



# WRITING A+ BIOLOGY PRAC REPORTS



# A GUIDE TO WRITING PRACTICAL REPORTS

The main purpose of scientific report writing is to communicate the results of your experiment so that other people can reproduce your results if necessary. The process of writing a scientific report gives you valuable practice in clearly explaining the theoretical concepts and interpreting and manipulating data. Since these skills are also vital for performing well in the written examination, mastering the art of writing practical reports is essential!

This document gives a general description of the sections of a scientific report; however, you should check with your teacher about their specific requirements as there may be differences in approach, style and presentation.

## WRITING STYLE

A scientific report should be written in a straight forward and precise manner so that it is easy for other people to read and understand.

- You should write in complete, grammatically correct sentences.
- Avoid elaborate vocabulary.
- Use chemical terms and conventions correctly, including chemical equation and units of measurement.
- Be concise. If you can use one word instead of a phrase with two or more words, then choose the one word (get around = avoid).
- Avoid long sentences. If most of your sentences are long (4 or more 'clauses' or parts) you will confuse the reader.
- Write in the third person ('it' rather than I or we).
- Write in past tense.
- Avoid definitive words (proves, definitely, will cause).

Useful words to use are: Possibly, inference, presumably, probably, apparently, not likely, seemingly, appear, suggest, seem, maybe.

- Write objectively: present facts and figures only, do not include your beliefs or feelings. Avoid colloquialisms such as 'the results dramatically showed...'

Avoid	Instead use
I observed the cell to be	The cell was
I suggest	It is suggested that
I found	It was found that
In this report I will show	This report shows
The loss in mass was due to	The loss in mass may have been due to
The results prove that	The results indicate that

## CHECKLIST FOR BIOLOGY PRACTICAL REPORTS

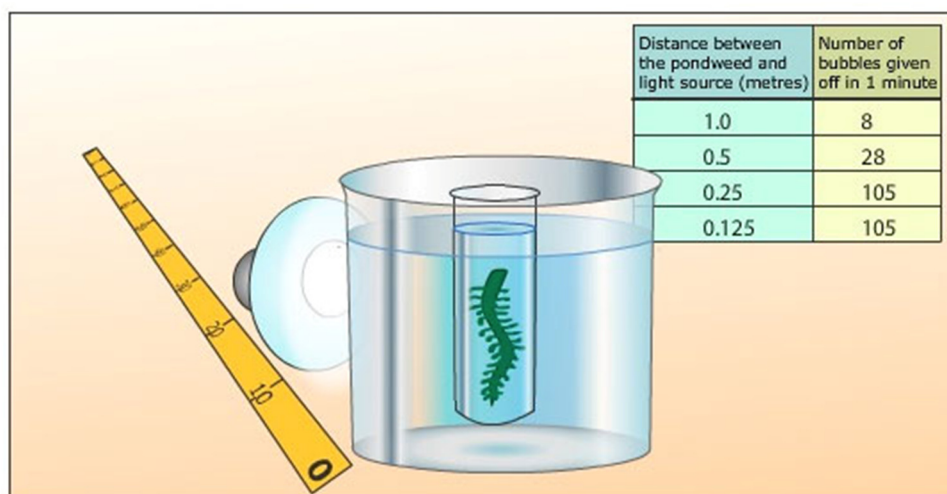
While different schools will vary in the sections required in a practical report, generally all reports follow a similar format as follows.

Design		Comments
A1	<b>Title, Aim and Hypothesis</b>	<ul style="list-style-type: none"> <li>• <b>TITLE:</b> Include a title that is detailed – i.e. it refers to your IV and DV.</li> <li>• <b>AIM:</b> Include an aim that clearly identifies what you were trying to do. It should also refer to your IV and DV.</li> <li>• <b>HYPOTHESIS:</b> Make a prediction about what you expect to happen.</li> <li>• <b>HYPOTHESIS:</b> Provide a reason for your prediction.</li> </ul>
A2	<b>Materials</b>	<ul style="list-style-type: none"> <li>• <b>LIST OF MATERIALS:</b> Include a list of equipment including how many of each item was needed and what size was needed (e.g. 2x 250ml beakers).</li> <li>• <b>DIAGRAM:</b> Include a labelled diagram or photo of the experimental set-up (please note: this is not a picture of all of the equipment on the bench).</li> </ul>
A3	<b>Variables</b>	<ul style="list-style-type: none"> <li>• <b>INDEPENDENT VARIABLE</b> – identify the variable that you have changed (with units)?</li> <li>• <b>DEPENDENT VARIABLE</b> – identify the variable that you have measured (with units)?</li> <li>• <b>CONTROLLED VARIABLES</b> – list the aspects that you kept the same to ensure that your experiment was reliable?</li> </ul>

<p style="text-align: center;"><b>A4</b></p>	<p style="text-align: center;"><b>Method</b></p>	<ul style="list-style-type: none"> <li>• <b>METHOD FOR COLLECTING DATA:</b> include a numbered set of steps that were followed in order to collect the data.</li> <li>• <b>METHOD FOR PROCESSING DATA:</b> include the steps that will be taken in order to <u>use</u> or analyse your data (e.g. find the average, graphing, etc.).</li> </ul> <div style="text-align: center;"> <p>The diagram illustrates the classification of data. It starts with 'Data' on the left, which branches into 'Qualitative' (Descriptive information) and 'Quantitative' (Numerical information). 'Qualitative' is exemplified by the sentence 'I drink coffee every day'. 'Quantitative' is further divided into 'Discrete (Counted)', exemplified by 'I drink 4 coffees every day' (with four coffee cup icons), and 'Continuous (Measured)', exemplified by 'I drink 80grs of coffee every day' (with a coffee cup icon and '80g').</p> </div>
<p style="text-align: center;"><b>Data Collection and Processing</b></p>		<p style="text-align: center;"><b>Comments</b></p>
<p style="text-align: center;"><b>B1</b></p>	<p style="text-align: center;"><b>Results: Data collection – data tables and observations</b></p>	<ul style="list-style-type: none"> <li>• Put your IV and DV in the correct positions in a table.</li> <li>• Accurately record your data in the table.</li> <li>• Include a column heading for each column included.</li> <li>• Provide units (if necessary) in the column heading.</li> <li>• Do not put units with your data.</li> <li>• Keep the number of decimal places consistent to each other and the scale of your recording equipment.</li> <li>• For hand drawn tables – use a ruler and pencil used, and be neat.</li> <li>• For electronic tables – make sure your data is aligned in the centre of each column and merge the top heading cell if there were multiple trials.</li> </ul>

