

How much gas can catalase make?

Yeast, hydrogen peroxide and a balloon.

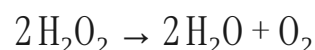
Change the substrate, watch the balloon, then ask what it really measured.

Name _____ Group _____

Fill in the white columns as you work. Calculate the shaded columns using the formulas in the dashed boxes.

1 The big idea

Cells make hydrogen peroxide as a toxic by-product. The enzyme **catalase** breaks it down very fast.



The **substrate** is H_2O_2 . Catalase is the enzyme. It binds the substrate at its **active site**, and is not used up.

Two different questions: How **much** oxygen was made in total (the **endpoint**)? How **fast** was it made (the **rate**)? Keep these apart all lesson.

Safety: goggles on the whole time. H_2O_2 irritates eyes. Stand flasks on a tray because they can foam over.

2 Predict

P1 Which balloon do you think will end up biggest?

(0% / 0.5% / 1% / 2% / 3%)

P2 What shape will each graph be?

Total O_2 against H_2O_2 concentration: (Straight line going up / Rises, then levels off / Flat)

Rate against H_2O_2 concentration: (Straight line going up / Rises, then levels off / Flat)

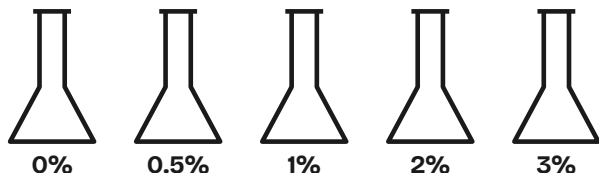
P3 Explain your predictions.

Try: I **think ... because more substrate means ...** . The rate will ... because the active sites ...

3 Method

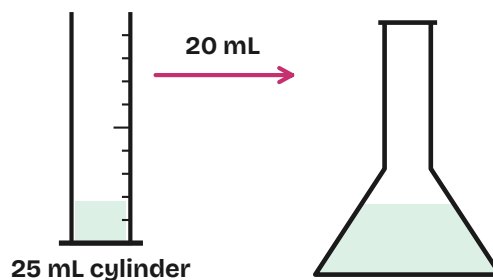
You will need (per group)

- 5 × 250 mL conical flasks
- 5 balloons
- Small funnel
- 5 g dried yeast (5 × 1 g)
- H₂O₂ at 0, 0.5, 1, 2 and 3%
- 25 mL measuring cylinder
- String and 30 cm ruler
- Stopwatch, goggles, tray



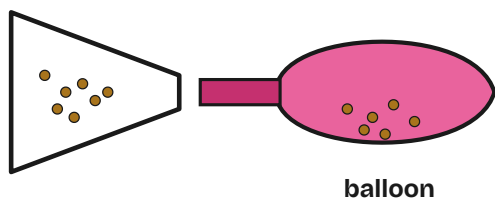
- 1 Set up.** Goggles on. Label five 250 mL conical flasks 0%, 0.5%, 1%, 2% and 3%.

H₂O₂ solution

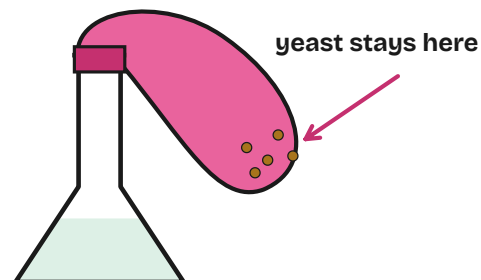


- 2 Add the hydrogen peroxide.** Measure 20 mL of each H₂O₂ solution with the measuring cylinder and pour it into the matching flask.

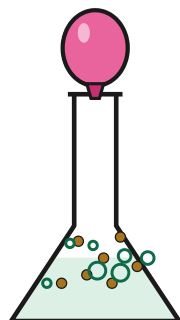
1 g dried yeast



- 3 Load the balloon.** Use the funnel to put 1 g of dried yeast into a balloon. Keep the yeast inside the balloon for now.

