

# Carbon dioxide and heat from respiring seeds

investigate the evolution of carbon dioxide and heat from respiring seeds or other suitable living organisms

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 germinating seeds release heat and carbon dioxide, using boiled (dead) seeds as a control.

## Background

All living cells respire. Aerobic respiration releases energy from glucose using oxygen, and produces carbon dioxide and water. Some of the energy released is transferred as **heat**, so a respiring organism warms up if the heat cannot escape.

Germinating seeds respire quickly because they are growing, so they make a good choice for detecting heat and carbon dioxide.

A **control** of boiled seeds is needed. Boiling kills the seeds, so they cannot respire. Any change that happens only with the living seeds must be caused by respiration. Both sets of seeds are rinsed in disinfectant so that microorganisms on the seeds do not respire and affect the results.

**Hydrogen-carbonate indicator** is red/orange in air with the normal amount of carbon dioxide. It turns yellow when carbon dioxide rises. Limewater turns cloudy (milky) when carbon dioxide is present.

## Hypothesis

Germinating seeds will release heat and carbon dioxide because they respire, but boiled seeds will not because they are dead.

## Variables

|                    |                                                                                                                                                                                                                                                                                                               |
|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Independent</b> | Whether the seeds are living (germinating) or dead (boiled)                                                                                                                                                                                                                                                   |
| <b>Dependent</b>   | The temperature in the flask (°C) and the colour of the hydrogen-carbonate indicator                                                                                                                                                                                                                          |
| <b>Control</b>     | <ul style="list-style-type: none"> <li>• Mass of seeds in each flask</li> <li>• Starting temperature of the seeds</li> <li>• Type of seed</li> <li>• Size of flask and the thermometer used</li> <li>• Volume of indicator and the volume of air drawn through it</li> <li>• Time between readings</li> </ul> |

## Equipment

- Pea seeds soaked in water for 24 hours (about 100 g), so they have started to germinate
- Pea seeds boiled for 5 minutes and cooled (about 100 g)
- 2 vacuum flasks
- 2 thermometers, -10 to 110 °C
- Cotton wool

- Weak disinfectant solution: dilute sodium hypochlorite (about 1%), such as diluted Milton sterilising fluid
- 2 beakers and a sieve or tea strainer
- Top-pan balance
- Syringe or small pump, tubing and clips
- 4 boiling tubes with bungs and delivery tubes: two to hold 10 g of seeds each on gauze, and two to hold 10 cm<sup>3</sup> of hydrogen-carbonate indicator (or limewater) each
- Stopclock or timer
- Eye protection and gloves

## Risk assessment

| Hazard                               | Risk                                                               | Precaution                                                                                                                                 |
|--------------------------------------|--------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| Disinfectant solution                | Irritates the skin and eyes.                                       | Wear eye protection and gloves. Wash splashes off immediately with water. Rinse the seeds well after the disinfectant.                     |
| Limewater (if used)                  | Irritant to the eyes and skin.                                     | Wear eye protection and wash hands after use. Hydrogen-carbonate indicator is low hazard.                                                  |
| Hot boiled seeds and water           | Scalds and burns.                                                  | Allow the boiled seeds to cool to room temperature before use. Do not pick up hot beakers.                                                 |
| Micro-organisms on germinating seeds | Moulds and bacteria can grow on seeds that are kept warm and damp. | Rinse in disinfectant, wash your hands after handling the seeds, do not eat the seeds and dispose of them as directed after the practical. |
| Glass thermometers and vacuum flasks | Cuts from broken glass.                                            | Handle with care, never force the thermometer through the cotton wool, and report breakages.                                               |

## Method

1. Soak the peas in water for 24 hours so that they begin to germinate. Boil a second batch of peas for 5 minutes to kill them, then cool to room temperature.
2. Put on eye protection. Rinse both batches of peas in the weak disinfectant (dilute sodium hypochlorite) for a few minutes, then rinse with clean water and drain them.
3. Weigh the same mass of each batch (for example 50 g) on the balance.
4. Put the germinating peas into the first vacuum flask and the boiled peas into the second. Label the flasks.
5. Put a thermometer in each flask, with the bulb in the middle of the peas, and plug the neck of each flask with cotton wool.
6. Record the starting temperature of each flask. Both should start at the same temperature.
7. Leave the flasks in the same place at room temperature, out of direct sunlight.
8. Record the temperature of each flask at the same time each day for four days.
9. For the carbon dioxide test, put 10 g of germinating peas on gauze in one boiling tube and 10 g of boiled peas on gauze in another. Add 10 cm<sup>3</sup> of hydrogen-carbonate indicator to each of two further tubes, and join each seed tube to an indicator tube with tubing so that air drawn through the seeds then bubbles through the indicator.

