule or 30 cm ruler
- Stop-clock
- Thermometer, -10 °C to +110 °C
- Scissors or scalpel and a white tile
- Eye protection
- For the extension investigations: sodium hydrogencarbonate solutions of 0, 0.25, 0.5, 0.75 and 1.0%, and a water bath with ice and hot water

Risk assessment

Hazard	Risk	Precaution
Mains-powered lamp	The bulb can get hot and burn skin. Water spilt near electrical equipment can cause shock.	Do not touch the lamp. Keep water away from the lamp and sockets, and mop up spills at once.
Scalpel or scissors used to cut the stem	Cuts.	Cut on a white tile, away from the fingers, and put the blade down after use.
Hot water for the temperature investigation	Scalds.	Use water no hotter than 50 °C and keep the beakers away from the edge of the bench.
Sodium hydrogencarbonate solution	Low hazard, may irritate eyes.	Wear eye protection and wash splashes off straight away.

Method

1. Put on eye protection. Fill a 250 cm³ beaker with 1% sodium hydrogencarbonate solution, so that the pondweed will be covered.
2. On a white tile, cut about 1 cm off the end of the Elodea stem with a sharp scalpel. Attach a paper clip to the stem to hold it down and place it in the solution with the cut end upwards.
3. Stand the beaker in a larger beaker of water, to act as a heat shield, and put the lamp 5 cm from the plant. Measure the distance with a ruler from the lamp to the plant.
4. Switch on the lamp. Leave the plant for 2 minutes so that it can adjust to the new light.
5. Count the number of bubbles from the cut end of the stem in 1 minute. Record the number.
6. Repeat step 5 twice more at the same distance, so that you have three counts, and calculate the mean.
7. Move the lamp to 10 cm and repeat steps 4 to 6. Check the thermometer in the large beaker and replace the water if the temperature rises by more than 1 °C.
8. Repeat for distances of 15, 20, 25 and 30 cm.
9. Calculate the mean number of bubbles per minute for each distance. Plot the graph.
10. Extension for carbon dioxide: keep the lamp at 10 cm and use 0, 0.25, 0.5, 0.75 and 1.0% sodium hydrogencarbonate solution in turn. Use the same Elodea, leave it for 5 minutes in each new solution, and count the bubbles in the same way.

- L1 . Extension for temperature: keep the lamp at 10 cm and the 1% solution. Stand the beaker in a water bath at 10, 20, 30, 40 and 50 °C. When the thermometer in the solution shows the right temperature, wait 5 minutes more, then count the bubbles.
- L2 . Switch off the lamp, empty the beakers and wash your hands.

Results

Number of bubbles in 1 minute at different distances from the lamp				
distance of lamp / cm	number of bubbles in 1 min: 1	number of bubbles in 1 min: 2	number of bubbles in 1 min: 3	mean rate / bubbles per min
5				
10				
15				
20				
25				
30				

Graph

Line graph. Plot the mean rate / bubbles per min on the y-axis and the distance of lamp / cm on the x-axis (the independent variable on the x-axis). Choose scales that use more than half of the grid. Mark each point with a cross (x) and draw a single thin smooth best-fit curve. For the extensions, plot the mean rate against concentration of sodium hydrogencarbonate / % and against temperature / °C in the same way.



Exam questions 10 questions · 28 marks

1 For the investigation of light intensity, identify the independent variable and the dependent variable. **[2 marks]**

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2 Give three variables that should be kept constant in the light intensity investigation. **[3 marks]**

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3 Sodium hydrogencarbonate was added to the water. Explain why. **[2 marks]**

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4 The larger beaker of water around the plant acts as a heat shield. Explain why this is needed. **[2 marks]**

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5 Table 6.1 shows the number of bubbles counted in 1 minute at a lamp distance of 25 cm. **[3 marks]**
(a) Identify the anomalous result. (b) Calculate the mean number of bubbles per minute, ignoring the anomalous result.

Table 6.1			
distance of lamp / cm	number of bubbles in 1 min: 1	number of bubbles in 1 min: 2	number of bubbles in 1 min: 3
25	12	11	25

Answer =

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- 6** Using the example results, describe the effect of increasing the distance of the lamp on the rate of photosynthesis and explain the effect. **[3 marks]**

- 7** A student collected the oxygen given off by Elodea at different concentrations of sodium hydrogencarbonate. The rate was 10 mm³ per min at 0%, 85 mm³ per min at 0.25% and 130 mm³ per min at 0.5%. It was 150 mm³ per min at both 0.75% and 1.0%. (a) Calculate the increase in rate between 0% and 0.5%. (b) State the lowest concentration at which carbon dioxide is no longer the limiting factor. (c) Suggest one factor that limits the rate above this concentration and explain how you know. **[4 marks]**

Answer =

- 8** Describe and explain the shape of the graph you would expect when the temperature of the water is increased from 10 °C to 50 °C. **[3 marks]**

- 9** A piece of Elodea gave off 1.8 cm^3 of oxygen in 12 minutes. (a) Calculate the rate of photosynthesis in cm^3 per min. (b) State why measuring the volume of oxygen is more accurate than counting bubbles. **[3 marks]**

Answer =

- 10** Suggest three improvements to the investigation that would make the results more reliable. **[3 marks]**

Teacher answers

Practical skill 6: Factors affecting the rate of photosynthesis. The example results are practice data, not real measurements.

