Cambridge NATIONALS

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SAMPLE LEARNER WORK WITH COMMENTARY

UNIT R073: HOW SCIENTISTS TEST THEIR IDEAS

SCIENCE

Level 1/2

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CONTENTS

INTRODUCTION

This is a guide for teachers so that you can see how we would mark work, Cambridge Nationals are designed to give the learners the project and let them create the work.

The guide contains sample learner work for this unit and covers all learning objectives, graded at Marking Band 1 (MB1) and Marking Band 3 (MB3).

The accompanying commentary explains why each piece of work was awarded its grade.

For MB1 graded work, additional guidance has been added to suggest improvements that could be made to make it an MB2 graded piece of work.

For MB3 graded work, additional guidance has been added to explain why it was awarded that grade and not the lower grade of MB2.

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Burning fuels – Sample Learner Work Marking Band 1

The following sample learner work is relevant to learning objectives 1, 2 and 5.

SAMPLE LEARNER WORK

Burning fuels - Alcohol as a fuel

Research

When fuels are burnt they give out heat and light energy. We can use fuels in cars to make them go.

Instead of fossil fuels we can use alcohol. Alcohol can be made by fermenting sugar and yeast. Ethanol is an alcohol and can be made from sugar.

Equation:

sugar > ethanol + carbon dioxide

They are made up of carbon and hydrogen atoms, each have different numbers of carbon atoms.

Ethanol is C_2H_5OH

Some alcohols:
Methanol
Ethanol
Propanol
Butanol.

Alcohols will burn in oxygen making carbon dioxide, water and gives out heat (energy).

e.g.

ethanol + oxygen > carbon dioxide + water

Burning ethanol gives out less energy than burning petrol or diesel. Ethanol also absorbs water which is corrosive in car engines.

I got my information from BBC Bitesize.

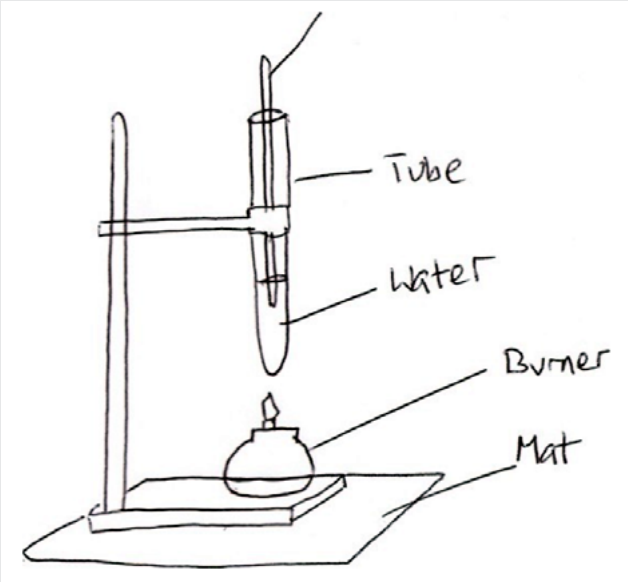
Plan

I am going to investigate if more carbon atoms in alcohol gives more heat energy when I burn them.

Equipment needed
Boiling tube
Clamp stand
Water
Measuring cylinder
Thermometer
Heat proof mat
Spirit burner
Alcohols
Balance
Ruler

SAMPLE LEARNER WORK

Method



- Put the boiling tube in clamp
- Put 100ml water in tube
- Put alcohol in spirit burner
- Weigh spirit burner
- Measure temperature of water
- Light spirit burner
- Leave for 3 minutes
- Put spirit burner out
- Measure temperature of water.

I will do this three times to make it accurate.
I will do the same for all the alcohols.

To make it a fair test

I will keep the same
Amount of water.
Distance between the wick and the boiling tube.
Keeping the amount of water the same and the distance between the wick and the boiling tube will mean that I'll have less errors.

I will measure
Temperature at start and the end and then work out the change.
Measure the mass of spirit burner at the start and end and then work out the alcohol burnt.

SAMPLE LEARNER WORK

Risk assessment

Keep to the rules of the laboratory.

- Tie hair back
- Tuck tie into shirt
- Wear goggles
- Put bags under desk

Hazard	Risk	Prevention
Spirit Burner	Break and cut Burn	Keep on heat proof mat Keep hair away from flame
	explode	Keep away from flames
Boiling tube	Break and cut Burn you	Keep tube in clamp Do not touch when hot
Measuring cylinder		Clear up breakages
Alcohol	Burn Fumes poisonous	Check Hazard Check CLEAPPS Report accident to teacher

Alcohol Methanol

Test	Start temp	End temp	Change (°C)	Start mass	End mass	Change (grams)
1	19	71	52	188.71	185.45	3.26
2	21	76	55	186.57	183.22	3.35
3	20	70	50	187.22	184.03	3.19
	Average		52.3333	Average		7.6733

Learning Objective 1 - Be able to plan a scientific investigation

Marking commentary on MB1 sample learner work

The report includes an outline plan, in bullet point form, variables and equipment list with diagram. There is mention of fair testing and minimising errors. Limited use has been made of secondary data/information; word equations have been given and chemicals symbols giving ethanol have been used.

Suggested improvements to progress sample learner work to MB2

The research is supported by only one source and not a range. Information is given that is relevant to the investigation although alcohols are listed their chemical structure is not, apart from ethanol. Explanation should be on the number of carbon atoms within the different alcohols as this is the focus of the investigation. The equipment is listed but there is no indication as why it was chosen. Although the idea of a fair test is indicated there is no explanation for the choice of the range and number of data points or for the number of replicates. The plan would be difficult to be followed by another person that was unfamiliar with the investigation.