B2	<p style="text-align: center;"><b>Results:</b></p> <p style="text-align: center;"><b>Data Processing and Presentation, Calculations and Graphs</b></p>	<ul style="list-style-type: none"> <li>• Perform any calculations that were necessary to analyse your data correctly.</li> <li>• Provide the results of these calculations in a separate table.</li> <li>• Make sure the number of decimal places in this table are kept the same as the original (raw) data.</li> <li>• Select the correct graph – e.g. line graph, scatter graph, column graph.</li> <li>• Make sure you put your IV and DV on the <b>correct</b> axis.</li> <li>• Put a detailed title on your graph.</li> <li>• Put headings on each axis <b>with units</b>.</li> <li>• Make sure you have used an appropriate scale on each axis.</li> <li>• Do not put any units in the scales used.</li> <li>• For hand drawn graphs – use a ruler and pencil used, and be neat.</li> <li>• For electronic graphs – make sure you include both axis lines and major tick marks.</li> </ul>
<b>Conclusion and Evaluation</b>		<b>Comments</b>
C1	<p style="text-align: center;"><b>Discussion</b></p>	<ul style="list-style-type: none"> <li>• <b>DESCRIPTION:</b> Discuss what happened in detail. Make sure you talk about your results here for each condition.</li> <li>• <b>ANOMALIES:</b> Discuss any results that do not fit with the other results collected or your prediction. (E.g. when your data for a condition is 3, 14, 2 and 3 – 14 is strange!)</li> <li>• <b>SCIENTIFIC EXPLANATION:</b> Use your class notes, textbook or the internet to attempt to <b>explain</b> your results.</li> </ul>

C2	Evaluation	<ul style="list-style-type: none"> <li>• <b>EVALUATE METHOD:</b> Was the method good at measuring your DV? Did you control enough variables? Does your data seem reliable data? Is the data for the multiple trials done spread out or consistent?</li> <li>• <b>EVALUATE EQUIPMENT:</b> Was the choice of materials appropriate? Did you use the best equipment/technique? If not, <b>explain why</b>.</li> <li>• <b>SUGGESTED IMPROVEMENTS</b> – Suggest ways to increase the reliability, accuracy <b>and</b> range of the data collected.</li> </ul>
C3	Conclusion	<ul style="list-style-type: none"> <li>• <b>STATEMENT</b> – Explain what you discovered in one sentence.</li> <li>• <b>ACCURACY OF PREDICTION</b> – Did your results support your hypothesis?</li> <li>• <b>APPLICATION</b> – Could you apply the conclusion made to real life examples?</li> </ul>
<b>Other</b>		
<ul style="list-style-type: none"> <li>• Written in the 3<sup>rd</sup> person (i.e. no personal pronouns).</li> <li>• Scientific language/vocabulary has been used.</li> <li>• Grammar, spelling and punctuation with little to no errors.</li> </ul>		



# GENERAL FORMAT OF PRACTICAL REPORTS

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## HEADING/EXPERIMENTAL DETAILS:

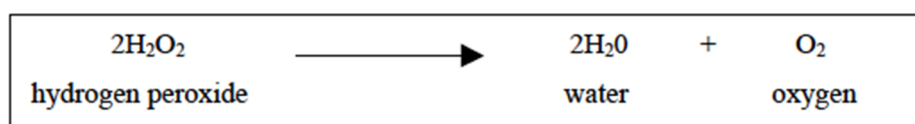
- Practical title
  - Your name
  - Laboratory partners
  - Date
- 

## INTRODUCTION:

Some teachers may like you to include relevant background information. For example:

Background information for an experiment on enzyme inhibition:

Catalase is an intracellular enzyme found in many plant and animal tissues, including liver. Its role in the cell is to catalyse the following reaction:



Hydrogen peroxide is toxic to cells if it is allowed to accumulate so it is converted into two harmless substances, water and oxygen. The enzyme has many factors that affect its activity such as temperature, pH, concentration, and presence of inhibitors.

Like all enzymes catalase has an active site, the surface of which comes into contact with the substrate. This leads to a change in shape of the enzyme to accommodate the substrate but there are certain substances called inhibitors that affect the active site thus they can slow down or completely stop the catalysis.

Copper sulphate is a known catalase inhibitor, specifically a non-competitive inhibitor wherein the inhibitor binds to the enzyme's allosteric site (i.e. any site of the enzyme excluding the active site) because it is not structurally similar to the substrate. This means it is not in competition with the substrate rather it causes a change in the shape of the enzyme's active site, making it non-functional, and this change is often irreversible. Another enzyme inhibitor is cyanide. This is a competitive inhibitor as it is structurally similar to the substrate and competes with the substrate for the active site of the enzyme. This type of inhibition is reversible.

Catalase activity can be measured by identifying the presence of oxygen after a reaction has taken place. Evidence of oxygen after a reaction can be seen as bubbling and as igniting a glowing splint.

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## **AIM:**

Writing an aim involves concisely describing the purpose of the experiment. There may be one aim or several.

### **A possible aim for this experiment would be:**

To investigate the effect of enzyme inhibitors on the activity of the enzyme catalase as measured by amount of oxygen gas produced in the decomposition of hydrogen peroxide.

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## **EQUIPMENT:**

Provide a list of the equipment that was used. Be specific. Clearly indicate the size of the glassware needed (50 mL beaker) and the concentrations of any solutions used. A list of equipment is usually included on the practical sheet and you may not be required to rewrite it. If this is the case, reference the practical sheet in this section and make sure you include it with your report. Any changes to the equipment used must be annotated on the practical sheet.

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## **METHOD:**

Provide progressive, step by step instructions of how to conduct the experiment from beginning to end so that it can be easily and accurately duplicated by others. Be explicit and accurate and quantify the steps as much as possible.

Normally, the method is given out as part of the practical notes and very rarely would you be required to rewrite it. Some teachers will be happy with a reference to the method. If any changes have been made, ensure that they are clearly annotated on the sheet.

**Example:** "Refer to *Heinemann Practical Manual* pg 26-28"

If you have taken a photograph of your experimental set up, you would include it here. Make sure it is given a descriptive heading. E.g. *Figure 1: Experimental set up*

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## **RESULTS:**

Any data collected or observations made during the experiment should be accurately recorded in this section. Your teacher may require you to include the rough copy of your results from the experiment in order to verify your work. The results section is divided into sub-sections as described below.



## OBSERVATIONS (QUALITATIVE RESULTS):

Observations include things like colour changes, the appearance of a gas, sounds that were made (popping, hissing) and also anything that could influence the outcome of the experiment. Do not analyse or comment on the relevance of the observations. This will be done in the discussion section.

### Examples:

- Some of the precipitate stuck to the bottom of the flask and could not be removed.
- There was a large/medium/small glow.
- The test tube felt warm.
- Even after thorough mixing, some of the fertiliser did not dissolve.
- The red solution became darker as time passed.

## NUMERICAL DATA:

Numerical data should be presented in tables, figures or graphs.

### Tables

- Require a descriptive title.
- Each column of data should be clearly labelled. Units should be included with the title of the column NOT in the body of the table where the numerical data is recorded. The associated uncertainty should also be stated.
- The number of significant digits should reflect the precision of the measurements.
- There should be no variation in the precision of raw data. For example, the same number of decimal places should be used if the measuring device is consistent.

