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GCSE (9-1) Biology A & B

AS and A Level Biology A & B

Language of Measurement in Context

The purpose of this exemplar investigation is to illustrate the use of the language of measurement terms in the context of a Biology practical activity.

Hydrogen peroxide and catalase

In this practical, a student investigates the effect of hydrogen peroxide concentration on the rate of reaction of the catalase, using potato cylinders.

Practical activity

The enzyme catalase is found in plant and animal cells. It catalyses the breakdown of hydrogen peroxide into water and oxygen.

$$\text{hydrogen peroxide} \xrightarrow{\textit{catalase}} \text{water} + \text{oxygen}$$

$$2H_2O_2 \xrightarrow{\textit{catalase}} 2H_2O + O_2$$

Five different concentrations of hydrogen peroxide (3.0%, 2.5%, 2.0%, 1.5%, 1.0%) are prepared. The student produces fifteen potato cylinders using a cork borer. These are used as the source of catalase. The cylinders are cut to 50 mm in length, measured using a ruler, as shown in Fig. 1.

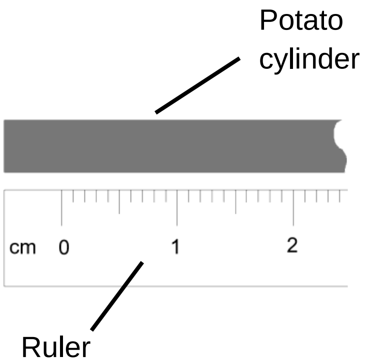

Fig. 1

Fig. 1 shows a **systematic error** when measuring the length of the potato cylinder with a ruler. The student has not measured using the zero mark on the rule. **Systematic errors** are consistent repeatable errors involving equipment.

Random error is always present in a measurement. Taking more repeat measurements and calculating a mean can reduce the effect of random error. A **random error** can be a sudden change in room temperature, which can affect the rate of the enzyme-controlled reaction.

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The apparatus is set up as shown in Fig. 2.

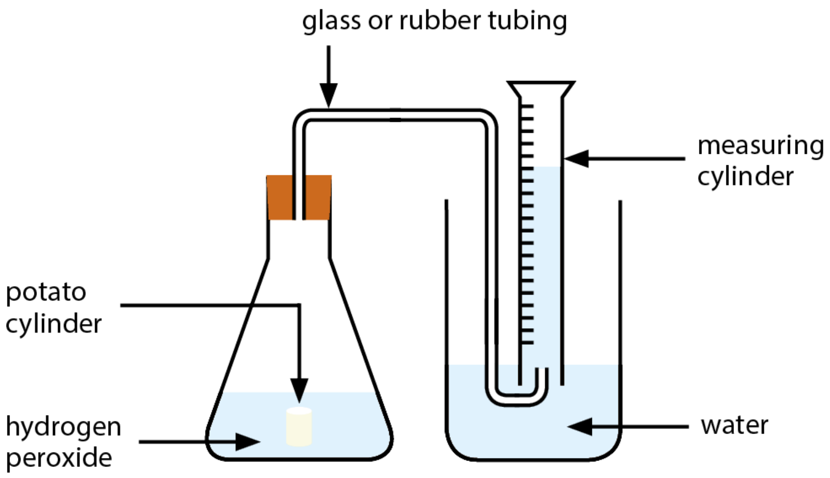

Fig. 2

The student drops the potato cylinder into the conical flask with the 20 cm^3 of 1.0% hydrogen peroxide and starts the stopwatch. The volume of oxygen produced at 3 minutes, is measured.

The **independent variable** in this practical is the concentration of hydrogen peroxide. This is because the student carrying out the practical is directly changing the concentration.

The **dependent variable** is the volume of oxygen produced in 3 minutes, because this has been directly affected by the change of the independent variable.

Control variables include the fixed volume of hydrogen peroxide, length of potato cylinder, and time to collect the oxygen. They are kept the same each time to ensure they do not influence the dependent variable.

To ensure **validity**, control variables need to be identified and kept constant. In this way other variables do not influence the dependent variable.

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At the end of the 3 minutes the student reads from the measuring cylinder as shown in Fig. 3. The student recorded it as 2.8 cm^3 .

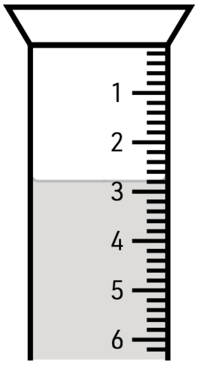


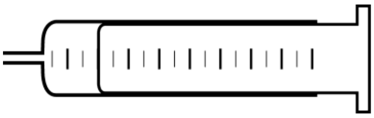
Fig. 3

When using apparatus with an analogue graduated scale, the **uncertainty** in a single measurement is typically taken to be ± half the smallest graduation, in this case 0.1 cm^3.

