

Rate of respiration

Investigate the rate of respiration in living organisms

For Edexcel GCSE Biology 1BI0 and Combined Science 1SC0. Teacher answers start on a new page.

Name

Date

Aim

To use a respirometer to measure the rate of respiration of germinating seeds at different temperatures, by measuring how far a drop of coloured liquid moves as oxygen is used up.

Background

Living organisms release energy by **respiration**. In aerobic respiration, glucose reacts with oxygen to produce carbon dioxide and water: $\text{glucose} + \text{oxygen} \rightarrow \text{carbon dioxide} + \text{water}$. Germinating seeds respire quickly because they are growing and need a lot of energy.

A **respirometer** measures how fast organisms use up oxygen. The carbon dioxide they produce is absorbed by **soda lime**, so the total volume of gas in the apparatus falls. This pulls a drop of coloured liquid in a capillary tube towards the organisms. The further it moves in a set time, the faster the rate of respiration.

Respiration is controlled by enzymes, so temperature affects its rate. A rise in temperature gives particles more energy, so enzymes and substrate collide more often and the rate increases. At high temperatures the enzymes denature and the rate falls.

The volume of oxygen used can be calculated from the distance moved by the liquid: $\text{volume} = \pi r^2 h$, where r is the radius of the capillary tube and h is the distance moved.

Hypothesis

As the temperature increases from 10 °C to 40 °C, the rate of respiration of the seeds will increase, because enzymes work faster at higher temperatures. At a much higher temperature the rate will fall, because the enzymes denature.

Variables

Independent	Temperature of the water bath (°C)
Dependent	Distance moved by the coloured liquid in 5 minutes (mm), used to find the rate of respiration (mm/min)
Control	• Mass and type of germinating seeds in the tube • Mass or volume of soda lime used • Volume of the boiling tube and the length of tubing, and the starting position of the liquid • Time over which the liquid moves (5 minutes) • Time the apparatus is left to settle at each temperature (5 minutes)

Equipment

- Germinating seeds (for example peas or mung beans soaked for 24 hours), about 10 g for each tube
- Respirometer tubes: boiling tube with a bung connected to a short length of capillary tube and a scale in mm
- Soda lime granules (corrosive)
- Cotton wool or gauze to separate the seeds from the soda lime
- Coloured liquid (for example food-colouring solution) to make a drop in the capillary tube
- Glass beads (for the control tube), the same volume as the seeds
- Water baths (or large beakers of water with a thermometer) at 10, 20, 30, 40 and 50 °C; ice to make the 10 °C bath
- Thermometer
- Stopwatch
- Syringe, to reset the position of the liquid
- Petroleum jelly, to seal the bung
- Eye protection and gloves

Risk assessment

Hazard	Risk	Precaution
Soda lime	Corrosive: can burn the skin and damage the eyes.	Wear eye protection and gloves. Do not touch the granules. Wash any splashes off immediately with plenty of water and tell your teacher.
Warm water	Water at 50 °C can scald if skin is in contact with it for some time; spills make the floor slippery.	Do not heat water above 50 °C. Stand beakers on a heatproof mat, do not carry full beakers and mop up spills.
Glass tubes and bungs	Cuts or injuries if glass tubing breaks while being pushed into a bung.	Do not force the capillary tube into the bung. Use pre-assembled apparatus and handle it carefully.
Germinating seeds	Microorganisms may grow on seeds; some people have allergies to seeds.	Wash hands after handling the seeds. Tell your teacher about any known seed allergies.

Method

1. Put on eye protection and gloves. Place a layer of soda lime about 1 cm deep in the bottom of a boiling tube.
2. Place a plug of cotton wool or gauze on top of the soda lime so that the seeds cannot touch it.
3. Add 10 g of germinating seeds on top of the cotton wool.
4. Put the bung with the capillary tube in the boiling tube. Seal the join with petroleum jelly so that no air can get in or out.
5. Set up a control tube in the same way, but use glass beads of the same volume instead of seeds.
6. Place both tubes in a water bath at 10 °C, with the capillary tubes pointing out of the water. Leave them for 5 minutes to reach the temperature of the water.
7. Use a syringe to put a drop of coloured liquid into the open end of each capillary tube so that it sits against the scale. Record the starting position of the liquid.
8. Start the stopwatch. After 5 minutes, read the new position of the liquid and calculate the distance it moved in mm.