### Example of a good results table:

Three groups of students, **A**, **B**, and **C**, carried out an experiment to investigate the effect of temperature on the action of the enzyme sucrase.

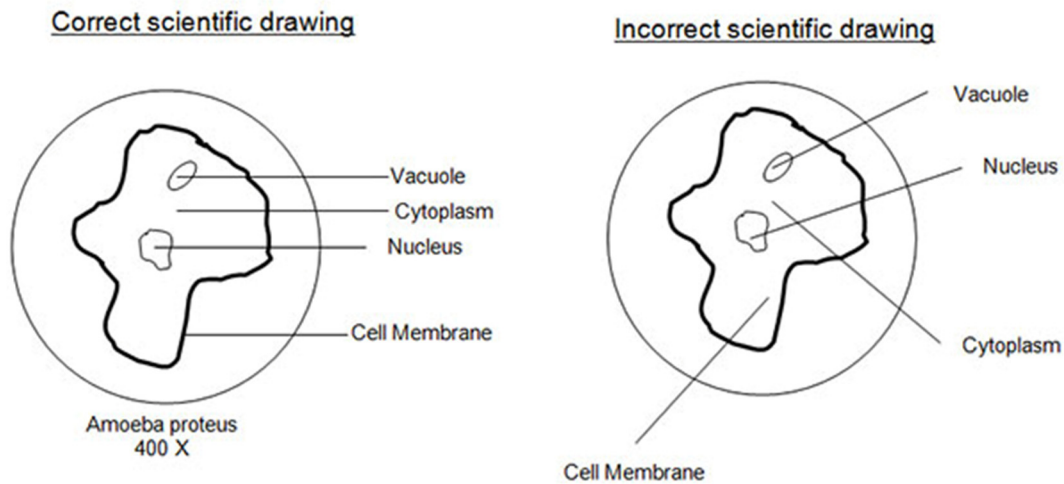
**Table 1: Time taken for sucrose to break down at different temperatures.**

Test-tube	Temperature (°C)	Time taken for sucrose to break down completely (minutes)			
		Group A	Group B	Group C	Average
1	0	49	53	51	51
2	10	15	14	16	15
3	20	10	6	9	8.3
4	30	4	5	4	4.3
5	40	4	7	6	5.7
6	50	26	30	28	28
7	60	90	140	100	110

## Figures

Figures can include graphs, scatterplots, drawings or even photographs. Essentially, figures are pictures of things. If you include a microscopic drawing as part of your results remember it needs to be in pencil, no shading and a heading and magnification must be shown.

### Example:



## Graphs:

The type of graph required depends on the type of data collected. In biology, the most common type of graph will be one that shows a relationship between two variables.

This type of data is best represented using a line graph.

### Line graphs require:

- A descriptive title.
- Labelled axes with units.
- A line of best fit.
- The independent variable (the variable you are in control of changing) goes on the x-axis.
- The dependant variable (the thing that you are recording) goes on the y-axis.

## Example:

### 3. Setting Up and Labelling the Axes

Graphs represent a relationship between two variables. When choosing which variables to put on each axis, remember that there is usually an independent variable (which the investigator chooses) and a dependent variable. For example, if students wish to find out how far a runner could run in 15 seconds, they may choose to measure the distance covered every 5 seconds. The time of each measurement has been chosen by the students and is the independent variable. The distance that is measured is therefore the dependent variable. Usually the independent variable is plotted on the horizontal x-axis and the dependent variable on the vertical y-axis. After deciding on the variable for each axis, you must clearly label the axes with the variable and the units in which the variables are measured. The unit is written in brackets after the name of the variable.

### 4. Setting Up the Scales

Each axis should be marked into units that cover the entire range of the measurement. For example, if the distance ranges from 0 m to 96 m, then 0 m and 100 m could be the lowest and highest values on the vertical scale. The distance between the top and bottom values is then broken up into equal divisions and marked. The horizontal axis must also have its own range of values and uniform scale (which does not have to be the same scale as the vertical axis).

#### The most important points about the scales are:

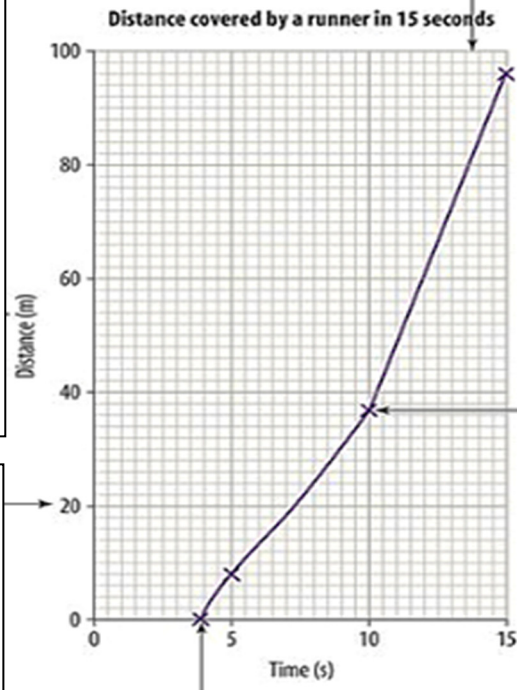
- They must show the entire range of measurements.
- They must be uniform; that is, show equal divisions for equal increases in value.

### 2. Title

Tell the reader what the graph is about! The title should describe the results of the investigation or the relationship between variables.

### 1. Grid

Graphs should always be drawn on grid paper to ensure that the values are accurately placed. Drawing freehand on lined or plain paper is not accurate enough for most graphs.



### 5. Putting in the Values

A point is made for each pair of values (the meeting point of two imaginary lines from each axis). The points should be clearly visible. Include a point for (0,0) only if you have the data for this point.

### 6. Drawing the Line

A line is then drawn through the points.

A line that follows the general direction of the points is called a 'line of best fit' because it best fits the data. It should be on or as close to as many points as possible. Some points follow the shape of a curve, rather than a straight line. A curved line that touches all the points can then be used.

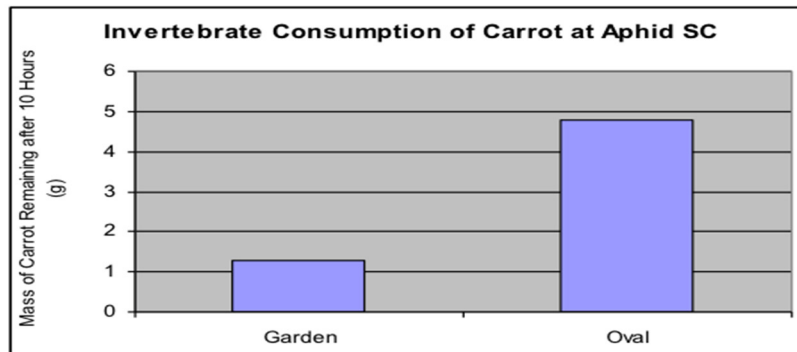
The type of data you are graphing may lead you to expect either a straight line or a curve. For example, you might expect the increase in temperature of water being boiled to be presented as a straight line because the temperature increases at a steady rate. A graph of the growth rate of a red panda would be curved and irregular because pandas have growth spurts. Inspection of the data will help you to decide whether your line should be a straight line or a smooth, curved line.