A **change** in the volume of oxygen in the measuring cylinder involves two readings. The absolute uncertainties for each reading must be added to give the absolute **uncertainty** in the combined measurement. So, the **absolute uncertainty** is:

$$2 \times 0.1\ cm^3 = 0.2\ cm^3$$

Note: Due to the ambiguity in some textbooks, in exams we will accept both the half and the smallest division as the absolute uncertainty.



Another student uses a gas syringe to measure the volume of oxygen produced. For the same concentration of hydrogen peroxide, they record 2.85 cm^3.

The gas syringe has smaller graduations, so has a higher **resolution**. Higher resolution instruments measure smaller changes.

The student repeats the practical 3 times, using the same volume of hydrogen peroxide and the same length of the potato cylinder, for each hydrogen peroxide concentration.

Results are **repeatable** if the use of the same equipment, same method, and same experimenter gives similar results. Repeating results can also reduce random errors and allow precision to be determined. The term ‘reliable’ shouldn’t be used, as its meaning is unclear.

Results

H_2O_2 conc. (%)	Volume of oxygen collected after 3 minutes (cm^3)				Mean rate of oxygen released ($cm^3\ min^{-1}$)
	Trial 1	Trial 2	Trial 3	Mean	
3.0	6.8	7.0	6.7	6.83	2.28
2.5	5.0	5.3	5.5	5.27	1.76
2.0	4.8	4.5	4.4	4.57	1.52
1.5	4.0	4.2	4.1	4.10	1.37
1.0	2.8	4.3	2.5	3.20	1.07

Just repeating the practical does not improve **accuracy**. The accuracy is influenced by both systematic and random errors.

Repeating the practical will allow you to identify an **anomalous** result. If you record the suspected anomaly due to an error or due to different conditions, then calculate the mean without the anomalous result. If you identify the anomaly during the practical, then you might consider repeating the practical.

The repeat measurements are close together, although there is variation. We can say the **precision** of the measurements is good.

The student compared their results with the results from another group of students.

H_2O_2 conc. (%)	Mean volume of oxygen collected after 3 mins (cm^3)
3.0	6.50
2.5	5.41
2.0	4.20
1.5	4.08
1.0	3.15

The student concluded that their results are **reproducible.**

Similar results obtained by other groups indicate that the results are **reproducible**. This is a test of the quality of the data.

Notes:

1. *This resource is in the style of a GCE practical, but many terms apply to GCSE too.*
2. *The words in bold are explained further in the 'Glossary of Terms'.*

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Control variable

Hydrogen peroxide volume is kept the same throughout the investigation.

Validity

To ensure validity, control variables need to be in place and kept constant so that they don't affect the dependent variable.

Random error

Random error can result from variations in the time between reading the time and recording the result. We can reduce the effect of random error on results by repeating and calculating the mean.

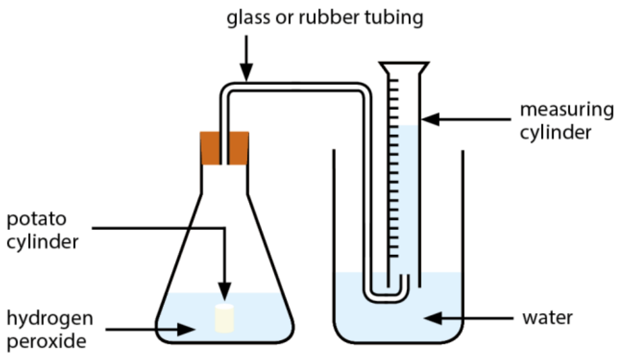
Accuracy

Repetition alone does not improve accuracy. Accuracy is affected by random and systematic errors.

Precision

Precision refers to repeated results. Precise results are clustered together. Repeating allows precision to be determined.

Investigating the effect of catalase on hydrogen peroxide



Method

1. Add 20 cm³ of 1.0% hydrogen peroxide to the conical flask.
2. Use a cork borer to cut out a potato cylinder. Carefully trim off the skin and cut to exactly 50 mm in length.
3. Connect the conical flask with a delivery tube to an upside-down measuring cylinder in the tub of water. Record the initial volume of oxygen.
4. Add the potato cylinder to the flask. Time for 3 minutes and then record the volume of oxygen in the measuring cylinder.
5. Repeat 3 times and calculate the mean. Use the same equipment and ensure the same person reads the volume of the oxygen produced.
6. Repeat for different hydrogen peroxide concentrations (1.5%, 2.0%, 2.5%, 3.0%).
7. Compare your results with other groups.