9. Repeat steps 7 and 8 twice more at 10 °C, resetting the liquid each time, and record all three distances.
10. Repeat steps 6 to 9 with water baths at 20 °C, 30 °C, 40 °C and 50 °C, keeping the temperature of the water bath constant.
11. Calculate the mean distance moved at each temperature. Divide by 5 to find the rate in mm/min.
12. Plot a graph of rate of respiration (mm/min) against temperature (°C).

Results

Distance moved by the coloured liquid in 5 minutes at different temperatures					
Temperature (°C)	Distance moved: trial 1 (mm)	Distance moved: trial 2 (mm)	Distance moved: trial 3 (mm)	Mean distance moved (mm)	Rate of respiration (mm/min)
10					
20					
30					
40					
50					

Graph

Draw a scatter graph with temperature (°C) on the x-axis and rate of respiration (mm/min) on the y-axis. Plot the mean rate at each temperature and draw a smooth curve of best fit (not dot-to-dot). The curve should rise to a maximum and then fall.



Exam questions 9 questions · 25 marks

1 Soda lime was placed in the boiling tube. Explain why. **[2 marks]**

2 Explain why the coloured liquid moved towards the seeds. **[2 marks]**

3 A control tube containing glass beads was set up. Explain why. **[2 marks]**

4 At 30 °C the liquid moved a mean distance of 22 mm in 5 minutes. Calculate the rate of respiration in mm/min. **[2 marks]**

Answer =

5 The capillary tube has a radius of 0.5 mm. The liquid moved 30 mm. Calculate the volume of oxygen used. Use volume = $\pi r^2 h$ with $\pi = 3.14$. Give the unit. **[3 marks]**

Answer =

- 6** The table shows the rate of respiration of seeds at different temperatures. Describe and explain the results at 50 °C. **[3 marks]**

Temperature (°C)	Rate of respiration (mm/min)
10	1.0
20	2.4
30	4.4
40	6.0
50	2.0

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- 7** State three variables that must be controlled in this investigation. **[3 marks]**

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- 8** Suggest how the student could improve the reliability of the results. **[2 marks]**

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9 Describe how a respirometer can be used to investigate the effect of temperature on the rate of respiration in germinating seeds. **[6 marks]**

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Teacher answers

Core practical 7: Rate of respiration. The example results are practice data, not real measurements.

Example results

Example results (practice data)					
Temperature (°C)	Distance moved: trial 1 (mm)	Distance moved: trial 2 (mm)	Distance moved: trial 3 (mm)	Mean distance moved (mm)	Rate of respiration (mm/min)
10	4	6	5	5	1.0
20	11	13	12	12	2.4
30	22	20	24	22	4.4
40	28	32	30	30	6.0
50	9	11	10	10	2.0

Conclusion

The rate of respiration increased from 1.0 mm/min at 10 °C to 6.0 mm/min at 40 °C. As temperature rises, enzymes and substrates collide more often and with more energy, so respiration is faster and oxygen is used up more quickly, which moves the liquid further. At 50 °C the rate fell to 2.0 mm/min because the enzymes involved in respiration began to denature, so their active sites no longer fit their substrates. The liquid moved towards the seeds because they used up oxygen, and the carbon dioxide they produced was absorbed by the soda lime, so the gas volume fell.