*Science Quest 8 Australian Curriculum Edition.*

A column graph is ideal for data presentation if two or more sets of data are discrete.

**Example:**

For an experiment where a petri dish containing grated carrot was left in two different locations overnight to investigate the number of invertebrates, the mass of carrot remaining in the garden is not directly linked to that remaining on the oval so a column graph would be more appropriate. Remember to leave a gap between the columns to show that the data is non continuous.



**CALCULATIONS:**

Calculations will only apply to particular experiments. All steps should be shown in a logical order and be clearly set out.

**Remember to:**

- Show all calculations including averages, additions and subtractions.
- Use the correct number of significant figures.
- Use SI units.
- If a calculation is repeated a number of times, the full working out can be shown once as an example and the others can be recorded in a table.

## **DISCUSSION:**

The discussion section is used to identify the significance and meaning of the results that were collected and to identify any flaws or errors that occurred.

The discussion should cover the following questions and is usually written in an essay style (i.e. not as a question and answer section). The general topics found in a discussion are:

### **Discussion of results:**

- What do the results show? How do they relate to known theory?
- Do the results answer the aim?
- Are the results consistent with those reported by other groups?
- For quantitative experiments, compare your value to the expected value.

### **Errors and Uncertainties:**

- If the results were not as expected, what are some possible explanations?
- What errors occurred and how did they affect the results?
- Comment on the overall error or % uncertainty in your quantitative results if possible.

### **Evaluation:**

- How could the experiment be improved?
- Were there any variables that should have been controlled but were not?
- Should more data have been collected in order to draw clearer conclusions?
- Could any of the errors and uncertainties be reduced or eliminated?
- Could the data have been measured more accurately?

## **FOCUS QUESTIONS:**

Sometimes there will be questions included on the practical sheet for you to answer. These questions should be answered in the discussion.

## **CONCLUSION:**

This is a brief statement of what you found out and may link with the final paragraph of your 'Discussion'. It is a good idea to read your 'Aim' again before you write your conclusion. Your conclusion should also state whether your hypothesis was supported. Don't be disappointed if it is not supported. Some scientists deliberately set out to reject hypotheses!

## SOME POINTS REGARDING ERRORS, MISTAKES AND UNCERTAINTIES

There are three types of errors that can occur during an experiment.

- i. **Human errors** in which the experimenter makes mistakes either in using equipment and instruments or in his or her mathematics.

These types of errors can often be reduced if you conduct an experiment carefully.



- ii. **Systematic errors** in which an item of equipment gives consistently high (or low) results and which is peculiar to that item of equipment.



- iii. **Random errors** due to the statistical spread of results that are quite normal, even when repeating a single measurement, a large number of times (e.g. the slight leaning on a bench can alter electronic scale measurements of the same item).



# HOW TO AVOID, IDENTIFY AND ESTIMATE ERRORS

## HUMAN ERRORS

- Be careful
- Repeat your experiment to make sure you haven't made a mistake.

*Measurements involving mistakes must be rejected and must not be included in any calculations. However, they should be recorded in your results and the reason for their rejection, if known, should be given.*

## SYSTEMATIC ERRORS

- Try to use the same piece of equipment when measuring data.
- Choose the equipment with an appropriate scale, that is, don't use a 100 mL beaker to measure 1 mL of water.
- Calibrate the equipment – this is often long and tedious, yet it ensures the equipment measures accurately.
- Try to use the same equipment to measure the same sample, for example, always use the same thermometer to measure the temperature change in a specific cup of water.
- Measure the same substance with different pieces of similar equipment and take an average.

## FORMING A HYPOTHESIS

Some experimental work will require you to form a hypothesis rather than stating an aim.

An aim identifies the purpose of the investigation. It is a straightforward expression of what the researcher is trying to find out from conducting an investigation. The aim typically involves the word "investigate" or "investigation".

A hypothesis is a precise, testable statement of what the researchers predict will be the outcome of the study. This usually involves proposing a possible relationship between two variables: the independent variable (what the researcher changes) and the dependant variable (what the research measures). Often a hypothesis is formulated in a statement;

"if y is done, then z will occur because.....".

Answering the "because" in this hypothesis is an important part of the criteria being evaluated. The known theory must be used to substantiate your hypothesis. The theory may be part of an introduction or abstract.

	Aim or Hypothesis?	
To determine the effect of light intensity on the rate of photosynthesis.		
If the temperature is increased a reaction will occur at a faster rate.		
When the volume of a gas is increased, the pressure will decrease if the temperature is held constant.		
To investigate the effect of caffeine on academic performance.		
Academic performance is not affected by drinking caffeine.		



## HOW TO PROPOSE A TESTABLE HYPOTHESIS

### Tips for writing a hypothesis.

- Try to write the hypothesis as an if-then statement. IF you take an action (independent variable), THEN a certain outcome (dependent variable) is expected.
- Identify the independent and dependent variable in the hypothesis. The independent variable is what you are controlling or changing. You measure the effect this has on the dependent variable.
- Write the hypothesis in such a way that you can support or disprove it. For example, a person has skin cancer, you can't prove (you can never prove a hypothesis) they got it from being out in the sun. However, you can demonstrate a relationship between exposure to ultraviolet light and increased risk of skin cancer.
- Make sure you are proposing a hypothesis you can test with reproducible results. If your face breaks out, you can't prove it was caused by the french fries you had for dinner last night. However, you can measure whether or not eating french fries is associated with breaking out. It's a matter of gathering enough data to be able to reproduce results and draw a conclusion.

a	b	c	d	e	f
If... the DV)...	relationship phrase to the IV	... then...	trend indicator effect on the DV	... when...	trend indicator action by the IV
	...depends on... ...results from... ...is affected by... ...is directly related to...		...show an increase/decrease ... ...be greater than/less than... ...be larger/smaller...		... increased/decreased... ...greater/less... ...large/small...

### This hypothesis can be further extended to:

'If the growth of tomato seedlings is directly related to the number of daylight hours it receives, since photosynthesis uses light to make glucose, then the seedlings will show an increase in growth when they are exposed to an increased number of daylight hours.'

**Here is an excellent hypothesis for a cellular respiration experiment involving yeast:**

**'If** the glucose concentration is increased, **then** the amount of CO<sub>2</sub> produced will also increase. This is because glucose is used by yeast to make ATP through cellular respiration. The more glucose that is available, the faster the rate of cell respiration, and the more CO<sub>2</sub> that will be produced. CO<sub>2</sub> is a product of cell respiration in yeast, so the more CO<sub>2</sub> the faster the rate of cell respiration.