- L0 . Check the joints are airtight, then use a syringe or pump to draw air slowly through each set of apparatus for the same time (for example 5 minutes) and at the same speed.
- L1 . Record the colour of the indicator in each tube at the start and after the 5 minutes. Repeat the air flow if there is no change, and record the colour again.
- L2 . Wash your hands, then clear away, disposing of the seeds as directed by your teacher.
- L3 . Plot a graph of temperature against time for both flasks.

## Results

| Temperature in the flasks |                                      |                                 |                             |
|---------------------------|--------------------------------------|---------------------------------|-----------------------------|
| Time (days)               | Temperature of germinating peas (°C) | Temperature of boiled peas (°C) | Temperature difference (°C) |
| 0                         |                                      |                                 |                             |
| 1                         |                                      |                                 |                             |
| 2                         |                                      |                                 |                             |
| 3                         |                                      |                                 |                             |
| 4                         |                                      |                                 |                             |

## Graph

Line graph with two lines on the same axes: time (days) on the x-axis (0 to 4) and temperature (°C) on the y-axis. Plot the germinating peas and the boiled peas with different symbols or colours, joined with straight lines or smooth curves through the points (no line of best fit is needed because the line shows a trend over time). Label each line.



**Exam questions** 10 questions · 28 marks

**1** Explain why one flask contained boiled seeds. [2 marks]

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**2** The seeds were rinsed in disinfectant before the experiment. Explain why. [2 marks]

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**3** Explain why vacuum flasks were used in the experiment. [2 marks]

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**4** The table shows the temperature of the flask of germinating peas. Calculate the mean increase in temperature per day between day 0 and day 4. [3 marks]

| Temperature of germinating peas |                  |
|---------------------------------|------------------|
| Time (days)                     | Temperature (°C) |
| 0                               | 20               |
| 1                               | 21               |
| 2                               | 24               |
| 3                               | 27               |
| 4                               | 29               |

Answer = .....

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**5** Use the data in question 4 to describe how the temperature of the germinating peas changed, and explain the change. **[3 marks]**

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**6** The temperature of the flask of boiled peas stayed at 20 °C throughout. State what this shows. **[2 marks]**

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**7** A student draws air through hydrogen-carbonate indicator after it has passed over germinating seeds. State the colour change of the indicator and explain it. **[3 marks]**

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**8** The student repeats the carbon dioxide test with germinating seeds that were kept in the dark. Predict the result and justify your answer. **[3 marks]**

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**9** Describe an investigation to show that respiring seeds release both heat and carbon dioxide. Include how you would make sure that the results are valid. **[6 marks]**

[illegible]

**10** Name one other organism, apart from seeds, that could be used to show that respiring organisms release carbon dioxide, and describe a suitable control. **[2 marks]**

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## Teacher answers

Practical 7: Carbon dioxide and heat from respiring seeds. The example results are practice data, not real measurements.

### Example results

| Example results (practice data): temperature of the flasks |                                      |                                 |                             |
|------------------------------------------------------------|--------------------------------------|---------------------------------|-----------------------------|
| Time (days)                                                | Temperature of germinating peas (°C) | Temperature of boiled peas (°C) | Temperature difference (°C) |
| 0                                                          | 20                                   | 20                              | 0                           |
| 1                                                          | 21                                   | 20                              | 1                           |
| 2                                                          | 24                                   | 20                              | 4                           |
| 3                                                          | 27                                   | 20                              | 7                           |
| 4                                                          | 29                                   | 20                              | 9                           |

### Conclusion

The temperature of the flask with germinating peas rose from 20 °C to 29 °C over four days, while the flask of boiled peas stayed at 20 °C. This shows that living seeds release heat, because respiration is exothermic and the vacuum flask reduces heat loss. In the carbon dioxide test, the indicator connected to the germinating peas changed from red/orange to yellow, while the indicator connected to the boiled peas stayed red/orange. This shows that the living seeds release carbon dioxide in respiration. The boiled peas are the control: they show that the changes are caused by respiration in living seeds and not by the apparatus or by micro-organisms.