Learning Objective 2 - Be able to collect scientific data

Marking commentary on MB1 sample learner work

There is a reasonable risk assessment, though the flammability of the alcohols is not cited. On the Unit Recording Sheet, the centre will indicate that careful supervision was required when igniting the alcohols. The limited results were recorded satisfactorily with headings and a unit.

Suggested improvements to progress sample learner work to MB2

A reasonable risk assessment has been given with some responses to prevent risk but no reference to the alcohol hazards has been presented.

Most risks should be managed successfully with no significant incidents or accidents and no requirement for teacher intervention is needed.

Little support should be required to set up the equipment.

The results have been recorded in table form but units have not always been applied to headings and the headings are not always clear.

Learning Objective 5 - Be able to communicate scientific information

Marking commentary on MB1 sample learner work

There is some limited use of scientific, technical and mathematical language.

There are some errors in SPG. A simple hand drawn diagram with some labelling has been presented.

Suggested improvements to progress sample learner work to MB2

Information was presented in a structured format but the use of scientific, technical and mathematical language, conventions and symbols were limited.

There are opportunities in both writing up the research and evaluation to display a sound knowledge of the science involved in the investigation.

Diagrams were simple and hand drawn not conforming to scientific conventions, not even a ruler was used.

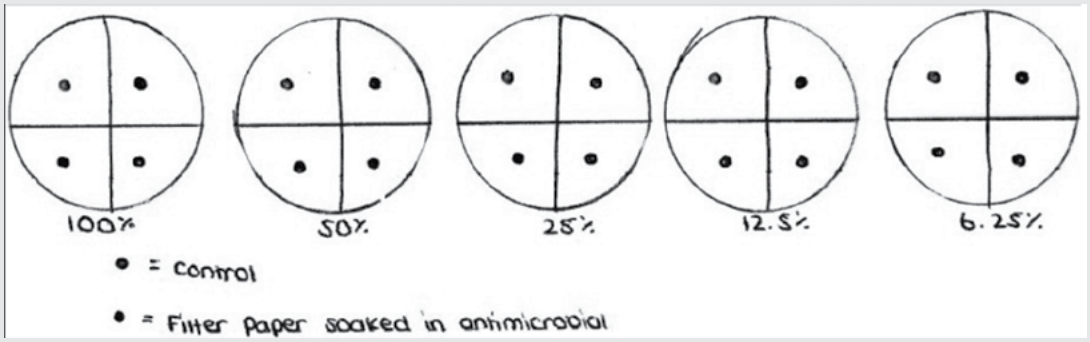
Antimicrobials – Sample Learner Work Marking Band 1

The following sample learner work is relevant to learning objectives 3, 4 and 5.

SAMPLE LEARNER WORK

Antimicrobials

Recorded results

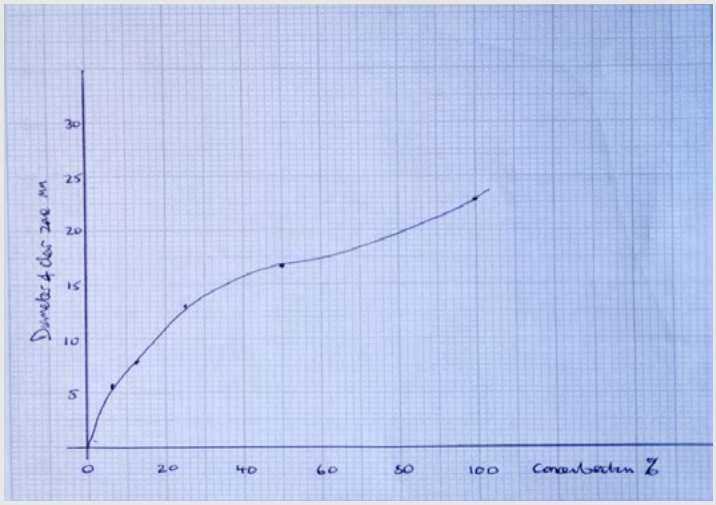


5 petri dishes and the different concentrations.

The diameter of the clear zone is measured with a ruler.

Concentration	Test				Average diameter mm of clear zone
	1	2	3	4	
	dia	dia	dia	dia	
100%	22	24	23	22	22.75
50%	16	18	17	16	16.75
25%	12	13	14	13	13
12.5%	7	8	8	9	8
6.25%	5	5	7	6	5.75

I use all my data to work out the mean and there were no outliers so my results are accurate and reliable.



My graph shows a pattern, I have found that the higher the concentration of the antimicrobial, the faster it can kill pathogens, as it has more particles of antimicrobial.

The bacteria we used was called Bacillus subtilis and the antimicrobial called hydrogen peroxide.

Learning Objective 2 - Be able to collect scientific data

Marking commentary on MB1 sample learner work

There is a reasonable risk assessment, though the flammability of the alcohols is not cited. On the Unit Recording Sheet, the centre will indicate that careful supervision was required when igniting the alcohols.

The limited results were recorded satisfactorily with headings and a unit.

Suggested improvements to progress sample learner work to MB2

A reasonable risk assessment has been given with some responses to prevent risk but no reference to the alcohol hazards has been presented.

Most risks should be managed successfully with no significant incidents or accidents and no requirement for teacher intervention is needed.

Little support should be required to set up the equipment.

The results have been recorded in table form but units have not always been applied to headings and the headings are not always clear.

Learning Objective 3 - Be able to analyse scientific information

Marking commentary on MB1 sample learner work

Means have been presented in the table, with raw data.