## AN EXAMPLE OF A MARKING SCHEME FROM VCE BIOLOGY PERFORMANCE DESCRIPTORS

VCE BIOLOGY SCHOOL-ASSESSED COURSEWORK					
Performance descriptors					
<b>Unit 3 Outcome 1 Explain the dynamic nature of the cell in terms of key cellular processes including regulation, photosynthesis and cellular respiration, and analyse factors that affect the rate of biochemical reactions.</b>	DESCRIPTOR: typical performance in each range				
	Very low	Low	Medium	High	Very high
	Very limited analysis and explanation of the dynamic nature of the cell in terms of key cellular processes.	Limited analysis and explanation of the dynamic nature of the cell in terms of key cellular processes.	Adequate analysis and explanation of the dynamic nature of the cell in terms of key cellular processes.	Well-developed analysis and explanation of the dynamic nature of the cell in terms of key cellular processes.	Comprehensive analysis and explanation of the dynamic nature of the cell in terms of key cellular processes.
	Very limited analysis of the factors that affect the rate of biochemical reactions.	Limited analysis of the factors that affect the rate of biochemical reactions.	Relevant analysis and explanation of the factors that affect the rate of biochemical reactions.	Detailed analysis and explanation of the factors that affect the rate of biochemical reactions.	Insightful analysis and explanation of the factors that affect the rate of biochemical reactions.
	Very limited application of the scientific method in the conduct of experiments with some analysis to recognise experimental errors and limitations.	Limited application of the scientific method in the conduct of experiments and some analysis to recognise experimental errors and limitations.	Adequate application of the scientific method in the conduct of experiments and satisfactory analysis to recognise experimental errors and limitations.	Skilled application of the scientific method in the conduct of experiments and well-founded analysis to recognise experimental errors and limitations.	Highly skilled application of the scientific method in the conduct of experiments and comprehensive analysis to recognise experimental errors and limitations.
	Incomplete collection and presentation of data with some use of qualitative and quantitative data from experiments, texts, tables, graphs and diagrams to draw conclusions.	Limited collection and presentation of relevant data and limited use of qualitative and quantitative data from experiments, texts, tables, graphs and diagrams to draw valid conclusions.	Appropriate collection and presentation of relevant data and appropriate use of qualitative and quantitative data from experiments, texts, tables, graphs and diagrams to draw valid conclusions.	Skilled collection and presentation of relevant data and well-considered use of qualitative and quantitative data from experiments, texts, tables, graphs and diagrams to draw valid conclusions.	Proficient collection and presentation of relevant data and highly skilled use of qualitative and quantitative data from experiments, texts, tables, graphs and diagrams to draw valid conclusions.
	Very limited use of biological terminology, representations and conventions.	Some appropriate use of biological terminology, representations and conventions.	Appropriate use of most biological terminology, representations and conventions.	Effective and appropriate use of biological terminology, representations and conventions.	Proficient and highly appropriate use of biological terminology, representations and conventions.

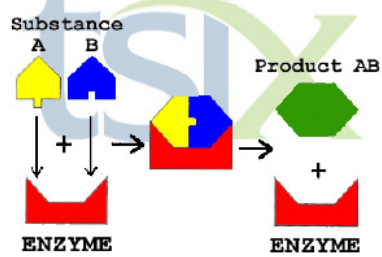
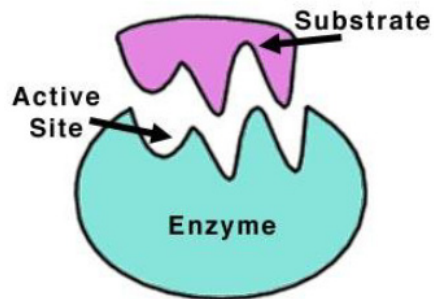
### KEY to marking scale based on the outcome contributing 50 marks

Very low 1–10	Low 11–20	Medium 21–30	High 31–40	Very high 41–50
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# BIOLOGY: PRACTICAL

## ENZYMES

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## **PART A**

### **INTRODUCTION**

Enzymes are specific proteins that serve as catalysts. They speed up or slow down reactions by decreasing the amount of activation energy required for a substrate to catalyse, but they remain unchanged upon doing so. Enzymes contain an important feature known as the active site. The active site is where the substrate binds to the enzyme, so that the substrate can either be broken down or bonded together with another. Each enzyme's active site is shaped specifically to allow for a specific substrate. However, there are certain factors such as temperature that can affect the active site, potentially resulting in a change of shape known as denaturation. The denaturation of an active site occurs when the optimum temperature range is exceeded; the optimum temperature range being the temperature in which an enzyme works most effectively. The enzymes found within liver are intracellular and have an optimum temperature of approximately 37.5°C. The higher the temperature leading up to the optimum temperature range, the more kinetic energy is in the system and therefore the substrates travel at a faster speed with more energy. This means there is a greater potential for collisions between substrate molecules and enzymes. However, if the temperature increases above the optimum temperature of 37.5°C, some of the weak bonds that shape the enzyme may be broken, leading to a thermal denaturation of the enzyme which leaves the enzyme or, more specifically, the active site, permanently inactive. An enzyme is considered to be denatured when the active site changes its shape so much that it is unable to catalyse substrates. In other words, it is when the tertiary stage of the enzyme is destroyed.

### **AIM**

To investigate the activity of enzymes and the effect temperature and surface area has on it.

### **HYPOTHESIS**

If the surface area of the liver increases by having the liver grounded, exposing the intracellular enzymes, then the rate of the reaction where hydrogen peroxide undergoes a catabolic reaction will increase due to an increased amount of enzymes, whereas if the temperature range of approximately 37°C, then the active site of the enzymes will become denatured and therefore no reaction will take place.

### **MATERIALS**

- Liver (fresh) finely cut
- 3 test tubes
- 3% hydrogen peroxide
- Mortar and pestle
- Hot plate/Bunsen burner
- Detergent
- Sand
- 100 ml beaker

## METHOD

1. Collect three small pieces of liver.
2. Place one in a beaker half filled with water and boil strongly for 5 minutes.
3. Place one in a mortar with a little sand and grind with the pestle.
4. Label the test tubes A, B and C and place 5 ml of hydrogen peroxide and 3 drops of detergent into each.
5. Into tube A place the fresh liver, into tube B the ground liver, and into tube C the boiled liver.
6. Record the height of the bubbles produced in each test tube and compare.

## RESULTS

Upon completing the practical investigation through following the outlined method, these are the results obtained.