### Errors and improvements

| Error                                                                                    | Effect on the results                                                                                                         | Improvement                                                                                                                      |
|------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|
| Micro-organisms on the seeds also respire.                                               | Heat and carbon dioxide may be released by bacteria and fungi, not only by the seeds, and the boiled seeds could also change. | Rinse all the seeds in disinfectant before starting, and use clean, sterilised apparatus.                                        |
| Heat is lost from the flasks to the surroundings.                                        | The temperature rise is smaller than the real heat released.                                                                  | Use vacuum flasks, plug the necks with cotton wool, and keep both flasks in the same place away from draughts and sunlight.      |
| The flasks started at different temperatures, or the seeds were not at room temperature. | The temperature difference is not a fair comparison.                                                                          | Cool the boiled seeds fully and check both thermometers read the same before starting.                                           |
| The two sets of apparatus received different volumes of air or different times.          | The indicator colour may change differently for reasons other than the seeds.                                                 | Use the same volume of air (counted syringe strokes), at the same speed and for the same time, and the same volume of indicator. |
| The indicator colour is judged by eye.                                                   | Different observers may disagree, especially for small colour changes.                                                        | Compare against a colour chart or standard tubes, or time how long each takes to change colour.                                  |

### Mark scheme

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

**1. [2]**

- boiling kills the seeds so they cannot respire / the boiled seeds are the control (1)
- to show that any heat / change in the other flask is caused by respiration in the living seeds (1)

**2. [2]**

- to kill micro-organisms / bacteria / fungi (1)
- because they would also respire and release heat / carbon dioxide, which could affect the result (1)

**3. [2]**

- vacuum flasks reduce heat loss (to the surroundings) (1)
- so the temperature rise is large enough to be measured (1)

**4. [3]**

- total increase =  $29 - 20 = 9\text{ }^{\circ}\text{C}$  (1)
- $9 \div 4$  (1)
- $2.25\text{ }^{\circ}\text{C}$  per day (1) allow 2.3; unit required

**5. [3]**

- temperature increased from  $20\text{ }^{\circ}\text{C}$  to  $29\text{ }^{\circ}\text{C}$  / by  $9\text{ }^{\circ}\text{C}$  (1)
- increase was fastest between day 1 and day 3 ( $3\text{ }^{\circ}\text{C}$  per day) / slower at the start and the end (1)
- because respiration in the seeds releases heat (1)

**6. [2]**

- the boiled peas do not respire / release no heat (1)
- so the rise in the other flask is due to the living seeds / respiration, not the surroundings (1)

**7. [3]**

- red / orange to yellow (1)
- carbon dioxide has been released by the seeds / carbon dioxide concentration has increased (1)
- carbon dioxide is a product of respiration (1)

**8. [3]**

- indicator turns yellow / same result as before (1)
- seeds respire in the dark and in the light (1)
- respiration does not need light (1) allow: germinating seeds do not photosynthesise because they have no leaves

## 9. [6]

|                        |                                                                                                                                                                                            |
|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Level 3<br/>5-6</b> | A full method that tests for both heat and carbon dioxide, with a control, the measurements and the expected results. Several control variables or precautions are included and explained. |
| <b>Level 2<br/>3-4</b> | A method for heat and/or carbon dioxide with a control and some detail, but missing some measurements, controls or expected results.                                                       |
| <b>Level 1<br/>1-2</b> | A few relevant ideas, for example seeds in a flask with a thermometer, with no control or little detail.                                                                                   |

### Indicative content

- germinating seeds in one vacuum flask and boiled (dead) seeds in another as the control
- same mass of seeds and the same starting temperature; rinse both in disinfectant
- thermometer in each flask, cotton wool in the neck; record temperature at regular intervals
- expect a rise in temperature with the living seeds only because respiration releases heat
- for carbon dioxide, draw air from the seeds through hydrogen-carbonate indicator (or limewater) for the same time and volume
- indicator turns yellow (limewater turns cloudy) with the living seeds only; carbon dioxide is released in respiration
- control variables: volume of indicator, time, volume of air, temperature; repeat for reliability

## 10. [2]

- any suitable living organism, such as maggots, woodlice, earthworms or yeast (1) ignore: any seeds
- a matching control, for example glass beads of the same volume / an empty tube for animals, or boiled yeast for yeast (1)

### Exam tips

- Always name the control and say what it shows: boiled (dead) seeds show that the change is caused by respiration in living seeds.
- Say 'hydrogen-carbonate indicator turns from red/orange to yellow' and 'limewater turns cloudy'. Do not just say it 'changes colour'.
- Heat is a product of respiration, so the temperature rises. The vacuum flask reduces heat loss; it does not make heat.
- Disinfectant kills micro-organisms that would also respire. This is a common mark.