

# Light and net gas exchange in a leaf

investigate the effect of light on net gas exchange from a leaf, using hydrogen-carbonate indicator

For Pearson Edexcel International GCSE Biology 4BI1 and Science (Double Award) 4SD0. **Biology only** This practical is not in the Double Award and is only examined on Paper 2. Teacher answers start on a new page.

Name .....

Date .....

## Aim

To investigate how light intensity affects the net exchange of carbon dioxide by a leaf, using hydrogen-carbonate indicator.

## Background

A leaf carries out **photosynthesis** and **respiration** at the same time. Photosynthesis takes in carbon dioxide and needs light. Respiration releases carbon dioxide and goes on all the time, day and night.

**Net gas exchange** is the overall result. In bright light, photosynthesis is faster than respiration, so there is a net uptake of carbon dioxide. In darkness only respiration happens, so there is a net release of carbon dioxide. At one light intensity the two rates are equal and there is no net change.

**Hydrogen-carbonate indicator** shows the carbon dioxide concentration of the air around it. It is red/orange in normal air, turns yellow when carbon dioxide rises and turns purple when carbon dioxide falls.

## Hypothesis

A leaf in bright light will take in carbon dioxide overall (indicator turns purple), and a leaf in darkness will release carbon dioxide overall (indicator turns yellow), because photosynthesis needs light but respiration does not.

## Variables

|                    |                                                                                                                                                                                                                                                                                                                                                                             |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Independent</b> | Light intensity (bright, dim, dark)                                                                                                                                                                                                                                                                                                                                         |
| <b>Dependent</b>   | The colour of the hydrogen-carbonate indicator (which shows the carbon dioxide concentration)                                                                                                                                                                                                                                                                               |
| <b>Control</b>     | <ul style="list-style-type: none"><li>• Size and mass of the leaf</li><li>• Type of leaf (from the same plant)</li><li>• Volume of indicator, 10 cm<sup>3</sup></li><li>• Time the tubes are left, for example 2 hours</li><li>• Temperature (use a water tank between the lamp and the tubes)</li><li>• Distance of each tube from the lamp, where light is used</li></ul> |

## Equipment

- 4 boiling tubes with bungs
- Hydrogen-carbonate indicator (red/orange, equilibrated with air)
- 3 similar leaves of equal size, such as privet or geranium, with a small piece of gauze or a wire holder to hold each leaf above the indicator
- Forceps
- Measuring cylinder, 10 cm<sup>3</sup>

- Aluminium foil
- Gauze or netting, one layer
- Lamp (bright light source) with a clamp stand
- Heat shield: a rectangular tank or beaker of water
- Boiling tube rack, ruler and marker pen
- Stopclock
- Eye protection

## Risk assessment

| Hazard                       | Risk                                                                                  | Precaution                                                                                                              |
|------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------|
| Mains-powered lamp           | The bulb gets hot and can burn skin; electrical fault if water spills on to the lamp. | Do not touch the lamp. Keep water away from electrical equipment and place the water tank on a mat, not near the plugs. |
| Hydrogen-carbonate indicator | Low hazard but may irritate the eyes.                                                 | Wear eye protection and wash splashes off immediately.                                                                  |
| Glass boiling tubes          | Cuts if broken.                                                                       | Stand tubes in a rack, and put bungs in gently. Report any breakages.                                                   |
| Cutting leaves               | Plant sap may irritate sensitive skin. Some plants are toxic.                         | Use only plants chosen by your teacher and wash your hands after handling leaves. Do not taste any plant material.      |