Errors and improvements

Error	Effect on the results	Improvement
The apparatus is not completely airtight.	Air leaks in or out, so the liquid moves for the wrong reason and the distance moved is not a true measure of oxygen use (systematic error).	Seal the bung and connections with petroleum jelly and check that the liquid does not move in the control tube.
Gas expands and contracts as the temperature changes, or the room temperature changes.	The liquid moves even if no oxygen is used, giving false readings.	Use the control tube with glass beads, leave the apparatus for 5 minutes to reach the temperature, and keep the water bath temperature constant.
The mass or number of seeds is not exactly the same each time, and the seeds are different ages.	Differences in the distance moved could be caused by the seeds, not the temperature.	Use the same mass of seeds from the same batch and germinated for the same time.
The position of the drop is hard to read, especially if it moves quickly.	The distance moved is estimated inaccurately (random error).	Use a clear scale with fine divisions, read at eye level, and take readings at fixed time intervals.
The temperatures tested are 10 °C apart.	The temperature with the highest rate could be anywhere between 30 °C and 50 °C, so it cannot be identified accurately.	Test more temperatures in this range, for example every 2.5 °C or 5 °C between 30 °C and 50 °C.

Mark scheme

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

1. [2]

- it absorbs the carbon dioxide produced by the seeds (1)
- so any change in gas volume is due only to oxygen being used up (1)

2. [2]

- the seeds use up oxygen (in respiration) (1)
- the carbon dioxide released is absorbed, so the volume / pressure of gas in the tube decreases and the liquid moves towards the seeds (1)
- do not accept 'the seeds suck in the liquid'

3. [2]

- to show that the movement of the liquid is caused by the living seeds / respiration (1)
- and not by changes in temperature or air pressure / a leak in the apparatus (1)

4. [2]

- rate = distance ÷ time, or $22 \div 5$ (1)
- 4.4 mm/min (1)
- Correct answer with no working gains 2 marks

5. [3]

- volume = $3.14 \times 0.5^2 \times 30$ (1)
- 23.55 (1) allow 23.6 / 24
- mm³ (1)
- allow 0.024 cm³ (3 marks)

6. [3]

- the rate decreases (sharply) between 40 °C and 50 °C, from 6.0 to 2.0 mm/min (1)
- because the enzymes (involved in respiration) denature / the shape of the active site changes (1)
- so the substrate no longer fits the active site, and less respiration takes place / less oxygen is used (1)

7. [3]

- mass / number of seeds (1)
- type / age of seeds (1)
- volume / mass of soda lime (1)
- time the liquid is allowed to move / time left to settle (1)
- volume of the apparatus / size of capillary tube (1)
- Max 3

8. [2]

- repeat the measurement at each temperature (1)
- calculate a mean and identify / ignore anomalous results (1)

9. [6]

Level 3 5-6	A clear, logically ordered method that could be followed, explaining how the respirometer measures oxygen uptake, how temperature is varied and controlled, how the rate is calculated, with at least two control variables and a control tube.
Level 2 3-4	A mostly complete method, but with missing detail on control variables, measurement or how the respirometer works.
Level 1 1-2	Some correct steps, but the method is incomplete or unclear.

Indicative content

- seeds in a boiling tube, separated from soda lime by cotton wool or gauze
- sealed to a capillary tube containing a drop of coloured liquid
- place in a water bath at a set temperature and leave to settle for several minutes
- measure the distance the liquid moves in a set time (for example 5 minutes)
- oxygen is used up and CO₂ absorbed, so the liquid moves towards the seeds
- repeat at different temperatures (10 to 50 °C) and calculate the mean
- controls: same mass of seeds, same time, same volume of soda lime; control tube with glass beads
- rate = distance ÷ time

Exam tips

- Explain what the soda lime does: it absorbs carbon dioxide so that the movement of the liquid shows only the oxygen used.
- The liquid moves towards the organisms because the gas volume falls. Do not say the organisms 'suck' the liquid.
- Rate = distance ÷ time. Give the unit (mm/min) and show your working.
- For the control tube, say it shows the change is caused by living organisms and not by temperature or pressure changes or leaks.
- At high temperature use the word denature: the active site changes shape so enzymes can no longer work.