

Photosynthesis

Revision notes • The photosynthesis equations, the role of chlorophyll, the starch test investigations, limiting factors and the hydrogencarbonate indicator practical.

For Cambridge IGCSE Combined Science 0653. **Supplement** is Extended content, only examined on Papers 2 and 4.

Photosynthesis Spec B6.1

Photosynthesis and chlorophyll Spec B6.1.1, B6.1.2, B6.1.3, B6.1.5, B6.1.6

Photosynthesis is the process by which plants synthesise carbohydrates from raw materials using energy from light. The raw materials are carbon dioxide and water. The carbohydrate made is glucose, and oxygen is released as a by-product.

Photosynthesis	the process by which plants synthesise carbohydrates from raw materials using energy from light
Chlorophyll	a green pigment found in chloroplasts that transfers energy from light into energy in chemicals, for the synthesis of carbohydrates

The word equation for photosynthesis is:

carbon dioxide + water → glucose + oxygen

This happens **in the presence of light and chlorophyll**. Light and chlorophyll are written above the arrow because they are needed for the reaction but are not raw materials.

What photosynthesis needs, and where it comes from	
Requirement	Where it comes from
Carbon dioxide	The air, entering the leaf through the stomata
Water	The soil, absorbed by the roots and carried to the leaf in the xylem
Light	The Sun (or another light source)
Chlorophyll	Chloroplasts in the plant cells

Chlorophyll and chloroplasts

Chlorophyll is a green pigment that is found in **chloroplasts**. It absorbs light.

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Chlorophyll **transfers energy from light into energy in chemicals**, for the synthesis of carbohydrates. The energy from light ends up stored as chemical energy in glucose.

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The balanced chemical equation

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The balanced chemical equation shows how many molecules of each substance take part. Six molecules of carbon dioxide and six of water make one molecule of glucose and six of oxygen.

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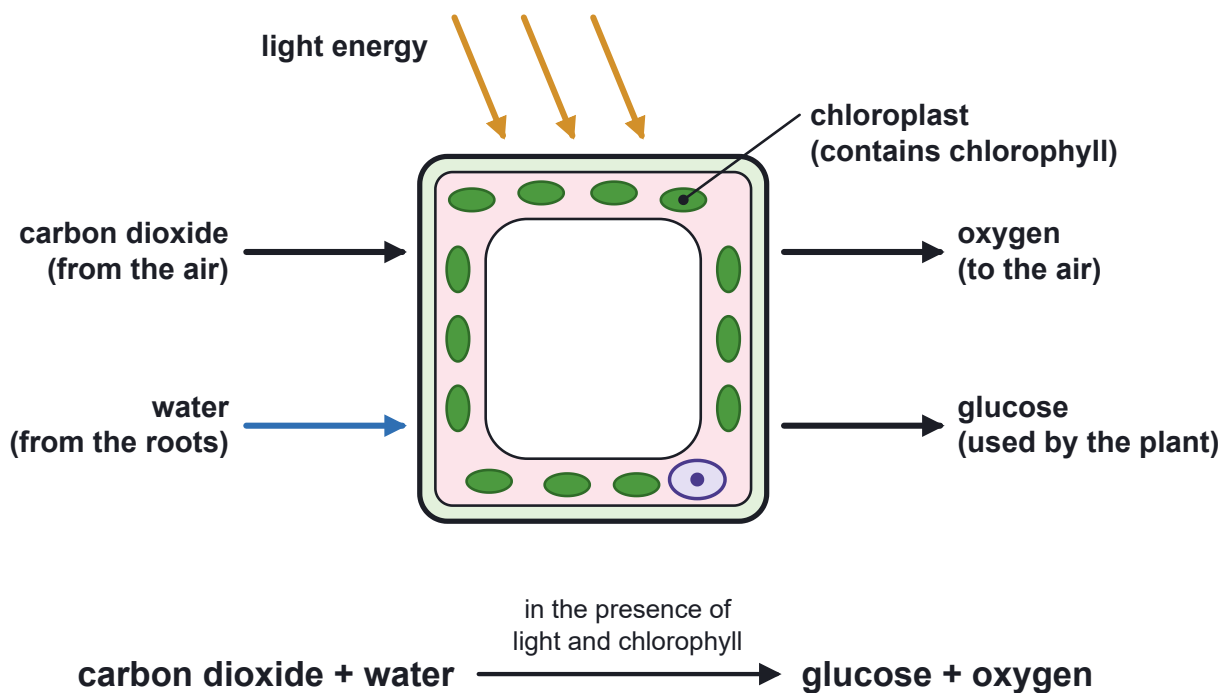


