

Investigating photosynthesis

investigate photosynthesis, showing the evolution of oxygen from a water plant, the production of starch and the requirements of light, carbon dioxide and chlorophyll

For Pearson Edexcel International GCSE Biology 4BI1 and Science (Double Award) 4SD0. Teacher answers start on a new page.

Name

Date

Aim

To show that a water plant gives off oxygen in the light, that a leaf makes starch, and that photosynthesis needs light, carbon dioxide and chlorophyll.

Background

Photosynthesis is the process by which plants use light energy to make glucose from carbon dioxide and water, releasing oxygen. The word equation is: carbon dioxide + water → glucose + oxygen (in the presence of light and chlorophyll).

Part A uses a water plant such as *Elodea* (pondweed). The bubbles of **oxygen** given off from the cut stem are a measure of the **rate of photosynthesis**. Moving a lamp closer increases the light intensity, which should increase the rate until another factor becomes limiting.

Parts B and C use the **starch test**. Plants store the glucose they make as starch, so a leaf that contains starch has been photosynthesising. Before the investigation the plant is **destarched** by leaving it in the dark for 24 to 48 hours, so that any starch found afterwards was made during the investigation. Changing one condition at a time shows that light, carbon dioxide and chlorophyll are each needed.

Hypothesis

The rate of oxygen production by pondweed will fall as the lamp is moved further away, because the light intensity is lower. Only the parts of a leaf that receive light, carbon dioxide and have chlorophyll will contain starch.

Variables

Independent	Part A: light intensity, changed by the distance of the lamp from the pondweed (cm). Parts B and C: the factor being tested (light, carbon dioxide or chlorophyll) present or absent
Dependent	Part A: number of oxygen bubbles released per minute. Parts B and C: the colour of the leaf with iodine solution (blue-black means starch present)
Control	- Part A: temperature (use a heat shield or LED lamp), the same piece of pondweed, and the same amount of sodium hydrogencarbonate in the water - Parts B and C: the same type of plant, time in the light, and the same method for the starch test - Parts B and C: a control leaf or area that has all the conditions needed

Equipment

- Part A: pondweed (*Elodea* or *Cabomba*), 250 cm³ beaker of dilute (about 1%) sodium hydrogencarbonate solution to supply carbon dioxide, inverted filter funnel and test tube, forceps or a glass rod, scissors, lamp (preferably LED), metre rule, clear container of water as a heat shield, thermometer, stopwatch, wooden splint
- Parts B and C: destarched potted plants (geranium or similar) and a plant with variegated leaves (for example variegated geranium or *Coleus*), aluminium foil or black paper, two conical flasks with bungs and soda lime (or sodium hydroxide solution) and petroleum jelly
- Starch test: Bunsen burner, tripod, gauze and 250 cm³ beaker of water (to boil, then use as the hot water bath), forceps, boiling tube, ethanol, white tile, iodine solution with dropping pipette
- Eye protection and heat-resistant mat

Risk assessment

Hazard	Risk	Precaution
Mains lamp near water	Electric shock if water gets on the lamp or cable; burns from a hot bulb	Keep the lamp, plug and cable away from the water; use an LED lamp or a heat shield; do not touch the bulb.
Ethanol	Highly flammable; vapour can ignite	Turn off all Bunsen burners before using ethanol; heat the ethanol only in a hot water bath, never over a flame; wear eye protection.
Boiling water	Scalds from spills	Use a beaker on a heat-resistant mat, hold leaves with forceps and handle boiling tubes with a holder.
Soda lime or sodium hydroxide solution	Corrosive; irritant to eyes and skin	Wear eye protection, do not touch soda lime with bare hands, and clear spills immediately.
Iodine solution	Irritant; stains skin and clothes	Wear eye protection; wash splashes off skin with water.

Method

1. Part A (oxygen from pondweed): put on eye protection. Cut the stem of a piece of pondweed at an angle and place it, cut end upwards, in a beaker of water containing a little sodium hydrogencarbonate, under an inverted funnel with a test tube filled with water over the end.
2. Place the beaker a measured distance (for example 10 cm) from the lamp, with a clear container of water between them as a heat shield. Switch off other lights and check that the temperature stays constant.
3. Leave the pondweed for 2-3 minutes to adjust, then count the bubbles from the cut stem in 1 minute.
4. Repeat the count twice more at the same distance and move the lamp to 20, 30, 40 and 50 cm, leaving the plant to adjust each time.
5. Calculate the mean number of bubbles per minute at each distance. To show that the gas is oxygen, collect it in the test tube and test it with a glowing splint, which relights.
6. Part B (starch test on a leaf): remove a leaf from a plant that has been in the light. Heat a beaker of water to boiling and dip the leaf in it for about 1 minute, using forceps, to kill the cells and soften it.