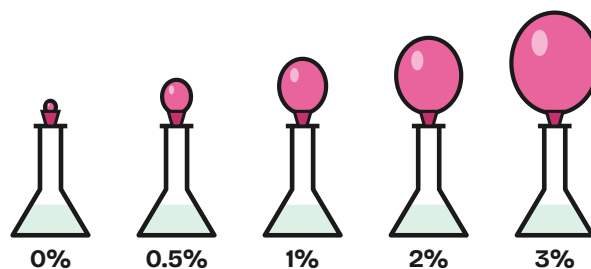


- 4 Attach without tipping.** Stretch the balloon over the neck of the flask. Let the yeast end hang over the side so no yeast falls in yet.

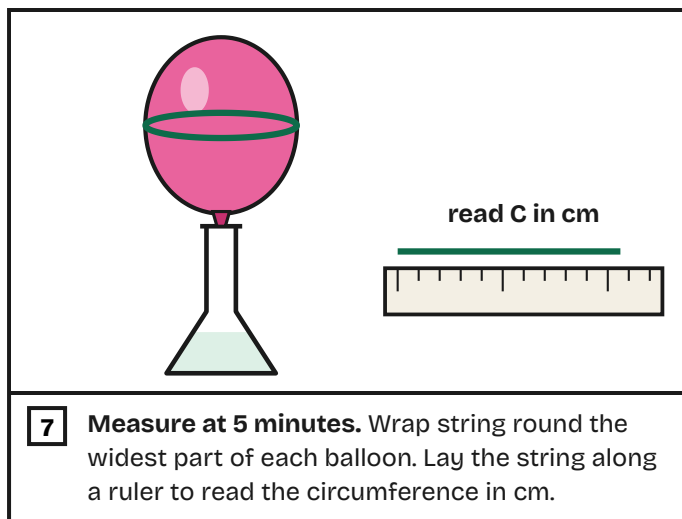


- 5 Tip and start timing.** On "go", one person lifts every balloon upright so the yeast drops in at the same moment. Start the stopwatch.

5 4 3 2 1



- 6 Rank at 30 seconds.** At 30 s, look at the five balloons and rank them by size (1 = biggest). This is your clue about rate.