Exam tip: Write light and chlorophyll over the arrow. Do not write them as raw materials on the left. Cambridge asks for the phrase 'in the presence of light and chlorophyll'.

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Common mistake: Do not say chlorophyll 'makes' energy. It transfers energy from light into chemical energy in the carbohydrate.

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Photosynthesis in a leaf cell: **chlorophyll** in the chloroplasts transfers energy from **light** into chemical energy in glucose.

Investigating the need for chlorophyll, light and carbon dioxide Spec B6.1.4

To show that chlorophyll, light and carbon dioxide are needed for photosynthesis, test leaves for **starch**. Glucose made in photosynthesis is converted to starch, so starch in a leaf is evidence that photosynthesis has taken place.

Destarching

Before each investigation, **destarch** the plant by leaving it in the dark for 24 to 48 hours. The plant uses up its stores of starch in respiration. Leaves from a destarched plant test negative for starch.

The starch test on a leaf

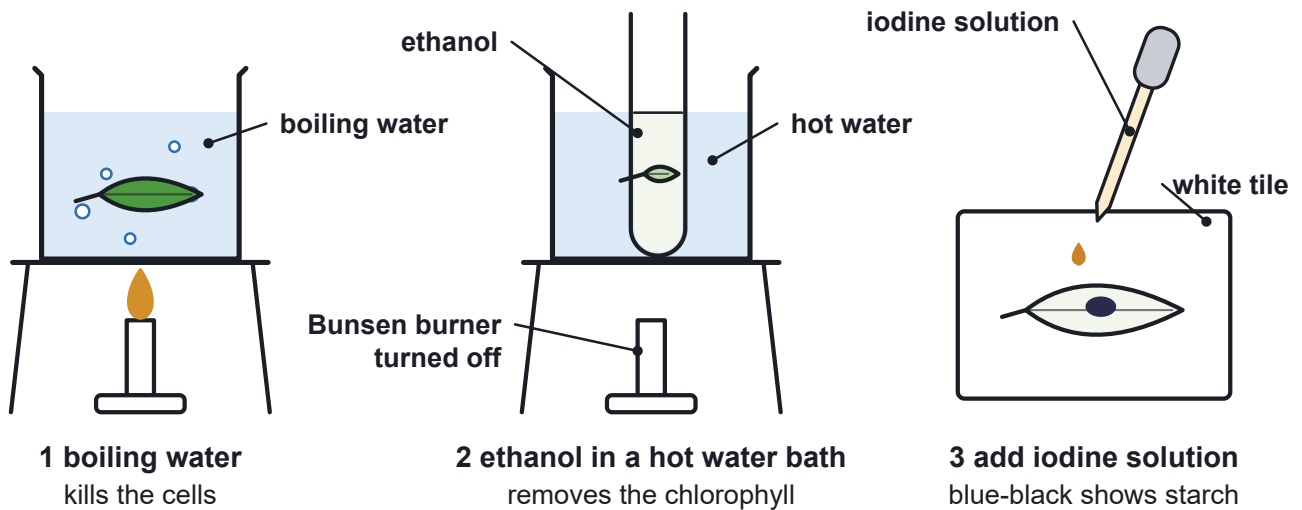
1. Drop the leaf into boiling water for about 30 seconds. This kills the cells and softens the leaf.
2. Turn off the Bunsen burner. Put the leaf in a boiling tube of ethanol and stand the tube in a beaker of hot water for several minutes. The ethanol removes the chlorophyll, so the leaf turns pale.
3. Dip the leaf back into the hot water to soften it, then spread it out on a white tile.
4. Add a few drops of iodine solution. Starch turns the iodine from **orange-brown to blue-black**.