- 7 . Turn off the Bunsen burner. Put the leaf in a boiling tube of ethanol and stand the tube in the hot water for about 5-10 minutes, until the leaf is pale.
- 8 . Rinse the leaf in warm water to soften it, spread it on a white tile and add drops of iodine solution. Record the colour: blue-black means starch is present; orange-brown means no starch.
- 9 . Part C (requirements): to test light, cover part of a leaf on a destarched plant with foil or black paper, leave the plant in bright light for several hours, then remove the leaf and carry out the starch test.
- 10 . To test carbon dioxide, enclose one leaf of a destarched plant in a flask with soda lime (seal the neck with petroleum jelly), and another leaf in a control flask without soda lime. Leave in bright light for several hours, then carry out the starch test on both leaves.
- 11 . To test chlorophyll, put a destarched plant with variegated leaves in bright light for several hours. Draw the leaf to show its green and white areas, then carry out the starch test and draw the result.
- 12 . Compare the iodine colour in the treated area with the control area for each requirement and record your results.

Results

Part A: bubbles of oxygen released by pondweed at different distances from the lamp				
Distance of lamp from pondweed (cm)	Bubbles per minute, count 1	Bubbles per minute, count 2	Bubbles per minute, count 3	Mean bubbles per minute
10				
20				
30				
40				
50				

Graph

Part A: plot mean bubbles per minute on the y-axis against distance of the lamp (cm) on the x-axis, with a smooth curve of best fit. (As an extension, calculate light intensity as $1 \div \text{distance}^2$ and plot the rate against this.) Parts B and C: record the starch test results in a table (area tested, iodine colour, starch present or absent) and draw the leaves before and after testing.



Exam questions 10 questions · 29 marks

- 1

In Part A, state the independent variable and the dependent variable.

[2 marks]
- 2

Explain why sodium hydrogencarbonate is added to the water in Part A.

[2 marks]
- 3

Describe how you could show that the gas given off by the pondweed is oxygen.

[2 marks]

4 Explain why a heat shield or an LED lamp is used in Part A. **[2 marks]**

5 The table shows the mean number of bubbles per minute at different distances. Describe the pattern shown and explain it. **[3 marks]**

Bubbles per minute at different distances	
Distance of lamp (cm)	Mean bubbles per minute
10	46
20	28
30	15
40	9
50	6

6 A leaf is tested for starch. Describe the steps and the result that shows starch is present. **[3 marks]**

7 Explain why the plant is left in the dark for 24 to 48 hours before an investigation into the need for light. **[2 marks]**

Teacher answers

Practical 5: Investigating photosynthesis. The example results are practice data, not real measurements.

Example results

Part A example results (practice data)				
Distance of lamp from pondweed (cm)	Bubbles per minute, count 1	Bubbles per minute, count 2	Bubbles per minute, count 3	Mean bubbles per minute
10	49	44	45	46
20	26	29	29	28
30	16	13	16	15
40	10	8	9	9
50	5	7	6	6

Conclusion

Part A: the number of bubbles per minute fell from 46 at 10 cm to 6 at 50 cm, so the rate of photosynthesis decreased as the lamp was moved further away. The light intensity is lower further from the lamp, so less light energy is absorbed by chlorophyll and less oxygen is released. A glowing splint relights in the gas collected, showing that it is oxygen. Parts B and C (practice results): after the starch test the uncovered part of the leaf turned blue-black but the area covered by foil stayed orange-brown, so light is needed for photosynthesis. The leaf in the flask with soda lime stayed orange-brown while the control leaf turned blue-black, so carbon dioxide is needed. On the variegated leaf the green areas turned blue-black and the white areas stayed orange-brown, so chlorophyll is needed. Starch is made from the glucose produced by photosynthesis, so starch in a leaf shows that photosynthesis has happened.