## Method

1. Put on eye protection. Label four boiling tubes 1 to 4: bright light, dim light, dark, and control.
2. Use a measuring cylinder to add 10 cm<sup>3</sup> of hydrogen-carbonate indicator to each tube. Check the indicator is red/orange in each tube.
3. Use forceps to put a similar leaf (same size) on the gauze or wire in tubes 1, 2 and 3 so the leaf is above the indicator and does not touch the liquid. Leave tube 4 with no leaf.
4. Put a bung in each tube straight away so that the tubes are airtight. Do not breathe into the tubes.
5. Wrap tube 3 completely in aluminium foil so that no light reaches the leaf.
6. Wrap tube 2 in one layer of gauze or netting to give dim light.
7. Leave tubes 1 and 4 uncovered.
8. Stand all the tubes in a rack the same distance from the lamp, with the water tank between the lamp and the tubes. Make sure the tubes are at room temperature.
9. Switch on the lamp and start the stopclock.
10. Leave the tubes for 2 hours.
11. After 2 hours, unwrap tubes 2 and 3 and immediately record the colour of the indicator in each tube.
12. Switch off the lamp and clear away the apparatus. Wash your hands.

Results

| Colour of the indicator after 2 hours |                   |                     |                      |                                                           |
|---------------------------------------|-------------------|---------------------|----------------------|-----------------------------------------------------------|
| Tube                                  | Light condition   | Colour at the start | Colour after 2 hours | Net change in carbon dioxide (increase / decrease / none) |
| 1                                     | Bright light      |                     |                      |                                                           |
| 2                                     | Dim light         |                     |                      |                                                           |
| 3                                     | Dark (foil)       |                     |                      |                                                           |
| 4                                     | No leaf (control) |                     |                      |                                                           |

Exam questions 10 questions · 28 marks

1 State the colour of hydrogen-carbonate indicator in a tube containing air with normal carbon dioxide, and the colour when the carbon dioxide concentration increases. [2 marks]

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2 Tube 4 contained indicator but no leaf. Explain why this tube was included. [2 marks]

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3 The indicator in the tube in bright light turned purple. Explain this result. [3 marks]

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4 The indicator in the tube covered in foil turned yellow. Explain this result. [3 marks]

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- 5** The indicator in the tube with dim light stayed red/orange. Explain what this tells you about photosynthesis and respiration in the leaf. **[2 marks]**

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- 6** Give two variables that must be kept the same in the four tubes. **[2 marks]**

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- 7** Explain why a water tank was placed between the lamp and the tubes. [2 marks]

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- 8** A student repeats the experiment with a tube in light, but with a pale (white) part of a variegated leaf, which has no chlorophyll. Predict the colour of the indicator after 2 hours and explain your prediction. **[3 marks]**

[illegible]

- 9** Describe how you could use hydrogen-carbonate indicator to investigate the effect of light intensity on the net gas exchange of a leaf. Explain the results you would expect. **[6 marks]**

[illegible]

**10** Suggest how the investigation could be improved to give quantitative results for the effect of light intensity on net gas exchange, instead of only describing the colours. **[3 marks]**

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# Teacher answers

Practical 8: Light and net gas exchange in a leaf. The example results are practice data, not real measurements.

## Example results

| Example results (practice data), after 2 hours |                   |                     |                      |                                                           |
|------------------------------------------------|-------------------|---------------------|----------------------|-----------------------------------------------------------|
| Tube                                           | Light condition   | Colour at the start | Colour after 2 hours | Net change in carbon dioxide (increase / decrease / none) |
| 1                                              | Bright light      | Red/orange          | Purple               | Decrease                                                  |
| 2                                              | Dim light         | Red/orange          | Red/orange           | None                                                      |
| 3                                              | Dark (foil)       | Red/orange          | Yellow               | Increase                                                  |
| 4                                              | No leaf (control) | Red/orange          | Red/orange           | None                                                      |

## Conclusion

In bright light the indicator turned purple, so the carbon dioxide concentration fell: photosynthesis in the leaf was faster than respiration, so there was a net uptake of carbon dioxide. In the dark the indicator turned yellow, so the carbon dioxide concentration rose: photosynthesis could not happen without light, but respiration continued and released carbon dioxide. In dim light the indicator stayed red/orange, because the rate of photosynthesis was about equal to the rate of respiration, so there was no net change. The tube with no leaf did not change colour, which shows the colour changes were caused by the leaves and not by the light, the heat or the air in the tube. In dim light the colour could be slightly yellow or purple depending on the light level.