Example results

Example results (practice data)				
distance of lamp / cm	number of bubbles in 1 min: 1	number of bubbles in 1 min: 2	number of bubbles in 1 min: 3	mean rate / bubbles per min
5	62	58	60	60
10	41	43	42	42
15	28	30	26	28
20	19	17	18	18
25	12	11	13	12
30	9	8	10	9

Conclusion

As the lamp was moved further away the rate of photosynthesis fell, from a mean of 60 bubbles per minute at 5 cm to 9 bubbles per minute at 30 cm. The further the lamp, the lower the light intensity, so less light energy was absorbed by chlorophyll and less photosynthesis took place. The rate fell quickly at first and then more slowly. The bubbles are oxygen, a product of photosynthesis, so the number of bubbles is a measure of the rate. In the extension investigations, the rate rises as carbon dioxide concentration increases and then levels off when another factor becomes limiting; with temperature the rate increases up to an optimum of about 30 to 40 °C and then falls as the enzymes are denatured.

Errors and improvements

Error	Effect on the results	Improvement
Bubbles are different sizes, so counting bubbles is not an accurate measure of the volume of oxygen.	The rate is not reliable, particularly when bubbles are very small or very large.	Collect the gas in a capillary tube or gas syringe and measure its volume in a set time.
The lamp heats the water.	The temperature rises at close distances, so the rate may increase because of temperature as well as light.	Use a beaker of water as a heat shield, check with a thermometer, or use an LED lamp.
Light from windows or other lamps reaches the plant.	The light intensity is higher than it should be at large distances.	Do the investigation in a dim room or with blinds closed, and shield the apparatus.
When the water is warmed in the temperature investigation, dissolved air comes out of solution as bubbles.	Some of the bubbles counted are not oxygen from photosynthesis, so the rate at high temperatures is too high.	Use solution that has already been brought to the temperature and left to stand, wait before counting, or collect the gas and measure its volume.
Carbon dioxide runs out when the plant is left in the same solution.	Carbon dioxide becomes the limiting factor so the rate is lower than it should be.	Use fresh sodium hydrogencarbonate solution for each run, at a concentration high enough (for example 1%) that carbon dioxide is not limiting.

Mark scheme

One mark for each point unless a maximum is given. Words in brackets are not needed for the mark.

1. [2]

- independent: distance of the lamp from the plant / light intensity (1)
- dependent: number of bubbles in one minute / rate of photosynthesis (1)

2. [3]

- same piece of Elodea / same plant (1)
- same temperature (1)
- same concentration / volume of sodium hydrogencarbonate solution (1)
- same time for counting / adjusting (1)
- Max 3

3. [2]

- it provides / releases carbon dioxide (1)
- so that carbon dioxide is not the limiting factor / is not in short supply (1)

4. [2]

- absorbs heat from the lamp / keeps the temperature constant (1)
- because temperature affects the rate of photosynthesis (so the temperature would be another variable) (1)

5. [3]

- (a) 25 (1)
- (b) $(12 + 11) \div 2$ (1)
- = 11.5 (bubbles per min) (1)

6. [3]

- as distance increases the rate decreases (1)
- quoting figures, e.g. from 60 to 9 bubbles per minute (1)
- light intensity decreases so less light energy for photosynthesis (1)

7. [4]

- (a) $130 - 10 = 120$ (mm³ per min) (1)
- (b) 0.75% (1) allow between 0.5% and 0.75%
- (c) light intensity / temperature (1)
- the rate stays the same / levels off even though the carbon dioxide concentration increases (1)

8. [3]

- the rate increases as temperature increases, up to an optimum (1) allow any optimum from 30 to 40 °C
- then the rate decreases (sharply) (1)
- enzymes are denatured at high temperature (1)

9. [3]

- (a) $1.8 \div 12$ (1)
- = 0.15 (cm³ per min) (1)
- (b) bubbles vary in size / volume measures the actual amount of gas (1)

10. [3]

- collect and measure the volume of gas (1)
- repeat and calculate a mean / use more distances (1)
- use an LED lamp / heat shield / thermometer to control the temperature (1)
- keep the room dark / shield from other light (1)
- allow plant more time to adjust (1)
- Max 3

Exam tips

- Say what is measured: the rate is the number of bubbles (or volume of oxygen) per minute, not just the number of bubbles.
- When asked about a graph, describe the trend, quote figures from the graph, then explain with the limiting factor. If the line is flat, say that another factor is limiting.
- Heat from the lamp is the commonest error: say that a heat shield or LED lamp keeps the temperature constant, because temperature affects enzymes.
- Light intensity is controlled by the distance of the lamp. Say that you measure the distance from the lamp to the plant.
- Use the slash style on tables and axes, for example distance of lamp / cm and mean rate / bubbles per min, and put no units in the body of the table.