IGCSE and O Level Biology photosynthesis

Notes, practice questions and answers for Cambridge IGCSE Biology 0610 and O Level Biology 5090. Free from numrahedu.com, where you can also run the pondweed lab online.

The photosynthesis equation

Word equation

carbon dioxide + water → glucose + oxygen

in the presence of light and chlorophyll

Balanced chemical equation

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

0610 Extended students and all 5090 students need this one.

Photosynthesis key words

Term	Meaning
Photosynthesis	The process by which plants make carbohydrates from raw materials, using energy from light.
Raw materials	Carbon dioxide, taken in through the stomata, and water, taken up by the roots.
Chlorophyll	A green pigment found in chloroplasts. It transfers energy from light into energy in chemicals, used to make carbohydrates.
Chloroplast	The part of a plant cell that contains chlorophyll, where photosynthesis takes place.
Rate of photosynthesis	How fast photosynthesis happens, for example the number of oxygen bubbles a plant gives off each minute.
Limiting factor	Whichever factor is in shortest supply and so holds the rate back. Increasing it increases the rate.
Destarching	Keeping a plant in the dark for about two days, so the leaves use up their starch before an experiment.
Hydrogencarbonate indicator	A solution that shows the carbon dioxide level by its shade: yellow for more carbon dioxide than air, red for the same as air, purple for less.
Variegated leaf	A leaf with green parts, which have chlorophyll, and white or cream parts, which do not.

What the plant does with the carbohydrates

- **Starch** an energy store, kept in leaves, roots and seeds
- **Cellulose** to build cell walls
- **Glucose** used in respiration to provide energy
- **Sucrose** for transport through the plant in the phloem
- **Nectar** to attract insects for pollination (named in 0610)

Mineral ions the plant needs

- **Nitrate ions.** Needed to make amino acids, which are joined to make proteins. Without them a plant grows poorly.
- **Magnesium ions.** Needed to make chlorophyll. Without them leaves turn yellow, because they have less chlorophyll, so less light is absorbed.

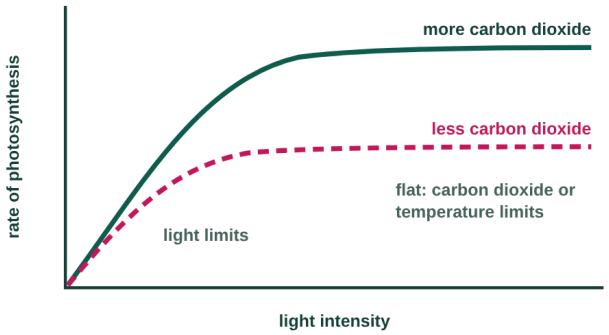
Limiting factors

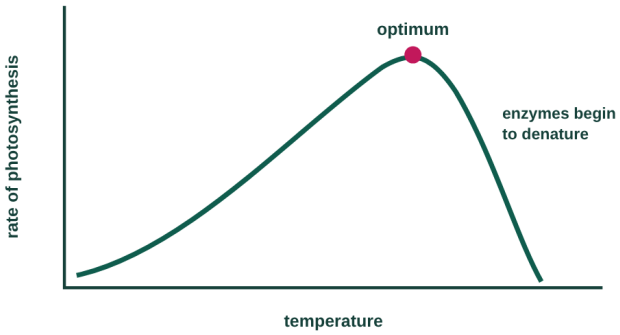
Photosynthesis needs light, carbon dioxide and a suitable temperature all at once. Whichever one is in shortest supply sets the rate. That factor is the limiting factor.

On a graph of rate against light intensity, the line rises at first: light is limiting, so more light means a higher rate. Then the line levels off. Adding more light now makes no difference, because something else is limiting, usually the carbon dioxide concentration or the temperature.

Raise the carbon dioxide and the whole curve levels off higher. That proves carbon dioxide was limiting on the flat part.

Temperature works differently. Photosynthesis is controlled by enzymes, so the rate rises up to an optimum temperature. Above the optimum the enzymes begin to denature, and the rate falls.





Numrahedu.com: the graphs show the shapes to learn, not real data.

What is likely to be limiting?