A graph was plotted although difficult to read the points plotted.

Simple trend in data described.

Suggested improvements to progress sample learner work to MB2

A simple mathematical technique has been used to calculate means. However the significant number used in the mean is inappropriate to the accuracy to which the initial measurement was taken. The values should be rounded up to reflect the accuracy of the measurements taken.

There was no qualitative treatment of the levels of uncertainty in the data.

The mathematical technique needs to be extended by calculating percentage error, substitution in an equation or calculation of the area of a simple shape.

How the anomalous result was identified needs to be explained. There was no real consideration of the accuracy within the experiment made.

The whole sheet of graph paper should be used to give the appropriate scale for the graph axis which in turn will allow greater precision when plotting points.

Learning Objective 4 - Be able to evaluate scientific information

Marking commentary on MB1 sample learner work

Claim for 'no outliers' made, and suggestion that this is because the data show a trend.

A simple conclusion has been provided.

There is some (limited) application of knowledge and understanding from R071 – How scientific ideas have an impact on our lives.

Suggested improvements to progress sample learner work to MB2

No real relevant comments were made about the quality of the data including accuracy and sources of error, linked to the methods of collection within the evaluation.

No suggestions for improvements were given.

Although a simple conclusion was given it was not justified based on an analysis of the data.

Only a limited rather than a sound understanding of the underlying science was demonstrated.

There must be some explicit link between the description of the pattern/trend and the data from which it is derived. The explanation of the trend/pattern must have some science in it and be largely correct.

Any anomalies in the data should have been spotted and taken into account.

A comparison between own results and secondary data should be made and reasons for similarities or differences suggested.

Learning Objective 5 - Be able to communicate scientific information

Marking commentary on MB1 sample learner work

There is some limited use of scientific, technical and mathematical language.

There are some errors in SPG. A simple hand drawn diagram with some labelling has been presented.

Suggested improvements to progress sample learner work to MB2

Information was presented in a structured format but the use of scientific, technical and mathematical language, conventions and symbols were limited.

There are opportunities in both writing up the research and evaluation to display a sound knowledge of the science involved in the investigation.

Diagrams were simple and hand drawn not conforming to scientific conventions, not even a ruler was used.

Burning fuels – Sample Learner Work Marking Band 3

The following sample learner work is relevant to learning objectives 1, 2 and 5.

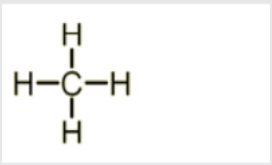
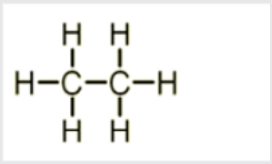
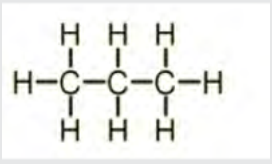
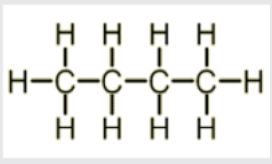
SAMPLE LEARNER WORK

Burning fuels - Alcohol as a fuel

Research

Chemical fuels are substances that release energy by reacting with oxygen by the process of oxidation. Most chemical fuels contain hydrogen and carbon.

Alkanes are saturated hydrocarbons with straight or branched chains which contain only carbon and hydrogen and have the general formula C_nH_{2n+2}. They generally have from 5 to 40 carbon atoms per molecule [1]

Alkane	Formula	Chemical structure
Methane	CH_4	
Ethane	C_2H_6	
Propane	C_3H_8	
Butane	C_4H_{10}	

Petrol is a blend of different chemical hydrocarbons which have large molecules made up of carbon and hydrogen such as isooctane (C_8H_{18}), even bigger molecules such as n-hexadecane ($C_{16}H_{34}$) are found in diesel fuel.

When a hydrocarbon fuel burns completely, the oxygen in the air combines with the hydrogen to form water (H_2O) and with the carbon to form carbon dioxide (CO_2).

Hydrocarbon + oxygen > water + carbon dioxide

for example methane:

$CH_4 + O_2 > H_2O + CO_2$

If the burning is not complete, then some of the carbon atoms only combine with one oxygen atom rather than two, to form carbon monoxide (CO), a highly poisonous gas.
For example when methane is burnt and if the oxygen supply is restricted then carbon monoxide is formed.

Methane + Oxygen > Carbon monoxide + Water

$2CH_4 + 3O_2 > 2CO + 4H_2O$

SAMPLE LEARNER WORK

Under ideal settings, where only hydrocarbon and oxygen are present, the chemical reaction combustion produces only water, carbon dioxide, and energy.

$CH_4 + 2O_2 > 2H_2O + CO_2 + Energy$

The energy gained from the reaction is greater than the energy put into the reaction. It is common knowledge that a spark is needed to make a hydrocarbon combust, the spark is the energy needed to break the carbon-carbon and carbon-hydrogen bonds of the hydrocarbon molecule as well as the oxygen-oxygen bond of the oxygen molecule.
Energy is then needed to make the bonds to produce the water and carbon dioxide.
The energy produced ΔH is given as:

$\Delta H = \sum \Delta H$ (bonds broken) - $\sum \Delta H$ (bonds formed)

Some alternative fuels are alcohols which contain oxygen atoms as well as carbon and hydrogen.
Traditionally, alcohol has been a popular alternative fuel in countries that produce large quantities of cereal crops. Sugar from the crops, or crop wastes, can be fermented by yeast to produce alcohol. In the USA, they use maize, for instance, and in Brazil, sugar cane. [2]
Alcohols burn more efficiently than petrol, thus increasing combustion efficiency. But alcohols absorb water and therefore become corrosive to engines. The longer the carbon chain, the more like petroleum fuels the alcohols become, and the less harmful to car engines. Higher-chain alcohols have energy densities close to petrol.
Ethanol is used as a fuel for cars either alone or in combination with other fuels, because of its environmental and long-term economical advantages over fossil fuel.