TEST TUBE	WAS THERE A REACTION?	HEIGHT OF FOAM (mm)	SPEED OF FOAM
A (normal liver)	Yes- bubbles	Overflowed. If it hadn't, approximately 210mm	Fast
B (crushed liver)	Yes- bubbles	Overflowed. If it hadn't, approximately 220mm	Extremely Fast
C (boiled liver)	No noticeable reaction	0mm	N/A

## DISCUSSION

1. **Comment on the relative activity of the three samples.**

Test tube A which contained the normal liver had a relatively fast reaction rate. Foam and bubbles were produced upon the hydrogen peroxide and detergent being placed within the beaker, signifying that a chemical reaction involving the catalase enzyme has taken place. The rate of reaction, that is, the speed of the foam, was at a relatively fast rate meaning that the enzymes were able to catalyse the substrate of hydrogen peroxide quickly, most likely due to the amount of enzymes or a relatively normal temperature and pH level. The foam was at such a height that it overflowed over the test tube which was at a height of 160 mm, although it can be predicted due to the amount of substance which overflowed that there would be a total height of 210 mm of foam.

Test tube B which contained the crushed liver had a relatively extremely fast reaction rate. Foam and bubbles were once again produced once the substrate and detergent was placed within the beaker, although the speed of the reaction was one of a much faster rate in comparison to test tube A. This can be explained by the fact that the liver was crushed up, releasing the intracellular enzymes, creating more, and with more enzymes the speed of reaction will also be of a greater speed as the chance of a substrate molecule colliding with an enzyme increases. The foam once again overflowed over the 160 mm test tube, although foam was approximately 220 mm, relatively similar to test tube A. Theory would suggest that if the level of substrate is the same, the level of reaction would also be equal, due to the fact that there is only so much substrate which can be catalysed and the enzyme level will *only* affect the speed it takes for the reaction to reach that total. The 10 mm difference in foam between test tubes A and B is relatively small and is most likely a result of miscalculations, human errors, or environmental factors.

Test tube C which contained the liver which had been boiled for over five minutes had no noticeable reaction whatsoever upon the substrate and detergent being added to the test tube. There was no foam and therefore obviously no speed for the reaction. The reason for the denaturation of the enzymes would have occurred as the liver had been boiled for over five minutes with the boiling temperature being far greater than the optimum temperature range of the catalase enzyme. With the optimum temperature range being approximately 37.5°C, as the temperature increases beyond this, weak bonds which form the shape of the active site break, altering the shape of the active site and enzyme and making it permanently inactive due to the fact that the substrate can no longer fit into the enzymes. Due to this, no reaction occurred.

**2. Why could you estimate the amount of activity of catalase by observing the amount of bubbling in the test tubes?**

Foam is a result of the substrate of hydrogen peroxide becoming catalysed due to the catalase enzyme and lets off oxygen in the form of bubbles as a result of the reaction. This reaction can be written as  $2H_2O_2 \rightarrow 2H_2O + O_2$ . Therefore, the higher the amount of bubbles produced, the higher the amount of enzyme activity, as the bubbles or foam signify such activity.

**3. What was the control used in this experiment? What variables were being tested in the other two test tubes?**

The control in this experiment was test tube A, as test tube A contained the relatively regular state for enzymes and the liver had not been severely tempered with or altered in any way. Test tubes B and C had varying factors and were therefore compared to test tube A in order to calculate the effects of the differences in both test tubes B and C in comparison to A. Test tube B contained the crushed liver and had a fast reaction. Although in order to work out the relative speed of the reaction, it needs to be compared to a standard piece of liver, that being test tube A. It was then determined that test tube B contained a relatively *extremely* fast reaction. Test tube C contained no noticeable reaction whatsoever although without a control it would be impossible to obtain whether this is supposed to happen or not.

**4. What effect does grinding up the liver have on enzyme activity? Explain why.**

The effect that grinding up liver has on the enzyme is one of great significance. The catalase enzyme is intracellular and therefore many enzymes are not able to be used, such as in a regular piece of liver such as test tube A. However, grinding the liver breaks down cellular membranes which results in the release of many intracellular enzymes, increasing the overall enzyme count. With the overall amount of enzymes increased, the substrate can be catalysed more efficiently and with a greater speed. This is demonstrated through the results, as test tube B had a much faster reaction in comparison to test tube A, the control of the experiment. This proves that grinding up the liver increases the amount of enzymes, which increases the amount of collisions between the substrate and enzymes and therefore amplifies the overall enzyme activity, as witnessed through the relatively extremely fast reaction rate of bubbles and foam in test tube B.

**5. Account for the reaction rate seen in test tube C.**

The reaction rate seen in test tube C was near to none. This is for the simple reason that the active site within the catalase enzyme has been denatured, meaning that the tertiary structure of the enzymes are completely destroyed, leaving it permanently inactive and unable to catalyse the substrate. The optimum temperature range for the catalase enzyme is approximately 37.5°C and as the liver within test tube C was boiled at a temperature well above this for over five minutes, the enzymes within the liver became denatured and instead of usually lowering the activation energy required to catalyse a substrate, they can no longer do so meaning no reaction can take place. This is evident due to the fact that the bubbles or foam which indicate that the chemical reaction  $2H_2O_2 \rightarrow 2H_2O + O_2$  has taken place was not apparent. If there was any slight bubbling of any sort, this may be for the reason that the odd enzymes were not entirely denatured.

**6. Explain the importance of enzymes in metabolic reactions.**

Enzymes are vital biological catalysts and are essential for us to live. Enzymes speed up chemical reactions throughout the body whether it is an anabolic or catabolic reaction. They are able to do so through lowering the necessary activation energy required to catalyse substrates by capturing the substrate within its active site through the induced fit or 'lock and key' mechanism. Without enzymes, these relatively simple reactions would take a significant amount of time, perhaps even thousands of years, far longer than what is required to be able to live.

Our metabolism is involved with many processes such as the synthesis of organic molecules, energy transformation and the breakdown of unwanted substances. All of these processes require hundreds of enzymes in order for reactions to be sped up to a sufficient speed. These enzymes are used in a chain reaction, when the product of one reaction is used as the product for the next, and so on, with the shape of the product evolving and changing with more reactions. Another significant and important fact about enzymes is that they can be reused over and over again and are not affected or altered by catalysing a substrate. This means that enzymes can constantly be reused and are always useful, unless denatured.



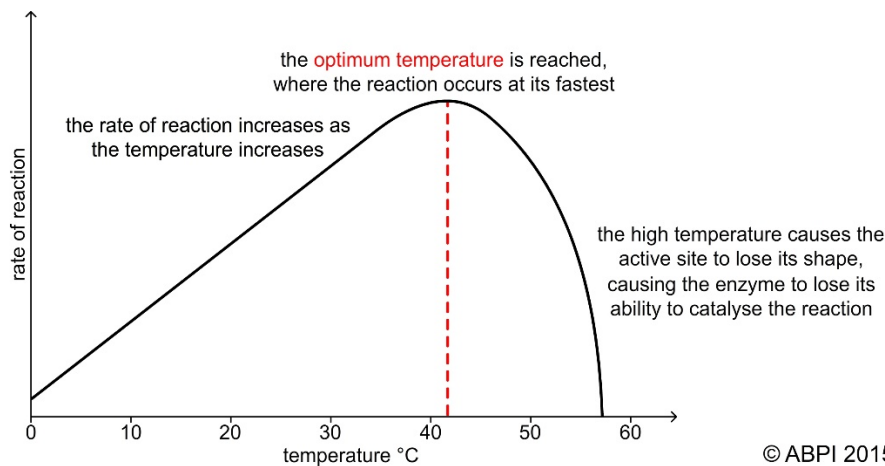
## 7. How do enzymes increase the rate of reactions?