Conditions	Likely limiting factor
Early morning, cool and dim	Light intensity, and possibly temperature.
Midday in summer, bright and warm	Usually carbon dioxide concentration.
A sunny day in winter	Usually temperature.
A greenhouse with a heater that burns fuel	The heater adds both carbon dioxide and warmth, so light may become limiting.

Photosynthesis experiments to know

Rate of photosynthesis with pondweed

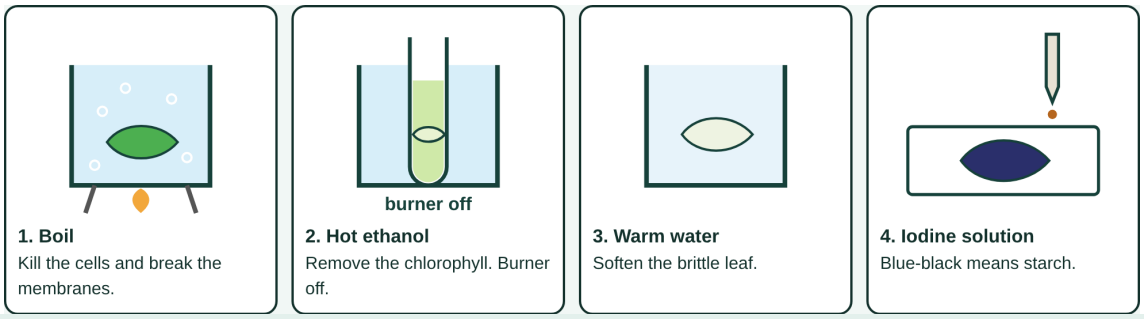
1. Put a piece of pondweed, cut end up, in a boiling tube of water with a little sodium hydrogencarbonate added, to supply carbon dioxide.
2. Stand the boiling tube in a beaker of water at a set temperature, and put a lamp 10 cm away.
3. Leave it for 5 minutes so the plant can adjust to the light.
4. Count the bubbles given off from the cut end in one minute. Count three times and find the mean.
5. Move the lamp to 20, 30, 40 and 50 cm, leave it for 5 minutes each time, and count again.

Fair test. Keep the same piece of pondweed, the same concentration of sodium hydrogencarbonate and the same temperature. Use an LED lamp, or a beaker of water between lamp and plant, so the lamp does not warm the water. Work in a darkened room.

Remember. Counting bubbles only estimates the rate, because bubbles vary in size. Collecting the gas in a syringe or measuring cylinder and measuring its volume is more accurate.

Testing a leaf for starch

1. Put the leaf in boiling water for about a minute. This kills the cells, stops reactions, and breaks the membranes so the iodine solution can get in.
2. Turn off the Bunsen burner. Put the leaf in a boiling tube of ethanol, and stand the tube in the hot water for about 10 minutes. The ethanol removes the chlorophyll.
3. Dip the leaf in warm water to soften it, because the ethanol makes it brittle.
4. Spread the leaf on a white tile and add iodine solution.



Result. Blue-black shows that starch is present. Orange-brown, the shade of the iodine solution itself, shows no starch.

Remember. Ethanol is flammable, so it is never heated over a flame. It is warmed only in hot water, with the burner turned off.

Showing that a plant needs chlorophyll, light and carbon dioxide

1. Destarch the plant first by keeping it in the dark for about two days.
2. **Chlorophyll:** use a plant with variegated leaves. After a day in light, only the green parts turn blue-black.
3. **Light:** cover part of a leaf on both sides with a strip of foil. After a day in light, the covered part stays orange-brown.
4. **Carbon dioxide:** seal a leaf in a clear bag with soda lime, which absorbs carbon dioxide. Seal another leaf in a bag with no soda lime. After a day in light, only the leaf without soda lime turns blue-black.
5. Test each leaf for starch.

Fair test. Each experiment needs a control that differs in one factor only: the green part of the leaf, the uncovered part, and the bag with no soda lime.