Investigating each requirement

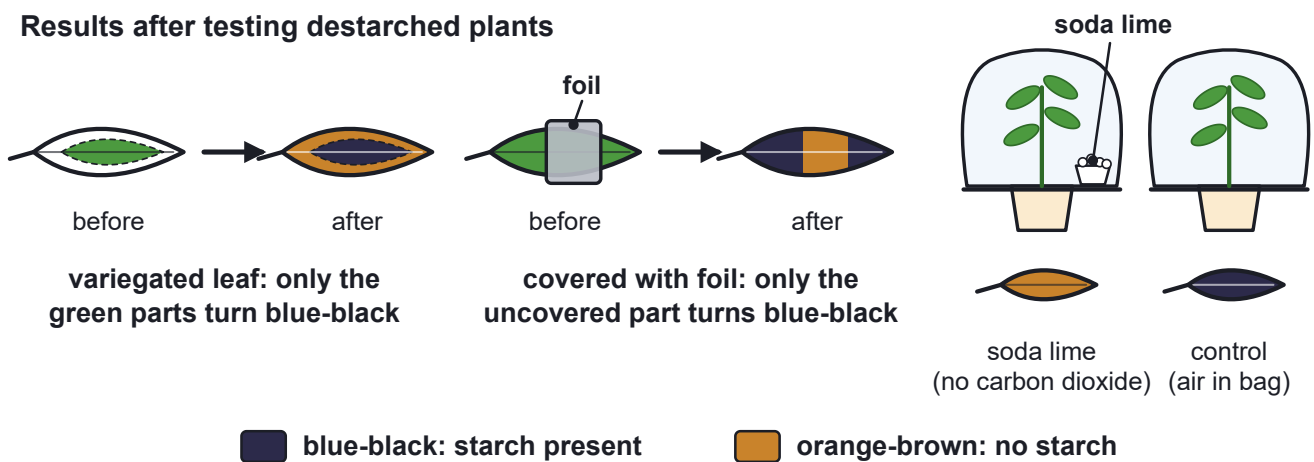
Investigating what photosynthesis needs			
To investigate	Method	Control	Result
Chlorophyll	Use a variegated leaf (green and white patches). Destarch, expose to light, then test for starch.	The green parts of the same leaf	Only the green parts, which contain chlorophyll, turn blue-black. The white parts stay orange-brown.
Light	Cover part of a destarched leaf with foil or black paper, leave the plant in the light, then test for starch.	The uncovered part of the same leaf	The uncovered part turns blue-black. The covered part stays orange-brown.
Carbon dioxide	Put a destarched plant in a sealed bag or bell jar with soda lime (or potassium hydroxide), which absorbs carbon dioxide, and leave in the light. Test a leaf for starch.	An identical plant sealed in a bag with no soda lime	The leaf without carbon dioxide stays orange-brown. The control leaf turns blue-black.

Practical skill: Use a control so that only one factor changes. In the variegated leaf and foil investigations the control is part of the same leaf, so everything else is identical. Ethanol is flammable: switch off the Bunsen burner before heating it, use a hot water bath, and wear eye protection.

Exam tip: If a question asks why the leaf was heated in ethanol, the answer is to remove (decolourise) the chlorophyll so the colour change with iodine can be seen.



Results after testing destarched plants



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The starch test, and the results that show photosynthesis needs **chlorophyll**, **light** and **carbon dioxide**.