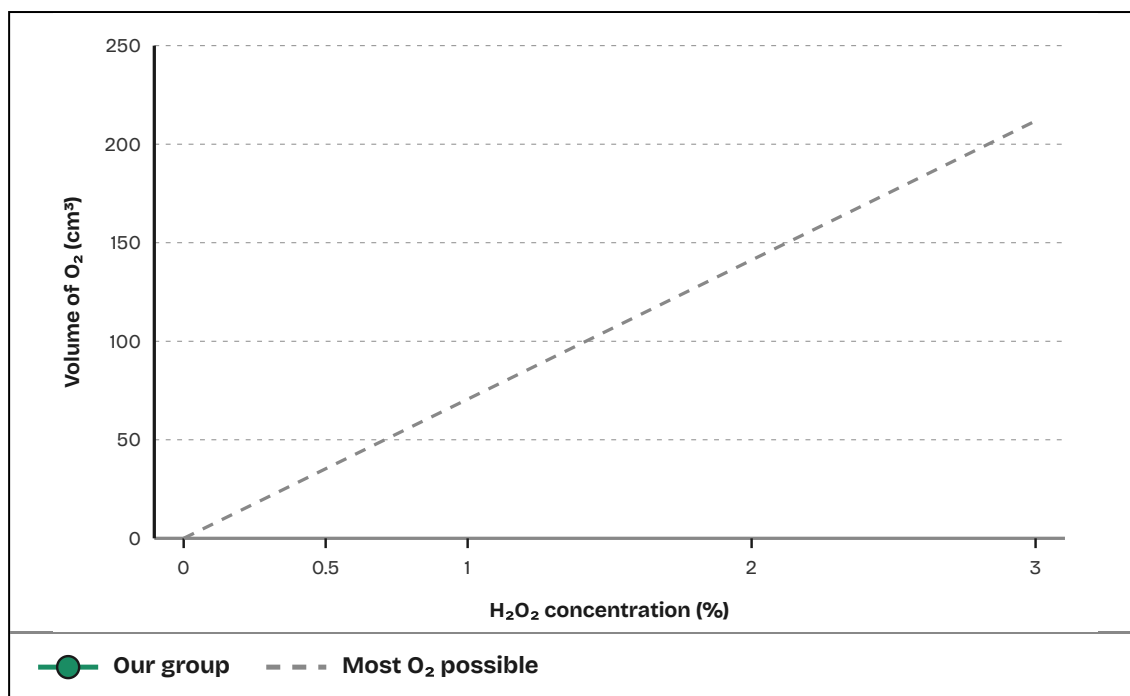
4 Your group's results

H ₂ O ₂ (%)	Rank at 30 s 1 = biggest	Circumference at 5 min (cm ± 0.5)	Radius (cm)	Volume (cm ³)	Observations
0%		_____			_____
0.5%		_____			_____
1%		_____			_____
2%		_____			_____
3%		_____			_____

If a balloon did not inflate at all, enter 0 for its circumference.

Radius: $r = C \div 2\pi$ · **Volume of a sphere:** $V = \frac{4}{3} \pi r^3$

Graph: volume of O₂ at 5 minutes



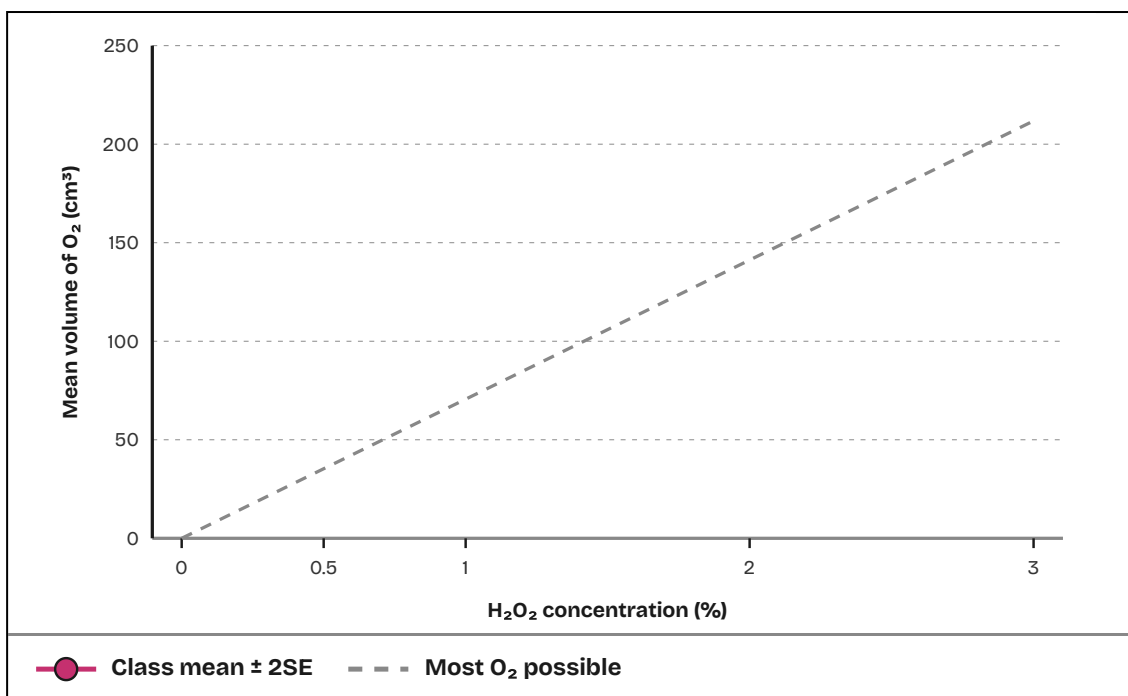
5 Class results

Estimated O₂ volume at 5 minutes (cm³) for every group. The pink columns calculate themselves. **Tap any value** to see how it was worked out.

Mean: $\bar{x} = \Sigma x \div n$ · **Standard deviation:** $s = \sqrt{[\Sigma(x - \bar{x})^2 \div (n - 1)]}$ · **Standard error:** $SE = s \div \sqrt{n}$ · **Error bars:** $\bar{x} \pm 2SE$

H ₂ O ₂ (%)	Gp 1	Gp 2	Gp 3	Gp 4	Gp 5	Gp 6	Mean	SD	SE	Mean ± 2SE
0%										
0.5%										
1%										
2%										
3%										

Graph: mean O₂ volume with ± 2 SE error bars



6 Why does AP use standard error?

Standard deviation and standard error answer **different** questions.