Enzymes increase the rate of reaction by providing an alternative route to products which requires a far less amount of activation energy. With less energy required to catalyse substrates, there is a far greater potential for a substrate to be catalysed through an enzyme rather than *without* the assistance of an enzyme. All enzymes have an active site. The active site is where the enzyme binds to the substrate and where the chemical reaction occurs. Whether it is an anabolic or catabolic reaction, enzymes bond with the substrate through the 'lock and key' or induced fit mechanism. The 'lock and key' mechanism can be described as an exact fit, while the 'induced fit' mechanism is when the enzyme adjusts its shape slightly in order to accommodate the substrate. Once the substrate has bonded with the enzyme, it can then be catalysed using a substantially lower amount of activation energy in comparison to if no enzyme were present.

Obviously with the more enzymes present, the higher the chance of the substrate colliding with an enzyme, and therefore the rate of reaction is increased. An analogy for this is if there was a long line for the toilets, with only one toilet present, that toilet can only accommodate one person at a time and therefore the line would move slowly (slow reaction rate). However, if ten more toilets were added, the line would move substantially quicker and the reaction rate would increase. Not only do enzymes substantially increase reaction rate through lowering the activation energy required for biological reactions, the more enzymes present would increase the rate of reaction even further.

## 8. Explain why there is a reduction in activity in enzymes exposed to high temperature. What happens to the enzymes when temperature returns to normal?

All enzymes have an optimal temperature range. An optimal temperature range is the temperature of which the enzyme will be most efficient. The catalase enzyme has an optimal temperature of 37.5°C. The level of enzyme activity increases higher and higher as the temperature goes up, leading to the optimal temperature range. However, once the temperature exceeds this temperature and gets to around 45°C, the rate of activity dramatically drops as the enzyme is beginning to become denatured due to the excessive heat which weakens and breaks the weak bonds in the tertiary structure of the enzyme which forms the shape of the active site. The higher the heat, the more deformed the active site becomes until it is eventually unable to bind to the substrate due to the difference in shape. The higher the temperature, the greater the percentage of enzymes which have lost their shape and the less likely it is for an enzyme to catalyse the substrate. Therefore, the higher the temperature is above the optimal temperature range, the less enzyme activity. Once the temperature reaches approximately 60°C, the enzyme becomes completely and permanently denatured and is 100% inactive and therefore useless. As the denaturation of enzymes is a chemical reaction and therefore permanent, once the temperature returns to normal that enzyme is still denatured as denaturation is a permanent process.



**9. Using the information that you have gained about enzymes, explain why high fevers may be dangerous.**

Remembering the fact that an increment of heat above the optimal temperature range denatures enzymes and slows the enzyme activity, high fevers may be extremely dangerous. Enzymes are important for many biological processes including the synthesis of organic molecules, energy transformations and the breakdown of unwanted substances. Without enzymes, these processes would not occur at a high enough rate and life would not be possible. If enzymes are required for many biological reactions that are essential to life, and the rate of enzyme activity decreases shortly after surpassing the optimal temperature range, then a high fever is potentially dangerous as certain essential reactions are simply not happening fast enough.

Even though enzymes denature at a temperature above the optimal temperature range, enzyme activity is still increasing at a temperature of approximately 41°C, well above the optimal temperature range. This means that the activity of enzymes is increased and therefore so is the metabolic rate. Many normal metabolic processes would therefore be affected by this. An increased heart rate is possible as well as muscle cell death and dehydration.

## **CONCLUSION**

Through conducting this experiment, it can be determined that temperature withholds a significant influence on the activity of enzymes. The higher the temperature leading up to the optimal temperature, the faster the enzyme activity as heat creates more energy. However, as the temperature begins to exceed well past the optimal temperature of the catalase enzyme (37.5°C), weak bonds in the tertiary structure of the enzyme break apart, deforming the shape of the active site so it can no longer catalyse substrates, therefore making the enzyme denatured. The experiment also determine that surface area of the liver plays a role on the enzyme activity rate, due to the fact that the catalase enzyme is intracellular. As the liver is grounded up, cell membranes are being broken, releasing the intracellular enzymes. The results prove that the more enzymes, the faster the level of reaction; however, the level of reaction does not change as long as the level of substrate remains the same.

## **PART B – EFFECT OF pH ON ENZYME ACTIVITY**

### **INTRODUCTION**

Enzymes are specific proteins that serve as catalysts. They speed up or slow down reactions by decreasing the amount of activation energy required for a substrate to catalyse, but they remain unchanged upon doing so. Enzymes contain an important feature known as the active site. The active site is where the substrate binds to the enzyme, so that the substrate can either be broken down or bonded together with another. Each enzyme's active site is shaped specifically to allow for a specific substrate. However, there are certain factors such as pH level that can affect the active site, potentially resulting in a change of shape known as denaturation. The denaturation of an active site can occur when the pH level is either too low or too high from its optimum pH level being the pH level in which an enzyme works most effectively. pH is measured on a scale from 0 – 14. 7 is considered to be neutral while anything below it is said to be acidic and anything above it is alkaline. The lower the number on the scale, the more acidic is the substance. If the pH level is too high or too low, the bonds in the enzyme break, permanently changing the shape of that enzyme so that the substrate can no longer bond to the enzyme.

### **AIM**

To investigate the effect that pH level has on the activity of enzymes.

### **HYPOTHESIS**

If the liver is exposed to a level of pH which deviates from the optimum pH range, then the rate of reaction where hydrogen peroxide undergoes a catabolic reaction will significantly decrease due to the level of enzyme activity decreasing as a result of it denaturing.

## MATERIALS

- Liver (fresh) finely cut
- 3 test tubes
- 3% hydrogen peroxide
- Detergent
- 5 ml HCl
- 5 ml NaOH

## METHODS

1. Collect three small pieces of liver.
2. Collect three test tubes and label them A, B and C and place 5 ml of hydrogen peroxide and 3 drops of detergent into each. Place an additional 5 ml of NaOH into test tube B and 5 ml of HCl into test tube C.
3. Place one piece of fresh liver into each test tube.
4. Record the height of the bubbles produced in each test tube and compare.