Rate of photosynthesis and limiting factors

Spec B6.1.7

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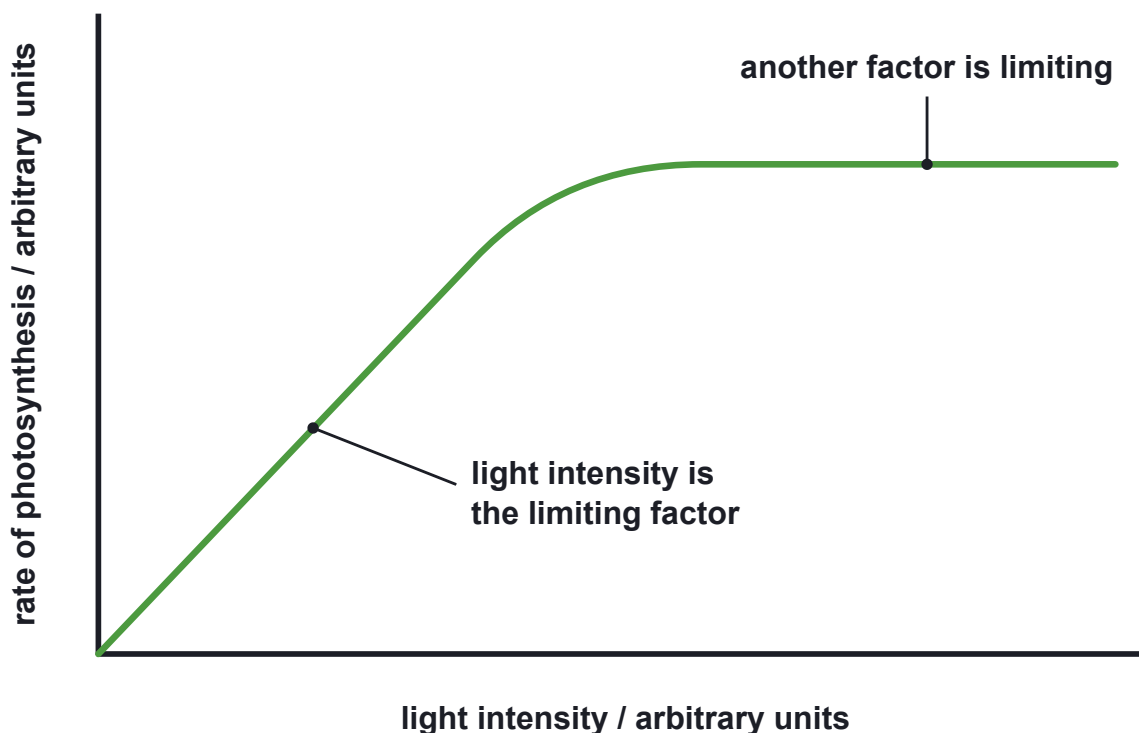
A **limiting factor** is the factor that is in shortest supply, so it stops the rate of photosynthesis from increasing. Increasing a limiting factor increases the rate. Increasing a factor that is not limiting makes no difference.

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How each factor limits photosynthesis

Factor	Why it limits the rate	Shape of the graph
Light intensity	Light provides the energy for photosynthesis. In dim light there is too little energy.	Rate rises as light intensity rises, then levels off
Carbon dioxide concentration	Carbon dioxide is a raw material. At low concentration there is too little to use.	Rate rises as concentration rises, then levels off
Temperature	Photosynthesis is controlled by enzymes. A higher temperature gives faster molecular movement and more collisions, but above the optimum the enzymes are denatured.	Rate rises to an optimum, then falls sharply