Alcohols will burn in oxygen to produce carbon dioxide, water and energy.

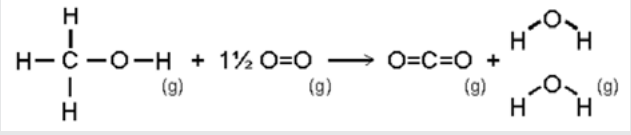
methanol + oxygen > carbon dioxide + water
$2CH_3OH + 3O_2 > 2CO_2 + 4H_2O$

propanol + oxygen > carbon dioxide + water
$2C_3H_7OH + 9O_2 > 6CO_2 + 8H_2O$

butanol + oxygen > carbon dioxide + water
$C_4H_9OH + 6O_2 > 4CO_2 + 5H_2O$

The energy given out involves breaking chemical bonds in the reactant molecules (an endothermic process) and forming new bonds in the products (an exothermic process).
Heat of Combustion of a substance is the heat liberated when 1 mole of the substance undergoes complete combustion with oxygen at constant pressure.
Combustion is always exothermic, the enthalpy change for the reaction is negative, ΔH is negative. [4]
By definition, the heat of combustion is minus the enthalpy change for the combustion reaction, ie, -ΔreactionH.

The energy produced can be calculated if the bond energies are known. The C-C bond requires 350 kJ/mol to break, the C-H bond requires 413 kJ/mol, and the O-O bond requires about 498 kJ/mol.
For example when methanol is burnt in oxygen:



SAMPLE LEARNER WORK

Total endothermic change for bond breaking	**Total exothermic change for bond making:**	**Bond Enthalpies in kJ/mol**
3 x C-H 1 x C-O 1 x O-H 1½ x O=O = (3 x +413) + +336 + +464 + (1½ x +498) = +2786 kJ	2 x C=O 4 x O-H = (2 x -805) + (4 x -464) = -3466 kJ	C-H = 413 C-O = 336 O-H = 464 O=O = 498 C=O = 805
ΔH = + 2786 + - 3466 = - 680 kJ/mol		

Typical energy values produced when burning alcohols:[3]

Alcohol		**Heat of combustion**
methanol	CH_3OH	ΔH = -726 kJ mol^{-1}
ethanol	C_2H_5OH	ΔH = -1367 kJ mol^{-1}
propanol	C_3H_7OH	ΔH = -2021 kJ mol^{-1}
butanol	C_4H_9OH	ΔH = -2676 kJ mol^{-1}
pentanol	$C_5H_{11}OH$	ΔH = -3329 kJ mol^{-1}
hexanol	$C_6H_{13}OH$	ΔH = -3984 kJ mol^{-1}

I can use the researched data to check the accuracy of my own results.

References

[1] BBC Bitesize. www.bbc.co.uk/education

[2] California Energy Commission. The alcohols – ethanol and methanol. Transportation Energy. A student's guide to alternative fuel vehicles. 2002. http://energyquest.ca.gov/transportation/alcohols.html

[3] Doc. Brown. Some enthalpy data patterns. The combustion of linear alkanes and linear aliphatic alcohols. 2000. http://www.docbrown.info/page07/delta1Hd.htm

[4] Wikipedia. Heat of combustion. 2012. http://en.wikipedia.org/wiki/Heat_of_combustion

SAMPLE LEARNER WORK

Planning

The combustion of alcohols is exothermic and in my experiment, I will use the energy released from burning a known mass of alcohol to heat a known amount of water. I can then compare the alcohols as fuels by calculating the quantity of energy transferred to the water. I will use the formula:

q	=	mcΔT
where q	=	energy transferred, in J
m	=	mass of water, in g
c	=	specific heat capacity of water, in J/g/°C
ΔT	=	temp change, in °C (or K)

I will measure the change in temperature from different fuels when they are burnt and heat water. From this I can calculate heat energy however some energy will be wasted as light energy.
I must consider the variables within the investigation.

Variables

The dependent variable, which I will be measuring, is the temperature rise of the water whilst the alcohol is burnt.

My independent variable is the alcohol which will have differing numbers of carbon atoms.

My control variables are:
- volume of water and so its mass, to be heated
- the same distance between the wick of the spirit burner and the boiling tube
- the same spirit burner each time. I will rinse it out each time with the new alcohol used.