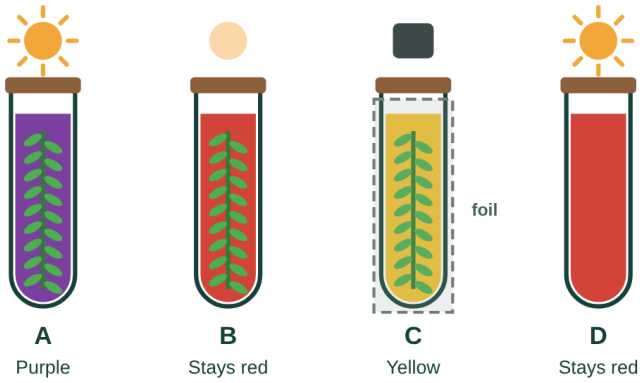
Remember. Destarching matters. Any starch found at the end must then have been made during the experiment.

Gas exchange with hydrogencarbonate indicator

1. Set up four tubes of red hydrogencarbonate indicator. Put pondweed in three of them.
2. Leave one pondweed tube in bright light, one in dim light, and wrap one in foil to keep it dark.
3. Leave the fourth tube, with no pondweed, in bright light.
4. Seal the tubes, and look at them again after a few hours.

Fair test. The tube with no pondweed stays red. This shows that light alone does not change the indicator.

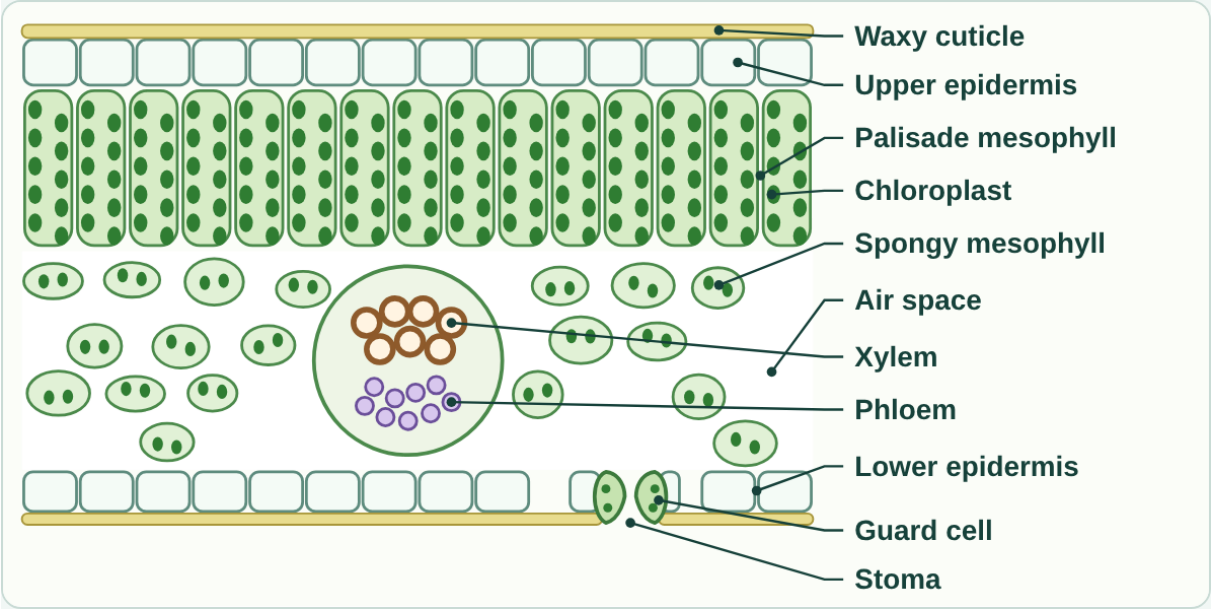
Remember. Plants respire all the time. The indicator shows the overall result of photosynthesis and respiration together.



Numrahedu.com: the tubes after a few hours. All four started red.

Tube	Set-up	Result	Why
A	Pondweed, bright light	Purple	Photosynthesis is faster than respiration, so carbon dioxide is taken out of the water.
B	Pondweed, dim light	Stays red	Photosynthesis and respiration happen at about the same rate, so there is no overall change.
C	Pondweed in the dark	Yellow	Only respiration happens, so carbon dioxide is added to the water.
D	No pondweed, bright light	Stays red	The control. Without a plant, nothing changes.

Leaf structure



Numrahedu.com: cross-section of a leaf, simplified.