Errors and improvements

Error	Effect on the results	Improvement
Counting bubbles of different sizes	Bubble count is not a true measure of the volume of oxygen, so rates are inaccurate	Collect the gas in a capillary tube or gas syringe and measure the volume per minute.
The lamp warms the water as it is moved closer	The temperature changes the rate of photosynthesis, so light is not the only variable that changes	Use an LED lamp or a heat shield, and check the water temperature with a thermometer.
Other light enters the room or the pondweed is not given time to adjust	The light intensity is not just from the lamp, and the rate may not be steady	Work in a dim room, shield the apparatus and allow 2-3 minutes after each move before counting.
The plant was not fully destarched, or the leaf was not fully decolourised	A false positive starch result, or the iodine colour cannot be seen against green	Leave the plant in the dark for 48 hours and heat the leaf in ethanol until it is completely pale.
Carbon dioxide leaks into the flask or the soda lime is used up	The leaf is not truly short of carbon dioxide, so the result may be misleading	Seal the flask neck with petroleum jelly, use fresh soda lime and include a control flask.

Mark scheme

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

1. [2]

- independent: light intensity (1) allow distance of the lamp from the pondweed
- dependent: number of bubbles (of oxygen) per minute (1) allow rate of photosynthesis / volume of oxygen per minute

2. [2]

- it supplies carbon dioxide (1)
- so carbon dioxide is not a limiting factor / does not limit the rate of photosynthesis (1)

3. [2]

- collect the gas in a test tube (1)
- a glowing splint relights (when put in the gas) (1)

4. [2]

- to stop the temperature of the water rising / to keep the temperature constant (1)
- because temperature also affects the rate of photosynthesis / so only light intensity changes (1)

5. [3]

- as the distance increases the number of bubbles per minute decreases (1) allow correct use of data
- further from the lamp the light intensity is lower (1)
- less light energy is absorbed / available for photosynthesis, so the rate of photosynthesis falls and less oxygen is released (1) allow light is the limiting factor

6. [3]

- put the leaf in boiling water (for about a minute) to kill the cells / soften it (1)
- heat in ethanol in a (hot) water bath to remove the chlorophyll (1)
- rinse in (warm) water and spread on a white tile (1)
- add iodine (solution); blue-black shows starch is present (1)
- Max 3

7. [2]

- so it uses up / gets rid of its stored starch (1)
- so any starch found afterwards was made during the investigation (1)

8. [3]

- B: no starch made because no light reached it, so light is needed for photosynthesis (1)
- C: no starch made because there is no chlorophyll, so chlorophyll is needed (1)
- D: no starch made because soda lime absorbed the carbon dioxide, so carbon dioxide is needed (1)

9. [6]

Level 3 5-6	A clear, logical method that includes destarching, a leaf with no carbon dioxide (soda lime or sodium hydroxide) and a control leaf, time in bright light, the complete starch test with expected results, and a safety precaution
Level 2 3-4	A method with most key steps, such as soda lime, light, and the starch test with results, but a control or the destarching step is missing or the detail is limited
Level 1 1-2	A basic description, for example 'remove the carbon dioxide and test the leaf'

Indicative content

- destarch the plant in the dark for 24–48 hours; enclose one leaf in a sealed flask with soda lime and a control leaf in a flask without it; seal with petroleum jelly; leave in bright light for several hours; test both leaves for starch (boil in water, heat in ethanol in a water bath, rinse, add iodine); the control leaf turns blue-black, the soda lime leaf stays orange-brown, so carbon dioxide is needed; safety: eye protection, no naked flame with ethanol, soda lime is corrosive

10. [4]

- ethanol is (highly) flammable / could catch fire (1)
- ethanol boils at a low temperature, so hot water is enough to heat it without a flame (1) allow a water bath keeps the temperature below the temperature of a flame
- heating in ethanol removes the chlorophyll / green colour (1)
- so the (blue-black) colour change with iodine can be seen (1)

Exam tips

- The independent variable in Part A is light intensity, and the distance is how you change it. Say this clearly.
- For the starch test, learn the order: boil in water, heat in ethanol, rinse, add iodine. State what each step does.
- Describe results in terms of colours: blue-black means starch present, orange-brown means starch absent. Link the result to the condition being tested.
- Always mention a control: a leaf or area that has light, carbon dioxide and chlorophyll, so you can compare it with the one that does not.
- Ethanol is flammable. Do not heat it over a naked flame; say 'turn off the Bunsen burner and use a hot water bath'.