## Errors and improvements

| Error                                                                             | Effect on the results                                                                                           | Improvement                                                                                                       |
|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| Heat from the lamp warms the tubes.                                               | Temperature changes the rates of photosynthesis and respiration, so the colour change is not due to light only. | Put a water tank (heat shield) between the lamp and the tubes, and use a cool light source such as an LED lamp.   |
| Breathing into the tubes, or leaving them open, adds carbon dioxide from the air. | The indicator turns yellow when it should not.                                                                  | Put the bungs in quickly and keep breath away from the tubes.                                                     |
| Leaves of different size or age are used.                                         | The rates of photosynthesis and respiration differ, so the tubes cannot be compared fairly.                     | Use leaves of similar size and mass from the same plant.                                                          |
| Judging the indicator colour by eye, especially in dim light.                     | Small colour changes are subjective, so different people may record different colours.                          | Compare each tube with a set of standard colour tubes or a colour chart; use a colorimeter to measure absorbance. |
| Only one leaf is tested in each condition.                                        | An unusual leaf could give a misleading result.                                                                 | Repeat with several leaves in each condition and give the most common colour.                                     |

## Mark scheme

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

**1. [2]**

- red / orange (1)
- yellow (1)

**2. [2]**

- it is a control (1)
- to show that the colour change in the other tubes is caused by the leaf / not by light, heat or the air (1)

**3. [3]**

- purple means carbon dioxide concentration decreased (1)
- photosynthesis took in carbon dioxide (1)
- rate of photosynthesis was greater than the rate of respiration / there was a net uptake of carbon dioxide (1)

**4. [3]**

- no light reached the leaf so no photosynthesis (1)
- respiration continued and released carbon dioxide (1)
- so carbon dioxide concentration increased (1)

**5. [2]**

- the rate of photosynthesis was equal to the rate of respiration (1)
- so there was no net change in carbon dioxide concentration (1)

**6. [2]**

- size / mass of leaf (1)
- volume of indicator (1)
- time left (1)
- temperature / distance from lamp (1)
- Max 2

**7. [2]**

- to absorb heat from the lamp / keep the temperature constant (1)
- because temperature affects the rates of photosynthesis and respiration (1)

**8. [3]**

- yellow (1)
- the white part cannot photosynthesise because it has no chlorophyll (1)
- it still respire, releasing carbon dioxide, so the carbon dioxide concentration increases (1)

## 9. [6]

|                        |                                                                                                                                                                                                         |
|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Level 3<br/>5-6</b> | A full method that includes the tubes at different light intensities, a control tube, the colour changes and an explanation in terms of photosynthesis and respiration. Control variables are included. |
| <b>Level 2<br/>3-4</b> | A mostly complete method with some expected results explained; one of the control tube, control variables or explanations is missing.                                                                   |
| <b>Level 1<br/>1-2</b> | A few relevant points, such as leaves in tubes with indicator in light and dark, with little explanation.                                                                                               |

### Indicative content

- same volume of indicator in sealed tubes, leaf held above indicator on gauze
- different light: bright light, dim light (gauze), dark (foil); control tube with no leaf
- same leaf size, time, temperature (heat shield), distance
- bright light: purple; photosynthesis faster than respiration, net uptake of carbon dioxide
- dim light: stays red/orange; rates equal so no net change
- dark: yellow; only respiration, net release of carbon dioxide
- control stays red/orange

## 10. [3]

- use a range of distances from the lamp / more light intensities (1)
- measure the time taken for the indicator to reach a particular colour / use a colorimeter or colour chart (1)
- repeat and calculate a mean (1) allow use of a light meter to measure the light intensity

### Exam tips

- Learn the three colours: yellow = more carbon dioxide, red/orange = no change, purple = less carbon dioxide.
- Always talk about the rates of photosynthesis and respiration, not just 'the leaf makes carbon dioxide'. Net gas exchange is the balance between the two.
- Respiration happens in the light and the dark. It is a common mistake to say that plants only respire at night.
- Explain the no-leaf control: it shows that the leaf, not the light or the air, caused the colour change.
- Do not breathe on the tubes. In errors questions, mention carbon dioxide from the air or breath.