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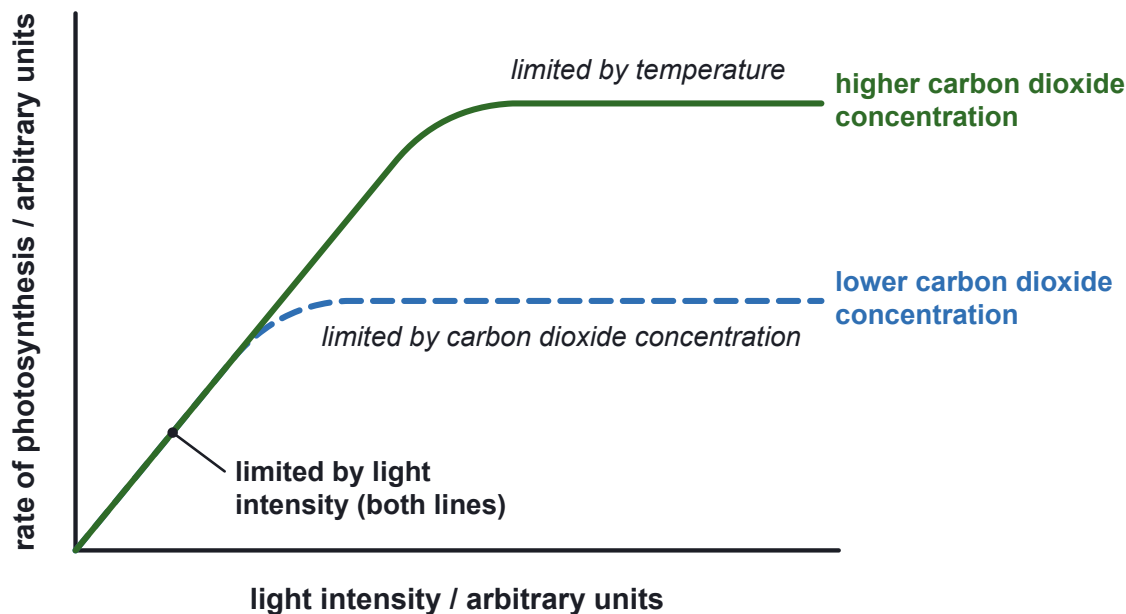
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Where the line rises, **light intensity** is the **limiting factor**; on the plateau another factor is limiting.

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Where the line is still rising, the factor on the x-axis is **limiting**. Where the line is flat, a different factor is limiting. With two lines, the **factor in shortest supply** sets the height of the plateau.

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Two lines: the **factor in shortest supply** sets the height of each plateau.

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Limiting factors in different environments

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Which factor is likely to be limiting?

Environment	Likely limiting factor	Explanation
Bright summer midday	Carbon dioxide concentration or temperature	Light is plentiful. Carbon dioxide is only a small fraction of the air, and enzymes may be too hot or too cool.
Dull winter morning	Light intensity and temperature	Little light energy is available and low temperature slows enzyme activity.
At night	Light intensity	No light energy, so photosynthesis cannot happen.
Floor of a dense woodland	Light intensity	Leaves above absorb most of the light.
Cold bright day	Temperature	Light and carbon dioxide are available, but enzymes work slowly in the cold.

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Exam tip: To identify the limiting factor, ask which factor would raise the rate if it were increased. In an explanation, name the factor, say it is in short supply, and link it to the process (light is the energy source, carbon dioxide is a raw material, temperature affects the enzymes).

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Common mistake: Do not say enzymes are 'killed' by high temperature. They are denatured.