Part	How it helps photosynthesis
Waxy cuticle	A waterproof wax layer. It cuts water loss, and it is clear, so light passes through.
Upper epidermis	A thin layer of clear cells with no chloroplasts, so light passes through to the cells below.
Palisade mesophyll	Long cells packed tightly near the top of the leaf, full of chloroplasts. Most photosynthesis happens here.
Chloroplasts	Contain chlorophyll, which absorbs light. They are most numerous in the palisade cells.
Spongy mesophyll	Rounded cells with fewer chloroplasts, loosely packed with air spaces between them.
Air spaces	Let carbon dioxide diffuse to the cells and oxygen diffuse out. They give a large surface for gas exchange.
Xylem	Brings water and mineral ions to the leaf, in the vascular bundle.
Phloem	Carries sucrose and amino acids away from the leaf to the rest of the plant.
Lower epidermis	The lower layer of cells, which has most of the stomata.
Guard cells and stoma	A pair of guard cells opens and closes each stoma. Through the stoma, carbon dioxide diffuses in and oxygen diffuses out.

The shape of the leaf

- **Large surface area.** Absorbs more light, and gives more room for stomata.
- **Thin.** Carbon dioxide has only a short distance to diffuse to the cells.

How to write your answers

Avoid	Write
Plants get their food from the soil.	Plants make their own carbohydrates by photosynthesis. Roots take in water and mineral ions from the soil.
Plants carry out photosynthesis in the day and respire at night.	Plants respire all the time, day and night. In light they also carry out photosynthesis.
Chlorophyll makes energy.	Chlorophyll transfers energy from light into energy in chemicals.
The bubbles are carbon dioxide.	The bubbles are mostly oxygen, given off by photosynthesis.
On the flat part of the graph, light is limiting.	On the flat part, more light makes no difference, so another factor, such as carbon dioxide or temperature, is limiting.
At 40 °C the enzymes are killed.	The enzymes begin to denature. Enzymes are not alive, so they cannot be killed.
Counting bubbles measures the oxygen made exactly.	Counting bubbles gives an estimate, because bubbles vary in size.
Heat the ethanol over a Bunsen burner.	Warm the ethanol in hot water with the burner turned off, because ethanol is flammable.

Fair tests and evaluation

- **Change one variable.** Change only the light intensity, and keep the carbon dioxide and the temperature the same.
- **Control the temperature.** Use an LED lamp, or a beaker of water as a heat shield, and check the water with a thermometer.
- **Let the plant adjust.** Wait a few minutes at each new distance before counting.
- **Darken the room.** Light from windows would add to the light from the lamp.
- **Repeat and find a mean.** Repeats help you spot an anomalous result and make the results more reliable.
- **Measure volume, not bubbles.** Bubbles vary in size, so collecting the gas and measuring its volume is more accurate.

Hazards and precautions

What	Hazard	Precaution
Ethanol	Flammable	No naked flame nearby. Warm it in hot water with the burner turned off.
Boiling water	Can scald	Handle the leaf with forceps, and stand the beaker on a heatproof mat.
Soda lime	Corrosive	Wear eye protection and do not touch it with your hands.
Iodine solution	Irritant, stains skin	Wear eye protection and wash off any spills.
Lamp	Gets hot, and is electrical near water	Do not touch the bulb, and keep the lamp and wires away from water.

Pondweed lab record sheet

Use this page with the pondweed lab at numrahedu.com/biology-photosynthesis/, or with a real experiment. Count three times at each distance, then calculate the mean.