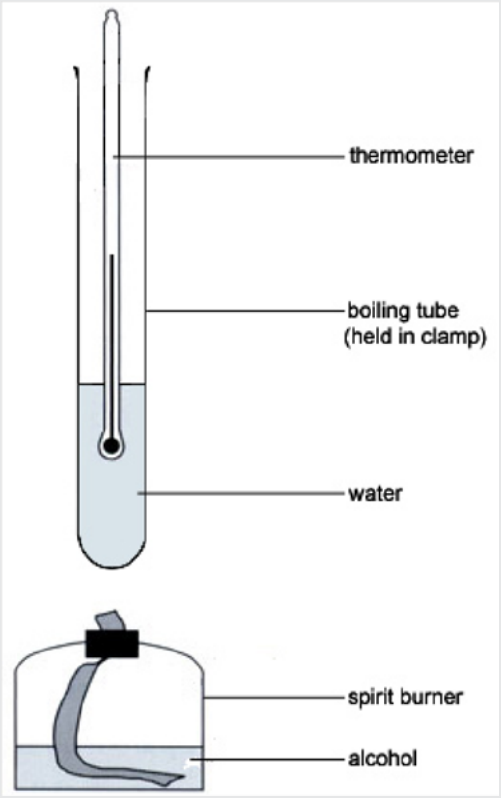
Equipment

- boiling tube to hold the water, the glass will allow me to take readings easily.
- clamp to hold the boiling tube at a set distance of 10cms above the wick (controlled variable).
- thermometer to take the temperature of the water, the thermometer readings to 1 degree ^{0}C so I can estimate to 0.5°C; my expected temperature rise will be in the range of 40°C so I can read to an accuracy of about 12%; the thermometer is an alcohol glass thermometer but a digital one would be more precise and can be read to 0.01°C so would increase the accuracy of the measurements to +/- 1%.
- the thermometer will also be used to stir the water, giving a consistent temperature through the water; so giving the true temperature reading.
- measuring cylinder to measure our 10cm^3 of water, the measuring cylinder reads to the cm^3 so I can estimate to 0.5 cm^3 which will give me an accuracy of 5%. (I am assuming 1 litre of water gives a mass of 1 kg at the temperatures I am working at).
- spirit burner with lid, I will use the same burner each time (controlled variable).
- digital balance to give the amount of fuel burnt, the balance can read to 0.001g which will give me an accuracy of about 1% for the range of mass of fuel burnt.
- heat proof mat to place the spirit burner, for safety.

I will consider where I will set up my equipment. I need space on the work bench to safely work and not to obstruct others.
The clamp needs to be on a stable bench.
I need to be able to easily take readings getting my eye in line with measured value.
I also need not to be in draughts so there are no uncontrolled cooling effects to the water being heated.

SAMPLE LEARNER WORK

Diagram of equipment set up



Method

Weigh the spirit burner without the lid which will contain 10 cm^3 of the alcohol to be investigated.
Add 10 cm^3 of water to the boiling tube which is clamped 10 cm above the top of the wick. A 10 cm^3 measuring cylinder as this is the smallest which can be used for most accurate results is used. When measuring the water make sure that the meniscus is at eye level and the bottom of the meniscus is at exactly zero for precision of reading.
Measure the start temperature of the water using the thermometer again checking that the eye level is that of the meniscus of the alcohol within the thermometer.
The spirit burner is lit so that the flame is directly under the boiling tube.
The fuel is burnt until the temperature of the water rises by about 40°C, then the lid is put on the spirit burner to put the flame out.

Then the end temperature of the water is measured very quickly so that heat is not lost after stirring the water to give a consistent temperature throughout the water. It will be important not to touch the glass or you will be measuring the heat conducted by the water to the glass.
The spirit burner is weighed without the lid as soon as the flame goes out.
From the results I can measure the temperature change and the change in mass of fuel.
I will repeat each alcohol measurement at least three times and/or until there is an insignificant variation between results so giving me precision in my final value of the heat of combustion.
Whilst planning my investigation I must also consider safety.

SAMPLE LEARNER WORK

Safety

The Health and Safety at Work Act 1974 gives responsibility to workers for their own safety and the safety of others around them so I must be aware of others working around me.
A risk assessment must be made before the practical investigation is undertaken. Both CLEAPSS which explains what is allowed to be done in school and HAZCARDS for information about the chemicals used and what to do if there is an accident.
All accidents go in the accident book because accidents can happen even if you do everything that you can to stop them.
Normal lab rules are displayed in the classroom which also must be followed - always wear a lab coat, tie your hair back and wear goggles. The environment is kept clear of all bags and coats.

Risk assessment

Hazard	Risk	Reducing risk	Comments
Glass Spirit Burner	May break and cut you. The wick has absorbed fuel which may get on your hands. Some of the fuel may make the outside slippery so you might drop it.	Hold carefully. Wash hands after use. Place firmly in the middle of the table.	Clear up breakages using the glass breakage kit in every room seek medical help if you cut yourself. Wash hands after use. Record accident in the accident book.
Glassware (boiling tube measuring cylinder)	When it gets hot you could burn your hand or you could drop it break it and cut yourself.	Use tongs when removing it from the clamp stand. Don't do the clamp stand up too tight.	Make sure the broken glass kit is available. Record accidents and seek medical help.
Test fuel	Flammable	Keep away from naked flames when not in use.	Always replace stopper when not in use.
Alcohols	Harmful, flammable. Methanol is toxic leading to blindness if swallowed.	Wear goggles and a lab coat. Wash hands after use. Always check with HAZCARD and CLEAPSS before carrying out an investigation. Make sure there is sufficient ventilation or air conditioning.	Make sure Hazcards are available. Seek medical help if you get burned or ingest any of the fuels.
Clamp stand	Could fall off the table and break your foot.	Clamp the stand to the table or make sure it is in the centre of the table.	Heat proof mat placed on clamp stand base on which the burner is to be placed.

SAMPLE LEARNER WORK

Results for Octanol ($C_8H_{17}OH$)

	Experiment		
	1st	2nd	3rd
Mass of water, g	9.49	9.89	9.82
Start temperature, °C	22	26	24
End temperature, °C	62	65	63
Temperature rise, °C	40	39	39
Start mass (fuel + burner) g	179.51	179.46	177.79
End mass (fuel + burner) g	177.82	177.83	176.11
Mass of fuel used, g	1.69	1.63	1.68

Range of results:

Temperature rise	40°C to 39°C	a range of 1°C
Fuel burnt	1.69g to 1.63g	a range of 0.03g

Range of results has insignificant variation so no more readings are needed.