Investigating light, carbon dioxide and temperature

Spec B6.1.7

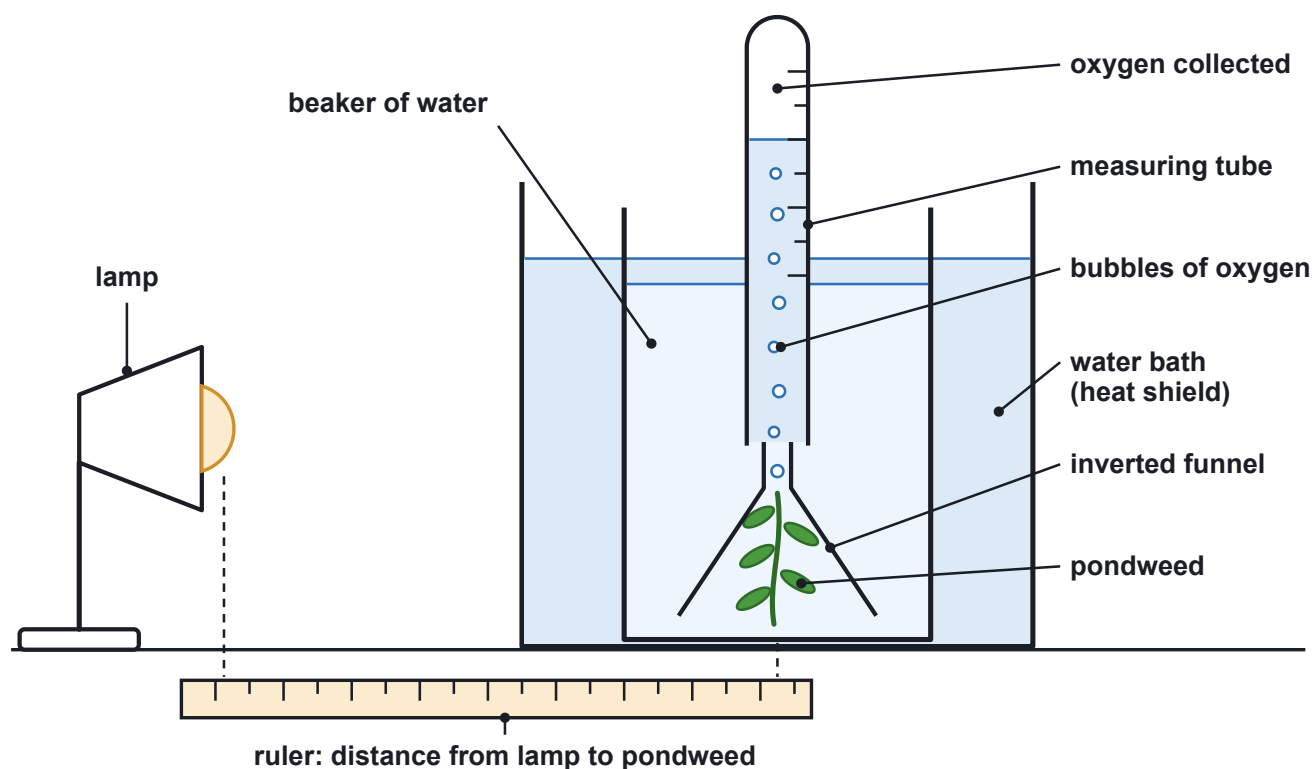
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Photosynthesis can be investigated by measuring the rate at which an aquatic plant such as *Elodea* (pondweed) releases oxygen. Bubbles of oxygen come from the cut end of the stem. Count the bubbles in a set time, or collect the gas and measure its volume.

Changing one factor at a time

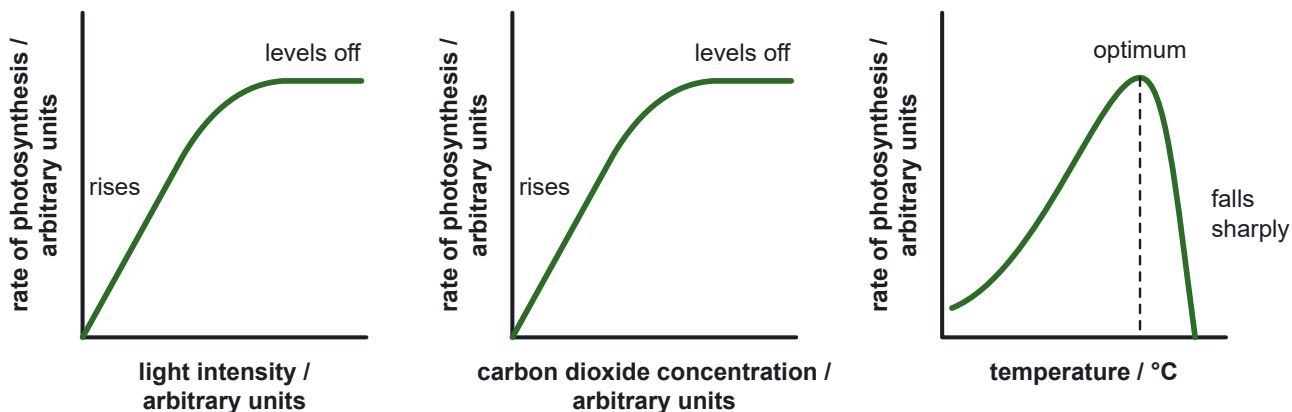
Independent variable	How to change it	Keep constant
Light intensity	Move a lamp to different distances from the plant, measured with a ruler (a closer lamp gives a higher light intensity)	Temperature, carbon dioxide concentration, the same plant
Carbon dioxide concentration	Add different amounts of sodium hydrogencarbonate to the water (it releases carbon dioxide)	Light intensity, temperature, the same plant
Temperature	Stand the beaker in a water bath at different temperatures and check with a thermometer	Light intensity, carbon dioxide concentration, the same plant