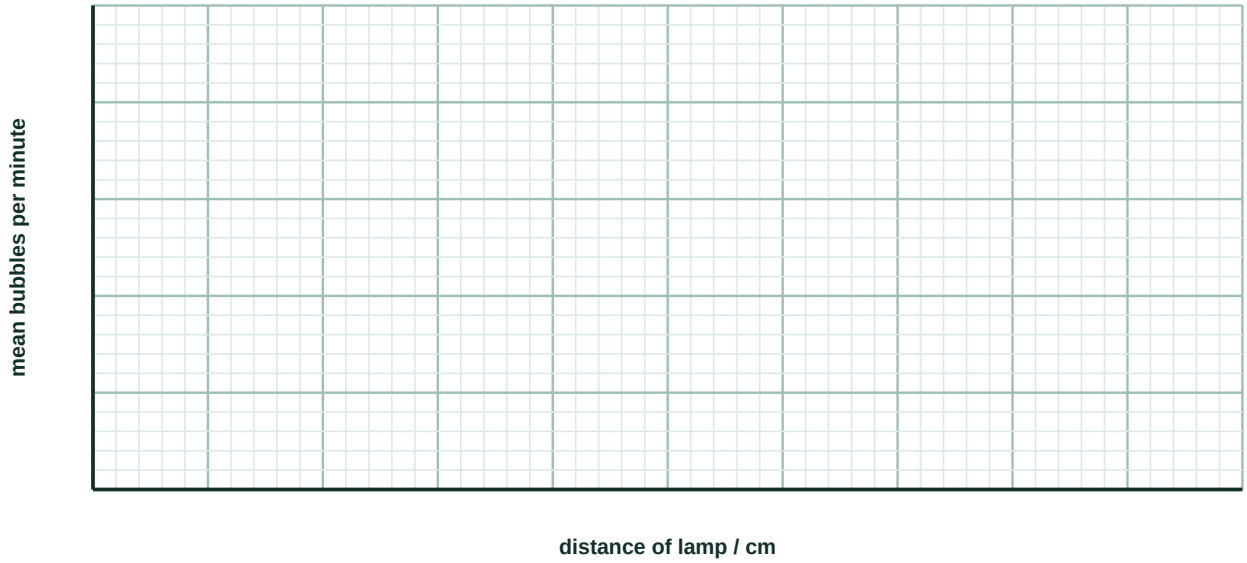
Conditions 1: carbon dioxide ..... temperature ..... °C

Distance / cm	Count 1	Count 2	Count 3	Mean
5				
10				
15				
20				
30				
40				
50				

Conditions 2: carbon dioxide ..... temperature ..... °C

Distance / cm	Count 1	Count 2	Count 3	Mean
5				
10				
15				
20				
30				
40				
50				

Plot both sets of means on the grid. Draw a line for each, and label which factor limits the flat part of each line.



Photosynthesis questions

13 original questions, 48 marks. Answer on paper, then mark your work with the answers at the end.

Q1. The equations [3 marks]

(a) State the word equation for photosynthesis. [2] (b) State the balanced chemical equation for photosynthesis. [1]

Q2. Using the carbohydrates [3 marks]

State three ways a plant uses the carbohydrates it makes in photosynthesis.

Q3. Counting bubbles [3 marks]

With the lamp 20 cm from some pondweed, a student counts 18, 22 and 20 bubbles in three separate minutes. (a) Calculate the mean rate. [1] (b) Explain why counting bubbles is only an estimate of the rate of photosynthesis. [2]

Q4. Reading a graph [5 marks]

Made-up results. Distance of lamp in cm and bubbles per minute: 10, 31. 15, 30. 20, 22. 30, 10. 40, 6. 50, 4. (a) Describe how the rate changes as the lamp moves from 10 cm to 50 cm. [2] (b) Suggest which factor is limiting at 10 cm, and explain your answer. [2] (c) Suggest how the student could test your answer to (b). [1]

Q5. The lamp warms the water [3 marks]

A student places a filament lamp very close to the pondweed. Explain why the results may not be valid, and suggest an improvement.

Q6. Hydrogencarbonate indicator [4 marks]

Three tubes of red hydrogencarbonate indicator are set up. Tube A has pondweed in bright light. Tube B has pondweed in the dark. Tube C has no pondweed and is in bright light. (a) Predict what each of tubes A and B shows after a few hours. [2] (b) Explain the result in tube A. [1] (c) State the purpose of tube C. [1]

Q7. The leaf starch test [4 marks]

(a) Explain why a plant is kept in the dark for two days before an experiment on photosynthesis. [2] (b) Explain why the leaf is put in hot ethanol during the starch test. [1] (c) State one safety precaution when using ethanol. [1]

Q8. A variegated leaf [3 marks]

A destarched plant with variegated leaves is left in light for a day. A leaf is then tested for starch. Describe and explain the result.

Q9. Is carbon dioxide needed? [4 marks]

Describe how a student could show that a plant needs carbon dioxide for photosynthesis.

Q10. Leaf structure [4 marks]

Explain how four features of a leaf help it to carry out photosynthesis.