Learning Objective 1 - Be able to plan a scientific investigation

Marking commentary on MB3 sample learner work

The report includes a very good plan, with a good discussion of variables. Ways of minimising error are incorporated into the method and in the selection of equipment and designated in how variables are to be controlled.

Numbers of repeats are satisfactory with an understanding of why there are repeats and the range is suitable.

There is a very good introduction, incorporating a range of relevant secondary data/information; referencing of sources. There is some justification of why the websites were used.

Why it was awarded MB3 not MB2

After initial research the learner has identified the "problem" that needs to "solved".

The learner has met the requirements of the model assignment as to what needs to be researched.

Research was focused on the "problem" and not general facts/characteristics. Secondary data was recorded so the learner's results could be compared for accuracy and so the efficiency of the control of the method used in the practical investigation. Although only 4 sources were reference, the range was sufficiently wide to obtain the necessary information.

The learner was be able to plan their investigation based on the relevant equation to calculate the energy transferred to the water. The plan was written so another person could follow it.

The learner has explained why they have chosen the equipment and why they have chosen the measurements and to what accuracy measurements can be taken using the equipment selected. [This can also feed into the evaluation to support analysis of the accuracy of the result]. The diagram drawn obeyed the format of a scientific diagram - in 2D with the labels formatted to the right which were linked to the diagram with straight lines.

Learning Objective 2 - Be able to collect scientific data

Marking commentary on MB3 sample learner work

The risk assessment is of a very high standard. It is expected that the centre has indicated that the practical was carried out independently.

The taking and recording of data was excellent, and outliers were obtained, and indicated. The precision and accuracy of measurements is referenced. Correct units are provided throughout.

Why it was awarded MB3 not MB2

The learner has referenced the ability to set up equipment safely and in a manner that measurements can be taken with precision.

The learner has referred to how equipment is set up in the plan – in terms of taking readings and ease of carrying out the practical.

Teachers could use a witness statement/competence sheet/teacher comment on recording sheet to support learner's ability.
The risk assessment is not just the laboratory rules but the learner has referred to CLEAPSS and HAZARD cards as well as having knowledge of the 1974 Health and Safety Act. The learner has recorded their measurements to the relevant significant value that the measuring equipment would allow. The table of results is clearly formatted with all the necessary readings with correct SI units to calculate the necessary values for the investigation(s).

Learning Objective 5 - Be able to communicate scientific information

Marking commentary on MB3 sample learner work

There is excellent use of scientific language throughout the report. Both chemical symbols and equations have correctly been used.

There are no errors in spelling, punctuation or grammar.

The tables are correctly formatted and the graph is very good, and excellent use has been made of the diagram.

Why it was awarded MB3 not MB2

Information presented is clear, well organised and structured, and in a coherent format.

Scientific, technical and mathematical language, conventions and symbols are used correctly and effectively. The language used was that associated with MB3.

No errors in grammar, punctuation and spelling were seen; at MB2 a few would be expected.

Diagrams and graphs are used appropriately and accurately following scientific convention.

Antimicrobials – Sample Learner Work Marking Band 3

The following sample learner work is relevant to learning objectives 2, 3, 4 and 5.

SAMPLE LEARNER WORK

Recorded results

Antimicrobial used was Hydrogen peroxide (H_2O_2).
A ruler was used to measure the diameter of any clear zones (zones of inhibition). The measurement was to the nearest millimetre and the test was repeated 5 times to be able to judge the accuracy of the measurements. The filter paper discs were of a diameter of 20mm.
The maximum diameter of the clear zone – where the circumference of the clear zone varied the maximum diameter was measured to the nearest mm. All variance was within one millimetre.

Concentration of antimicrobial (%)	Diameter of clear zone (mm)							
	1	2	3	4	5	mean	range	
							lowest	highest
100	40	40	40	38	41	39.8	38	41
90	40	40	40	35	38	38.6	35	40
70	30	40	40	23	35	36.25	30	40
50	25	40	40	21	40	33.2	21	40
40	23	25	20	21	23	22.4	20	25
30	22	22	20	20	20	20.8	20	22
20	21	20	20	20	20	20.2	20	21
0	20	20	20	20	20	20	20	20