The dependent variable is the number of bubbles (or the volume of oxygen) produced per minute. Allow the plant to adjust for a few minutes after each change. Repeat each condition at least three times and calculate a mean.



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Investigating light intensity: change the **distance** of the lamp and measure the **oxygen** produced.



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Typical results: light intensity and carbon dioxide concentration give a rise then **level off**; temperature gives an **optimum** then a sharp fall.

Typical results: as light intensity or carbon dioxide concentration increases, the rate increases and then **levels off**. As temperature increases, the rate rises to an optimum and then **falls** as enzymes are denatured.

Calculating a rate

A piece of pondweed releases 24 cm³ of oxygen in 6 minutes. Calculate the rate of photosynthesis in cm³ per minute.

1. rate = volume of oxygen ÷ time
2. rate = 24 ÷ 6

Answer: 4 cm³ per minute

Practical skill: A lamp heats the water, so control the temperature by placing a beaker of water between the lamp and the plant, or use a cool LED lamp. When describing results, state the trend and quote figures from the table or graph.

Common mistake: Counting bubbles is not very accurate because bubbles differ in size. Collecting and measuring the volume of gas is more accurate.

Gas exchange in light and dark: hydrogencarbonate indicator Spec B6.1.8 Supplement

Hydrogencarbonate indicator solution changes colour with the concentration of carbon dioxide in the solution. It is used to show whether an aquatic plant is taking in or giving out carbon dioxide.

Colours of hydrogencarbonate indicator	
Colour	Carbon dioxide concentration
Yellow	High (more than in air)
Red	Same as in the air (atmospheric level)
Purple	Low (less than in air)