Q11. Mineral ions [3 marks]

A plant is grown without magnesium ions and its leaves turn yellow. (a) Explain why. [2] (b) State why a plant needs nitrate ions. [1]

Q12. Spot the mistakes [3 marks]

Read this student's account: "Plants take in oxygen for photosynthesis. They only respire at night. The stomata change light energy into glucose." Give three corrections.

Q13. Planning [6 marks]

Plan an experiment to find out how light intensity affects the rate of photosynthesis of pondweed.

Answers

Q1. The equations

- (a) One mark for carbon dioxide and water on the left.
- (a) One mark for glucose and oxygen on the right.
- (b) One mark for $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$.

Q2. Using the carbohydrates

- Any three of these, one mark each:
- Stored as starch.
- Made into cellulose for cell walls.
- Glucose used in respiration to provide energy.
- Changed to sucrose for transport in the phloem.
- Made into nectar to attract insects.

Q3. Counting bubbles

- (a) One mark for 20 bubbles per minute.
- (b) One mark because bubbles are not all the same size.
- (b) One mark for a reason such as: some oxygen dissolves in the water, or fast bubbles are hard to count.

Q4. Reading a graph

- (a) One mark for the rate falling as the distance increases, or as the light intensity falls.
- (a) One mark for the rate staying about the same between 10 cm and 15 cm.
- (b) One mark for carbon dioxide concentration or temperature.
- (b) One mark because moving the lamp closer does not increase the rate, so light is not limiting.
- (c) One mark for adding more sodium hydrogencarbonate, or warming the water, and counting again to see if the rate rises.

Q5. The lamp warms the water

- One mark for the lamp warming the water.
- One mark because temperature also changes the rate, so two variables change at once.
- One mark for using an LED lamp, or a beaker of water as a heat shield, or checking the temperature with a thermometer.

Q6. Hydrogencarbonate indicator

- (a) One mark for tube A turning purple.
- (a) One mark for tube B turning yellow.
- (b) One mark because photosynthesis is faster than respiration, so carbon dioxide is taken out of the water.
- (c) One mark for a control, showing that light alone does not change the indicator.

Q7. The leaf starch test

- (a) One mark for the starch in the leaves being used up.
- (a) One mark so that any starch found later must have been made during the experiment.
- (b) One mark for removing the chlorophyll, so the result with iodine solution can be seen.
- (c) One mark for no naked flame, or warming it in hot water with the burner turned off.

Q8. A variegated leaf

- One mark for the green parts turning blue-black.
- One mark for the white parts staying orange-brown.
- One mark because only the parts with chlorophyll can carry out photosynthesis and make starch.

Q9. Is carbon dioxide needed?

- One mark for destarching the plant first.
- One mark for sealing a leaf in a clear bag with soda lime, to absorb carbon dioxide.
- One mark for a control leaf in a bag with no soda lime, kept in the same light for the same time.
- One mark for testing both leaves for starch, where only the control turns blue-black.

Q10. Leaf structure

- Any four of these, one mark each:
- Large surface area to absorb more light.
- Thin, so carbon dioxide diffuses only a short distance.
- Palisade cells near the top, full of chloroplasts, to absorb most light.
- Stomata let carbon dioxide in and oxygen out.
- Air spaces let gases diffuse through the leaf.
- Xylem brings water to the leaf.
- Clear cuticle and epidermis let light through.

Q11. Mineral ions

- (a) One mark because magnesium ions are needed to make chlorophyll.
- (a) One mark because with less chlorophyll the leaves are yellow, and they absorb less light.
- (b) One mark for making amino acids, for proteins.

Q12. Spot the mistakes

- One mark for taking in carbon dioxide, and giving out oxygen.
- One mark for respiring all the time, day and night.
- One mark for chlorophyll in chloroplasts transferring the energy from light, not the stomata.

Q13. Planning

- Any six of these, one mark each:
- Put pondweed in water with sodium hydrogencarbonate added.
- Place a lamp at a measured distance, such as 10 cm.
- Change the distance, using at least five distances.
- Let the plant adjust for a few minutes at each distance.
- Count bubbles, or measure the volume of gas, in a set time.
- Keep the temperature the same, using a heat shield or LED lamp.
- Keep the same pondweed and the same carbon dioxide concentration.
- Darken the room.
- Repeat and calculate a mean.

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