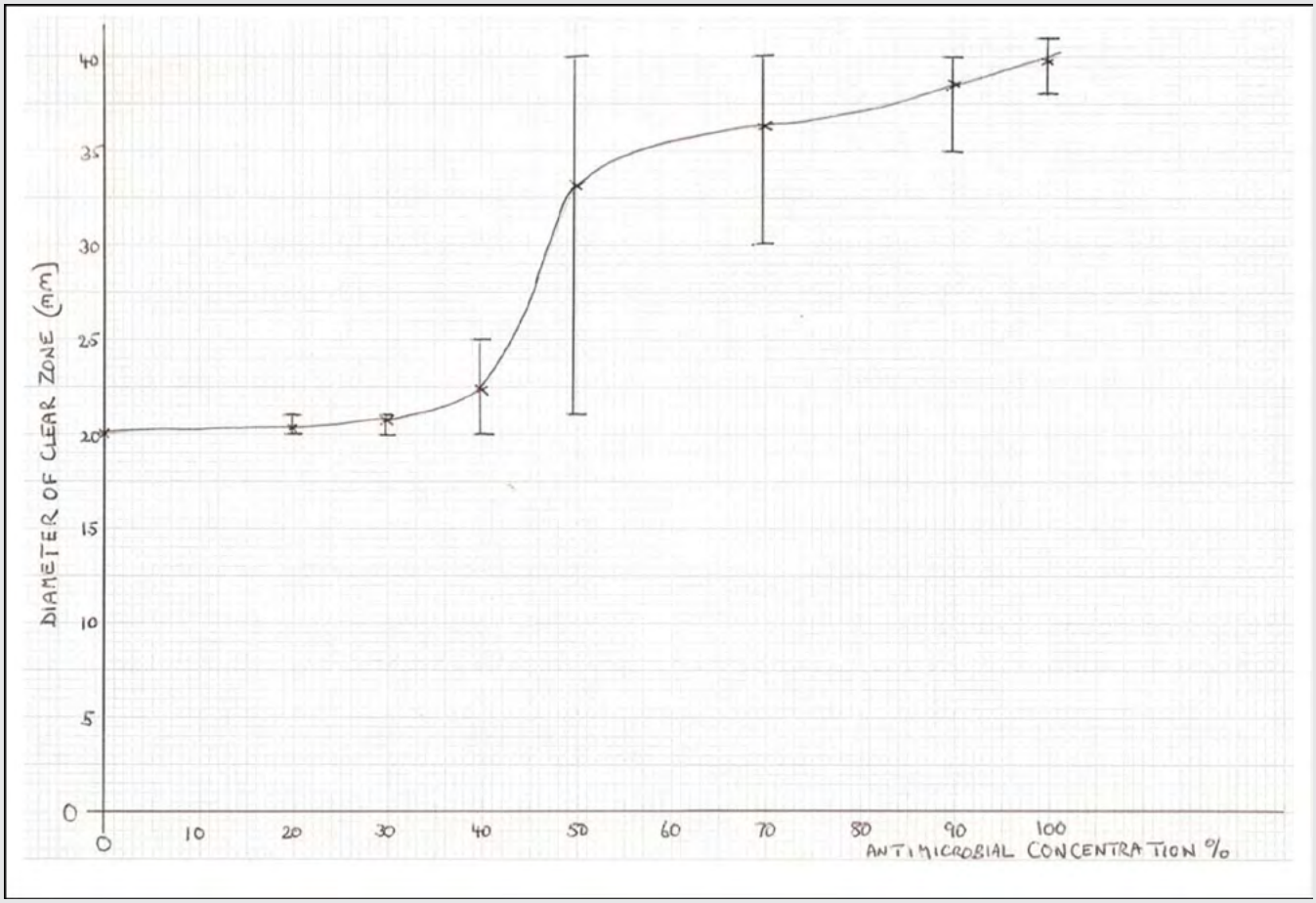
One anomalous result (outlier) is highlighted in the table.

Using the mean diameter of the clear zone the area of the clear zone was calculated.

Concentration of antimicrobial (%)	Mean Diameter of clear zone (mm)	Radius of clear zone (mm)	Radius squared (mm^2)	Area of clear zone (mm^2)
100	39.8	19.9	396.01	1243.47
90	38.6	19.3	372.49	1169.62
70	33.6	16.8	282.24	886.23
50	33.2	16.6	275.56	865.25
40	22.4	11.2	125.44	393.88
30	20.8	10.4	108.16	339.62
20	20.2	10.1	102.01	320.31
0	20.0	10.0	100.00	314.00

SAMPLE LEARNER WORK

The results for the clear zone (zone of inhibition) diameter show that the effect of the antimicrobial concentration between 20% and 100% is almost double. However the true effect is represented by the area of the clear zone, the effect is four times greater between 20% and 100% concentrations.
Disc diameter is 20mm, no agar is seen under the disc.
The diameter of the clear zone is plotted against the concentration of the antimicrobial.



Within the concentration range of 0% - 40% the repeatability for the test is within 20mm to 25 mm giving a minimum accuracy of 20%. Within the concentration range of 70% to 100% the minimum accuracy was 25% however the accuracy between the 40% and 70% concentration the accuracy of the results dropped to 60%.

The size of the zone of inhibition, the clear zone, will be limited by its extent to which the antimicrobial diffuses through the agar and the effect of the antimicrobial.
There will be a balance between the dilution of the antimicrobial – it is expected the lower the concentration the easier the antimicrobial will diffuse through the agar; the higher the concentration the greater effect it will have on the bacteria within the agar. So there is a mechanical process as well as a biological process.

The accuracy of the results will be effected by:

- how much antimicrobial is actually absorbed by the filter paper disc
- the diffuse of the antimicrobial through the filter paper disc
- the diffusion of the antimicrobial diffusing through the agar
- the measurement of the diameter of the zone of inhibition, which is approximately 1mm in 20mm a 5% accuracy or less for the investigation.

SAMPLE LEARNER WORK

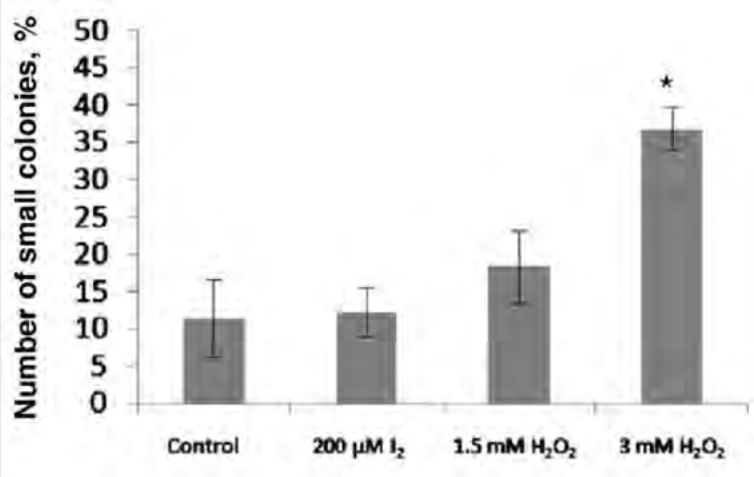
The accuracy of results would be improved by not using filter paper discs but by inserting a glass rod into the agar and making a well, then a measured amount (using a pipette) of antimicrobial is placed in the well – so the inaccuracy of the amount of antimicrobial absorbed by the filter paper and the diffusion through the filter paper is removed.
This in turn should reduce the range of results for each concentration.