Method

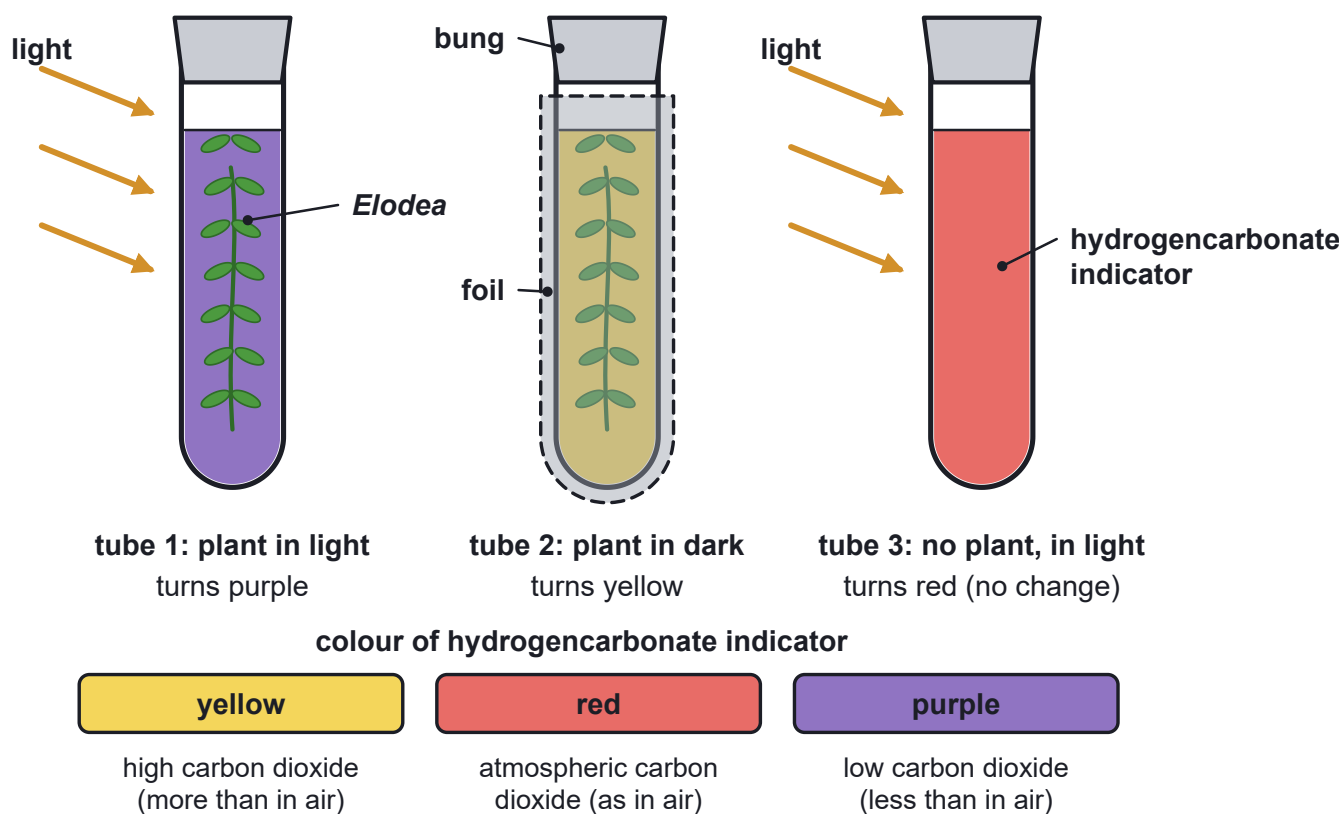
1. Set up three boiling tubes, each with the same volume of hydrogencarbonate indicator solution. The indicator starts red.
2. Put a similar piece of aquatic plant (for example *Elodea*) in tube 1 and place it in bright light.
3. Put an identical piece of plant in tube 2 and wrap the tube in foil so that it is in the dark.

4. Leave tube 3 with no plant in the light as a control.
5. Seal the tubes with bungs and leave for a few hours, then record the colour of each.

Typical results		
Tube	Final colour	Explanation
1: plant in light	Purple	Photosynthesis uses carbon dioxide faster than respiration releases it, so the carbon dioxide concentration falls
2: plant in dark	Yellow	There is no photosynthesis. The plant respire and releases carbon dioxide, so the concentration rises
3: no plant (control)	Red (no change)	Shows that the colour change in the other tubes is due to the plant

Plants **respire all the time**, in the light and in the dark. In the light, photosynthesis is faster than respiration, so there is a **net uptake of carbon dioxide**. If light is dim, the two rates may be equal and the indicator stays red.

Practical skill: The control tube with no plant is essential, because it shows the indicator does not change colour on its own. Keep the volume of indicator, the size of the plant and the time the same in every tube.



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Hydrogencarbonate indicator: **purple** in the light (net uptake of carbon dioxide), **yellow** in the dark (respiration only).

Quick check

1. Give the word equation for photosynthesis.
2. What colour does iodine solution turn in the presence of starch?
3. **Supplement** Write the balanced chemical equation for photosynthesis.

Quick check answers

Photosynthesis

1. Carbon dioxide + water $\rightarrow$ glucose + oxygen, in the presence of light and chlorophyll.
2. Blue-black.
3. $6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$