## RESULTS

TEST TUBE	WAS THERE A REACTION?	HEIGHT OF FOAM (mm)	SPEED OF FOAM
A (normal liver)	Yes- bubbles	Overflowed. If it hadn't, approximately 210mm	Fast
B (NaOH)	Yes- bubbles	Overflowed. If it hadn't, approximately 190mm	Slow
C (HCl)	Weak reaction. >1mm bubbles	0mm	N/A

*These are the results obtained upon the completion of the experiment.*

## DISCUSSION

### 1. Did the results support or disprove your hypothesis?

The results obtained strongly support the hypothesis. Test tube A which contained liver not exposed to additional chemicals contained the fastest enzyme activity rate indicating that the pH level was at the optimal temperature range due to the fact that there were no additional chemicals altering the optimal pH level of the catalase enzyme found within the liver. Due to this, the results were in line with what the hypothesis had stated and there was a fast reaction rate which produced bubbles as a result, which overflowed the 160 mm test tube as well as an additional 50 mm of spillage producing a cumulative total of 210 mm of bubbles. The fact that bubbles were produced is a result of the chemical reaction  $2H_2O_2 \rightarrow 2H_2O + O_2$  taking place.

Excess oxygen was produced as a result, as evident through the bubbles that were produced. The speed of the reaction was one of a fast pace, suggesting the enzymes were at their pH optima.

Test tube B which contained the additional sodium hydroxide (NaOH) had a slow but consistent reaction. Bubbles were produced as a result of the experiment suggesting that at enzyme activity was clearly evident. However, the rate of which the bubbles were made was at a relatively slow rate suggesting a low amount of enzyme activity. This is due to the pH level of NaOH not being at the optimal range for that of the catalase enzyme. The catalase enzyme functions most efficiently with a neutral pH level of approximately 7. However, the pH level of NaOH is approximately 14. Although the substrates were still catalysed as proven by the production of oxygen bubbles, it occurred at a relatively slow rate suggesting a poor enzyme activity as a result, caused by the NaOH. Having said this, the amount of bubbles produced overflowed the 160 mm test tube as well as an extra spillage of approximately 30 mm producing a cumulative total of 190 mm of oxygen bubbles. This is relatively very similar to the level of substrate (hydrogen peroxide) remained the same in both test tubes, meaning that the amount of substrate being catalysed is relatively equal in both test tubes. Enzymes do not produce more reaction, they only increase the speed of which it occurs. This explains why although both test tubes A and B produced the same amount of oxygen bubbles suggesting the same amount of reaction, they occurred at different speeds due to the difference in enzyme activity caused by the NaOH affecting the ideal pH level of test tube B.

Test tube C which contained hydrochloric acid (HCl) had little or no reaction. HCl has a pH level of approximately 1, highly acidic. This is far from the optimal pH level of 7 in which catalase contains. As a result, the non-existent reaction occurred. Due to the strong acidic nature of HCl, this broke down weak bonds in the tertiary structure of the catalase enzyme, deforming the active site as a result so that it no longer can bond to substrates due to the denaturation of the active site. This explains why little to no enzyme activity was evident in test tube C. The only reaction was very light "fizzing" within the solutions. This is an indicator that some enzyme activity is evident, most likely as a result of not all of the enzymes being 100% denatured. In comparison to test tube A which had a fast reaction rate, it is evident that the high acidic rate far from the pH optima of catalase affected the rate of enzyme activity within the solution.

Therefore, all results strongly correlated with the hypothesis.

## **2. What features of your experimental design ensured that it was controlled?**

There were many features of the experimental design that ensured that the experiment was controlled. Many aspects and features of the experiment were consistent or equivalent, with minimal change between each test tube. This ensured the consistency and control of the experiment. Test tube A was the control of the experiment, due to the fact that no additional bases or acids were added to it, as opposed to test tubes B and C where NaOH and HCl were added to the test tubes respectively. Due to test tube A containing no additional chemicals, the catalase enzymes were at their pH optima due to there being no additional chemicals evident that are not in correspondence with the pH optima of catalase. Therefore, with nothing to alter the pH level, the pH level was at its optimum, therefore producing the optimum enzyme activity. In other words, test tube A contains the normal pH level for which the catalase enzyme activity can take place, therefore making the test tube A the control of the experiment. Test tubes B and C are the test tubes tested upon which don't contain the normal pH level for catalase and the results of test tubes B and C are compared to test tube A in order to determine what effect test tubes B and C contained.

Other elements within the experiment ensuring the control and reliability of the results include many measured consistencies between each of the three test tubes. Only one piece of liver was placed within each test tube, with each piece being relatively equal in size. This ensured the experiment was controlled due to the fact that the same amount of enzymes was present within each of the three test tubes. Three drops of detergent was also added into each test tube with no more or no less in any of the three test tubes. Each test tube also contained 5 ml of hydrogen peroxide meaning each test tube contained the same amount of substrate. Therefore, the only alternating factor between each test tube was the pH level due to the additional chemicals in test tubes B and C, and therefore it can be determined that it was the pH level that affected the results rather than any other factor. All these measures were taken in order to ensure that the experiment was controlled.

## **3. Explain how or why the experimental method and equipment used could have been improved.**

The experimental method and equipment could have been improved in many ways. The pH scale ranges from 1 – 14, yet with the exception of the control of the experiment in test tube A, only chemicals with a pH level of 1 and 14 were tested on the liver. This provides the outcome of the experiment with inconclusive and unreliable results. If the enzyme activity of catalase per specific levels of pH was measured on a line graph, to draw the curve of the graph would be very inaccurate with only the results for a pH level of 1, 7 and 14 being obtained. To improve the accuracy of the results, the experimental method should have included more tests on different pH levels in order to provide a stronger indication as to how certain pH levels affect the rate of enzyme activity.

The equipment could have improved in order to more accurately accommodate the reactions of the experiment. Both test tubes A and B contained a reaction of oxygen bubbles which overflowed over the top of the test tube, making it very difficult to accurately record or distinguish between results. A more practical approach to the experiment would be to either have longer test tubes to accommodate such reactions, or alternatively wider test tubes or even a beaker. Another way to ensure no spillage occurs is to reduce the level of substrate within each test tube, perhaps reducing the level of bubbles by 50%. To improve and make all results precise, measures could be taken such as measuring the liver, weighing the liver, accurately measuring chemicals as well as the bubbles and many other things which would guarantee equality between each of the test tubes within the experiment, allowing more precise results as to the effect of pH on enzyme activity.

## CONCLUSION

Through conducting this experiment, it can be determined that pH level plays a significant role as to the level of enzyme activity. Each enzyme has its own pH optima, with the pH optima of catalase being 7. The results prove that when the pH level remains at seven, the faster the enzyme activity. The faster the enzyme activity, the faster the substrate is catalysed. The experiment also outlines that the enzyme activity is reduced or halted altogether if the pH level is not near the pH optima. NaOH containing a pH of 14 still produced bubbles as a result of the experiment but at a slow rate, suggesting enzyme activity is still present but just not working most efficiently due to the difference in pH level. HCl containing a pH of 1 (highly acidic) almost entirely prevented the substrate of hydrogen peroxide to be catalysed. This is also due to the difference in pH level. In conclusion it is safe to confidently state that although the catalase enzyme activity is most efficient at a pH of 7, it is still slightly efficient at a pH of 14, while hardly at all efficient at a pH of 1. Therefore, the closer the pH level is to that of the pH optima, the better the enzyme activity rate.