Systematic error

Not taking readings from the zero mark on the ruler would introduce a systematic error. These are consistent, repeatable errors due to equipment.

Resolution

Apparatus with higher resolution will give readings with more decimal places. A gas syringe might have a higher resolution than a measuring cylinder.

Dependent variable

The variable that's being measured.

Repeatable

Results are repeatable if repeats with the same equipment, method and experimenter give similar results.

Independent variable

This is changed directly by the person carrying out the investigation.

Reproducible

Results can be produced by different groups, equipment, or methods. If the results are similar they are reproducible.

Glossary of terms

Term	Definition	Notes
accuracy	a measurement result is considered accurate if it is judged to be close to the true/acceptable value	Accuracy is a property of a single result. Random and systematic errors reduce accuracy.
anomaly (outlier)	value in a set of results that is judged not to be part of the inherent variation	Calculate the mean without the anomaly if you suspect an anomaly due to an error or due to different conditions. If you identify an anomaly during the practical, then consider repeating the measurement. In **Maths**, you may use the term 'outlier'.
control variable	variables other than the independent and dependent variables which are kept the same	These are quantities or conditions that are kept the same in a practical. Changes in these conditions could affect the validity of your method and results.
dependent variable	variable which is measured whenever there is a change in the independent variable	The dependent variables are recorded as either numerical values with units (quantitative) or in the form of descriptive comments (qualitative).
independent variable	variable which is deliberately changed or selected by the person in the planning of a practical activity	The independent variable is recorded in the first column of a results table. The dependent variable is recorded to the right with processed data in the far-right columns. In a graph, the independent variable is usually plotted on the *x*-axis with the dependent variable on the *y*-axis.
line of best fit	a line drawn on a graph that passes as close as possible to the data points. It represents the best estimate of the underlying relationship between the variables.	A line of best fit can be a straight line or a curve. This differs from **GCSE Maths**, where a line of best fit is always a straight line.
precision	a quality denoting the closeness of agreement between measured values obtained by repeated measurements	Precision refers to more than one value. Precise results are clustered together. You can only determine if your results are precise by repeating the measurement. Reducing the effect of random errors improves precision. A systematic error does not affect precision, as it is the same error each time. You may have precise results with a systematic error, but not accurate results.
random error	error in a measurement due to small uncontrollable effects	We can't correct random errors, but we can reduce their effect by making more measurements and calculating the mean. Random errors contribute to uncertainty.

Term	Definition	Notes
range (of a variable)	the maximum and minimum values of the independent or dependent variables	In **Maths** the range is the difference between the biggest and smallest value of a variable.
repeatability	precision obtained when measurement results are produced in one laboratory, by a single operator, using the same conditions, over a short timescale	A measurement is repeatable when repetition under the same conditions gives similar results. Anomalous results can be identified by repeating the measurement. However, never discard data simply because it does not correspond with expectations.
reproducibility	precision obtained when measurement results are produced by different laboratories and therefore by different operators using different pieces of equipment	A measurement is reproducible when similar results are produced by different groups or different equipment or altered methods. If the results are reproducible then you can be more confident in the quality of the results.
resolution	smallest change in the input quantity being measured by a measuring instrument that gives a perceptible change in the reading of the measuring instrument	For example, the resolution of a ruler is 1 mm and the resolution of a burette is 0.1 cm^3. It is not correct to describe equipment with a higher resolution as being more precise, as precision is a property of repeated results.
systematic error	error due to the measured value differing from the true value by the same amount each time	Methods or equipment may introduce systematic errors, producing consistent errors in results. Using the same equipment each time avoids introducing more systematic errors. Calibrating equipment where appropriate reduces systematic errors. A **zero error** is when the measuring device indicates a value when the quantity being measured is zero. Systematic errors contribute to uncertainty.
uncertainty	interval within which the true value can be expected to lie, with a given level of confidence or probability	Uncertainties depend on a range of factors, including systematic and random errors. Analogue apparatus typically has an uncertainty of ± half the smallest graduation. The uncertainty of the digital apparatus is ± the resolution of the apparatus.
validity (of an experiment)	suitability of the method used to answer the question being asked	To ensure validity, identify control variables and keep them constant to avoid affecting the dependent variables. In the case of field studies there are naturally changing variables. Ensure the control variables are as similar as possible when repeating.

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