

Respiratory quotient and respiration practicals

Revision notes · The respiratory quotient, and the two core practicals on respiration in yeast and with a simple respirometer.

For Pearson Edexcel International AS Biology XBI11 and International A Level Biology YBI11. **A Level only** is IA2 content (Units 4 to 6), not needed for the International AS.

Respiratory quotient and respiration practicals **Spec 7.6-7.8** **A Level only**

Respiratory quotient (RQ) **Spec 7.6**

The **respiratory quotient (RQ)** compares the carbon dioxide produced with the oxygen consumed by an organism or tissue over the same time.

$$\text{RQ} = \text{volume of CO}_2 \text{ produced} \div \text{volume of O}_2 \text{ consumed}$$

RQ has no units, because it is a ratio. Its value depends on the substrate being respired, because different substrates contain different proportions of oxygen.

Typical RQ values		
Substrate respired	Typical RQ	Reason
Carbohydrate (glucose)	1.0	6CO ₂ produced for 6O ₂ used
Lipid	about 0.7	Lipids have little oxygen in the molecule, so more O ₂ is needed per CO ₂ released
Protein	about 0.9	Between lipid and carbohydrate

A mixture of substrates gives a value between those shown. An RQ greater than 1.0 means that more CO₂ is being produced than O₂ used, so some anaerobic respiration may be taking place in the tissue (for example, in yeast).

Calculating RQ

A sample of germinating seeds uses 40 cm³ of oxygen and produces 36 cm³ of carbon dioxide in 10 minutes. Calculate the RQ and suggest which substrate was respired.

1. $\text{RQ} = \text{volume of CO}_2 \text{ produced} \div \text{volume of O}_2 \text{ consumed}$
2. $\text{RQ} = 36 \div 40$

Answer: RQ = 0.9, which suggests that protein (or a mixture of substrates) is being respired.

Maths skill: RQ is a ratio, so no units. Write the working as ' $\text{CO}_2 \text{ produced} \div \text{O}_2 \text{ consumed}$ ' and state what the answer suggests about the substrate.

Core practical 15: redox indicator and yeast **Spec 7.7**

Core practical: Core practical 15: use an artificial hydrogen carrier (redox indicator) to investigate respiration in yeast.

During respiration, dehydrogenase enzymes remove hydrogen from the substrate and normally pass it to NAD. A **redox indicator** (for example methylene blue or DCPIP) can accept this hydrogen instead, so it acts as an artificial hydrogen carrier. When it is reduced, it changes colour (blue to colourless). The faster the yeast respire, the faster the indicator is decolourised.

1. Make a suspension of yeast in a glucose solution of known concentration.
 2. Place equal volumes of the suspension in boiling tubes in water baths at different temperatures (the independent variable), and let them reach the temperature.
 3. Add the same volume of the redox indicator to each tube and mix. A layer of oil may be added to exclude oxygen, which would re-oxidise the indicator.
 4. Start a stopwatch and record the time taken for the blue colour to disappear, or until it matches a colour standard.
 5. Repeat at each temperature and calculate a mean. Rate of reaction is proportional to $1 \div \text{time}$.
- Independent variable: temperature (or glucose concentration, or yeast concentration).
 - Dependent variable: time for the indicator to lose its colour.
 - Control variables: volume and concentration of yeast, glucose and indicator; pH; the colour end-point used.
 - Control experiment: boiled and cooled yeast should not decolourise the indicator.
 - Risks: hot water can scald; use a thermometer and a water bath that is not boiling. Methylene blue stains skin and clothes; wear eye protection and gloves, and wipe up spills.
 - Limitation: judging the colour end-point is subjective, so use the same colour standard, or a colorimeter for the endpoint.

Exam tip: If asked why the indicator changes colour, say that it accepts hydrogen released by the dehydrogenase enzymes in place of NAD, so a faster colour change means a faster rate of respiration.

Core practical 16: respirometer and RQ Spec 7.8

Core practical: Core practical 16: use a simple respirometer to determine the rate of respiration and RQ of a suitable material (such as germinating seeds or small invertebrates).

A simple respirometer is a sealed tube containing the organisms and connected to a capillary tube containing a drop of coloured fluid. As the organisms respire, the gas volume in the tube changes and the fluid moves.

1. Place the organisms (for example germinating seeds or woodlice) in the tube on a gauze or platform, above a small tube of potassium hydroxide solution (or soda lime) that absorbs the CO_2 they produce. Keep the organisms from touching the potassium hydroxide.
2. Set up a control tube, with an equal volume of glass beads or dead / boiled seeds in place of the organisms, to correct for changes in air temperature and pressure.
3. Place the apparatus in a water bath at constant temperature and wait about 10 minutes for the temperature to equalise.
4. Close the tap or bung, introduce a drop of coloured fluid and mark its position. Measure the distance it moves in a set time.
5. Repeat without the potassium hydroxide to find the net change in gas volume.

With KOH present, CO_2 is absorbed, so the fluid moves towards the organisms by a distance that shows the oxygen consumed. Without KOH, O_2 is still used up but CO_2 is released, so the movement is smaller (zero if $\text{RQ} = 1$, or away from the organisms if RQ is above 1) and shows the oxygen consumed minus the

carbon dioxide produced. The volume of gas is calculated from the capillary's radius: $\text{volume} = \pi r^2 \times \text{distance moved}$.