Standard deviation (SD)

How spread out are the individual results?

It describes the data. Collecting more groups does not make it smaller. It just gets a better estimate of the real spread.

Standard error (SE)

How sure are we about the mean?

$SE = SD \div \sqrt{n}$. More groups $\rightarrow$ smaller SE. It describes how precise the mean is.

You want to **compare means**: did 2% really make more O₂ than 1%? That is a question about the means, so AP uses error bars of $\pm 2SE$. That range is about a 95% confidence interval for the mean.

The rule of thumb: if the $\pm 2SE$ error bars of two groups **do not overlap**, the difference is probably real (statistically significant). If they **overlap**, you cannot claim a difference.

7 Analyse

A1 Which concentration gave the largest mean volume of O₂?

(0% / 0.5% / 1% / 2% / 3%)

A2 Do the $\pm 2SE$ error bars for 1% and 2% overlap?

(Yes, they overlap / No, they don't overlap)

A3 After about 5 minutes the fizzing stops. What has run out?

(The enzyme (catalase) / The substrate (H_2O_2))

A4 If all the H_2O_2 is used up, what does the *final* balloon size actually measure?

Try: The final size measures how much ... there was, not how ... catalase worked, because ...

A5 The 3% balloon was biggest. Does that prove catalase worked fastest in the 3% flask? Use your 30-second ranking.

A6 Compare with the most O_2 possible.

Suggest two reasons why your measured volume is lower than the maximum.

A7 Why did we need a 0% flask?

8 Making it quantitative

Mr Bradford says

Balloons are brilliant for *seeing* a reaction. They are terrible for *measuring* one. Let's work out why, and what scientists would do instead.

M1 Give two reasons a balloon is a poor measuring tool.

Think about: shape · stretchiness · gas escaping when you attach it · reading the string

M2 We measured the widest part and treated the balloon as a sphere. Will the volume be too high or too low?

(Too high / Too low)

M3 Which method would measure the rate?

(Measure the balloon after 10 minutes instead of 5 / Collect gas in a gas syringe and read the volume every 10 s / Use bigger balloons)

M4 With a proper rate method, what shape would rate against H_2O_2 concentration be?

(Straight line going up forever / Rises, then levels off / Falls as concentration rises)

Explain the shape using active sites.

9 Conclude

Step 1: build the science

As H_2O_2 concentration increased, the total volume of O_2 (increased / decreased / stayed the same). The reaction stopped because the (enzyme / substrate) ran out. So the final balloon size measures (the rate of reaction / the amount of enzyme / the amount of substrate). To compare rates, we must measure (early, at a fixed time / after the reaction stops / only the 3% flask).

Step 2: which statements does your evidence support?

Tick only the ones your data and the science actually back up. Watch out for claims that go too far.

- ☐ More H_2O_2 produced more O_2 in total.
- ☐ Catalase works fastest at 3% H_2O_2 .
- ☐ Catalase is not used up in the reaction.
- ☐ Our balloon volumes are accurate to the nearest cm^3 .
- ☐ If the $\pm 2\text{SE}$ bars of two concentrations don't overlap, the difference is probably real.
- ☐ All enzymes produce oxygen gas.

Step 3: write your conclusion (Claim, Evidence, Reasoning)

Claim How does H_2O_2 concentration affect the O_2 produced?

Evidence Quote class means with $\pm 2SE$. Say which error bars overlap.

Try: At 3%, the mean volume was ... $\pm$... cm³, compared with ... at 1%.

Reasoning Explain using substrate, active site, and why the endpoint is not the rate.

10 Evaluate

Don't just name a problem. Say **what it did to your results** and **exactly how to fix it**.

Weakness in method	Effect on results	Specific improvement

Ideas to think about: **gas lost while attaching** · **balloon shape** · **yeast clumping** · **string reading** · **starting all flasks together**

✓ Before you hand in

- ☐ My table has my own results, not the practice numbers
- ☐ I have quoted means with $\pm 2SE$ in my evidence
- ☐ I explained why the final size shows amount, not rate
- ☐ I suggested a better method for measuring rate
- ☐ Each weakness has an effect and a specific improvement