The graph indicates:
1. Concentration range 0% to 40% there is a limited antimicrobial affect – there is a 10% increase in the zone of inhibition.
2. Concentration range 40% to 70% there is a greater effect of 80% increase in the zone of inhibition.
3. Concentration range 70% to 100% the effect increases but at a slower rate at about a 12% increase in the zone of inhibition.

The major effect of the antimicrobial is between the 40% to 50% concentration.

The investigation did support that the use of the oxidising agent Hydrogen Peroxide as an antimicrobial agent due to its ability to form free OH-radicals which will break DNA and oxidizing thiol-groups of proteins and lipids; and that increasing concentrations of the antimicrobial has a greater effect; and that ranges of different concentrations have differing effects.

Group results were used as secondary data to compare my results against. The values compare were within the accuracy and range of my results.
This is also supported by the research article:
Co-operative inhibitory effects of hydrogen peroxide and iodine against bacterial and yeast species
by Elena I Zubko and Mikhajlo K Zubko.



Their results showed an exponential growth curve which is comparable to the total overview of the plotted graph from my collected results.

Learning Objective 2 - Be able to collect scientific data

Marking commentary on MB3 sample learner work

The risk assessment is of a very high standard. It is expected that the centre has indicated that the practical was carried out independently.

The taking and recording of data was excellent, and outliers were obtained, and indicated. The precision and accuracy of measurements is referenced. Correct units are provided throughout.

Why it was awarded MB3 not MB2

The learner has referenced the ability to set up equipment safely and in a manner that measurements can be taken with precision.

The learner has referred to how equipment is set up in the plan – in terms of taking readings and ease of carrying out the practical.

Teachers could use a witness statement/competence sheet/teacher comment on recording sheet to support learner's ability.
The risk assessment is not just the laboratory rules but the learner has referred to CLEAPSS and HAZARD cards as well as having knowledge of the 1974 Health and Safety Act. The learner has recorded their measurements to the relevant significant value that the measuring equipment would allow. The table of results is clearly formatted with all the necessary readings with correct SI units to calculate the necessary values for the investigation(s).

Learning Objective 3 - Be able to analyse scientific information

Marking commentary on MB3 sample learner work

The graph has been drawn with appropriate scales and labels on axes; the points have been correctly plotted and error bars have been included. The means and areas of zones of inhibition have been calculated.

An appropriate curve has been used to join the points.

The main pattern in the data has been described, as well as the three phases in the graph referencing quantitative data.

Why it was awarded MB3 not MB2

Appropriate graphical and mathematical techniques have been used to reveal patterns in data.

Appropriate scales and axes used in graphs and data plotted accurately, including where appropriate, use of lines of best fit and not joining point to point.

Correct uses of complex mathematical techniques have been used. If the learner had just correctly calculated means the technique would not have been complex enough. By calculating areas of the zones of inhibition and quantitative comments on accuracy has put the mark into MB3.

The main trends/patterns in the data is described in detail and interpreted correctly with reference to quantitative data phase by phase of the graph (if the learner had only given a qualitative statement on the overall pattern then only a mark in MB2 would be given). The learner has also used secondary data to support their evaluation. Relevant scientific understanding has also been shown in why the values were such.

Learning Objective 4 - Be able to evaluate scientific information

Marking commentary on MB3 sample learner work

The learner has identified an outlier and has provided a justification for its designation. The learner has discussed the narrow spread of data for concentrations ranging from 0-40% and commented on the fact that results are less repeatable at higher concentrations. The learner has accounted for the range of results at the higher concentrations with pertinent reasons.

The learner has stated that the results support the hypothesis, and linked this to additional science. There has been a discussion for the pattern of the graph with reference to secondary sources.

Knowledge and understanding have been applied from R071 – How scientific ideas have an impact on our lives.

Why it was awarded MB3 not MB2

Detailed and critical consideration has been given to the data and methods used to obtain them.

Sources of error and quality of data discussed and explained, including accuracy, repeatability and uncertainty using quantitative statements.

Limitations of the method have been identified and suggestions for improvements justified.

The conclusion given was justified based on analysis of primary and secondary data, clearly linked to relevant scientific understanding.

Learning Objective 5 - Be able to communicate scientific information

Marking commentary on MB3 sample learner work

There is excellent use of scientific language throughout the report. Both chemical symbols and equations have correctly been used.

There are no errors in SPG.

The tables are correctly formatted and the graph is very good, and excellent use has been made of the diagram.

Why it was awarded MB3 not MB2

Information presented is clear, well organised and structured, and in a coherent format.

Scientific, technical and mathematical language, conventions and symbols are used correctly and effectively. The language used was that associated with MB3.

No errors in grammar, punctuation and spelling were seen; at MB2 a few would be expected.

Diagrams and graphs are used appropriately and accurately following scientific convention.

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