Rate of respiration and RQ

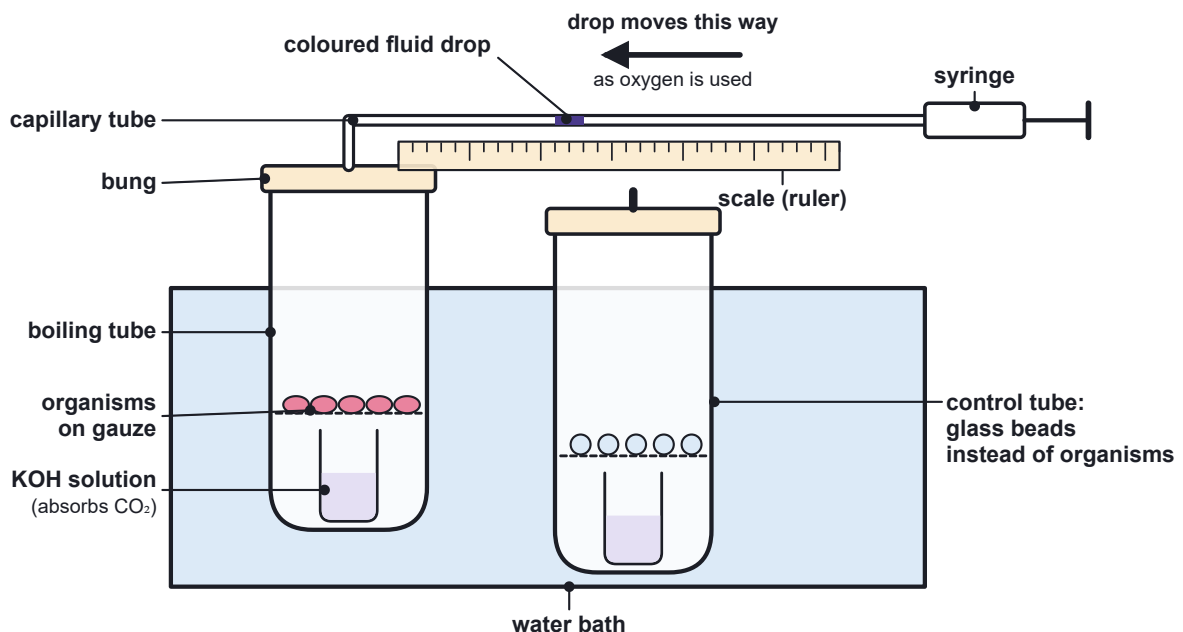
In a respirometer, the fluid in a capillary tube of radius 0.5 mm moved 24 mm in 5 minutes with potassium hydroxide present. Without potassium hydroxide it moved 6 mm in 5 minutes. Calculate the rate of oxygen uptake and the RQ.

1. Volume of O_2 consumed = $\pi r^2 \times \text{distance} = \pi \times 0.5^2 \times 24 = 18.85 \text{ mm}^3$
2. Rate of O_2 uptake = $18.85 \div 5 = 3.77 \text{ mm}^3 \text{ min}^{-1}$
3. Without KOH, net volume decrease = $\pi \times 0.5^2 \times 6 = 4.71 \text{ mm}^3$, which is O_2 consumed – CO_2 produced
4. CO_2 produced = $18.85 - 4.71 = 14.14 \text{ mm}^3$
5. $\text{RQ} = \text{CO}_2 \text{ produced} \div \text{O}_2 \text{ consumed} = 14.14 \div 18.85$

Answer: Rate of oxygen uptake = $3.77 \text{ mm}^3 \text{ min}^{-1}$ (accept 3.8). $\text{RQ} = 0.75$, so the organism is probably respiring mostly lipid or a mixture of substrates.

- Variables: independent variable e.g. temperature or type of organism; dependent variable distance moved by the fluid in a set time. Control the mass of organisms, temperature, time and the volume of apparatus.
- Divide by the mass of the organisms to compare rates, e.g. $\text{mm}^3 \text{ O}_2 \text{ g}^{-1} \text{ min}^{-1}$.
- Risks: potassium hydroxide is corrosive, so wear eye protection and gloves and prevent contact with the organisms. Handle animals gently and return them to their habitat, and wash hands after handling germinating seeds.

Core practical: The respirometer works because CO_2 is absorbed. Be clear which gas each reading refers to: with KOH the movement is due to O_2 used; without KOH the movement is O_2 used minus CO_2 produced.



As oxygen is used and CO_2 is absorbed by the KOH, the **drop moves towards the organisms**; the syringe resets it.

Quick check

1. What is the formula for the respiratory quotient?
2. What is the typical RQ when carbohydrate is respired?
3. In Core practical 15, why does the redox indicator change colour?
4. In a respirometer, what is the purpose of potassium hydroxide?

Quick check answers

Respiratory quotient and respiration practicals

1. $RQ = \text{volume of CO}_2 \text{ produced} \div \text{volume of O}_2 \text{ consumed}$.
2. About 1.0.
3. It accepts hydrogen from dehydrogenase enzymes, so it is reduced and loses its blue colour.
4. It absorbs carbon dioxide, so that the movement of fluid shows the volume of oxygen consumed.