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SCIENCE
LEVEL 1/2

UNIT R073 - HOW SCIENTISTS TEST THEIR IDEAS: BURNING FUELS

LEARNER STYLE WORK

LEVEL 2 DISTINCTION

CONTENTS

Introduction	Page 4
Level 2 Distinction Example	Page 5
Unit Record Sheet	Page 9
Moderators Comments	Page 12

INTRODUCTION

This work has been developed to provide examples of the content and standard of work required to evidence the identified assessment criteria (Level 2, R073 Model Assignment). This is one approach that could be used but it must not be directly replicated or any part plagiarised by learners.

Teachers may choose to identify their own approach for learners to follow but evidence submitted must clearly meet the assessment criteria.

This is not real learner work; its purpose is to provide ideas and approaches.

The text in the blue boxes are examples of annotations teachers may add to work. The annotations are of good practice and are not a compulsory element of teacher marking.

All centres should complete a unit record sheet for each candidate. The unit record sheet should include comments related to the marking of candidates work. The unit record sheet should not be returned to candidates once work has been marked.

LEVEL 2 DISTINCTION
HOW SCIENTISTS TEST THEIR IDEAS: BURNING FUELS

Alcohol as a fuel

LO1 - MB1 bullet 3

Alcohol can be burned as a source of energy instead of using fossil fuels. Smith and Workman [1] say that alcohol has been used as a fuel for the internal combustion engine since its invention. Reports on the use of alcohol as a motor fuel were published in 1907 and detailed research was conducted in the 1920s and 1930s.

The level of interest in using alcohol as a motor fuel follows fuel shortages. It can also linked to low grain prices (which can be fermented by yeast to produce alcohol). [1]

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]

The use of ethanol as a fuel for internal combustion engines, either alone or in combination with other fuels, has been given much attention mostly because of its possible environmental and long-term economic advantages over fossil fuels. [3] Ethanol is often blended with petrol, to produce E5, E10, etc. The 'E' number stands for the percentage of ethanol. In the UK, ethanol has been blended into petrol in recent years. Tesco, as well as others, sell it. Tesco's '99 RON Super unleaded is an E5 blend. In other words, it contains 5% ethanol.

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, are not as volatile or corrosive as ethanol, and do not readily absorb water. Branched-chain alcohols such as isobutanol (2-methyl-1-propanol) have higher-octane numbers, resulting in less knocking in engines. Until recently, higher alcohols have never been produced from a renewable source with yields high enough to make them viable as a petrol substitute, but now a new strategy has been developed at UCLA. . "These alcohols are typically trace by-products in fermentation," said Professor Liao. But to they are usually toxic to organism in higher concentrations." Now Professor Liao's team has genetically-modified the bacterium Escherichia coli (E.coli) to produce several higher-chain alcohols from glucose, a renewable carbon source, including isobutanol, 1-butanol, 2-methyl-1-butanol, 3-methyl-1-butanol and 2-phenylethanol. [4]

Another team in Korea has modified the bacterium Clostridium acetobutylicum, to produce large quantities of butanol, another possible fuel. [5]

The websites I have chosen for my information are reliable, as they are official university or government sites. The last two sources came from Science Daily. This was created by Canadian-American science writer/editor Dan Hogan and his wife Michele Hogan in December 1995, but is now science news service with roughly 2000 contributing organisations worldwide. I therefore believe it is reliable.

Planning the experiment

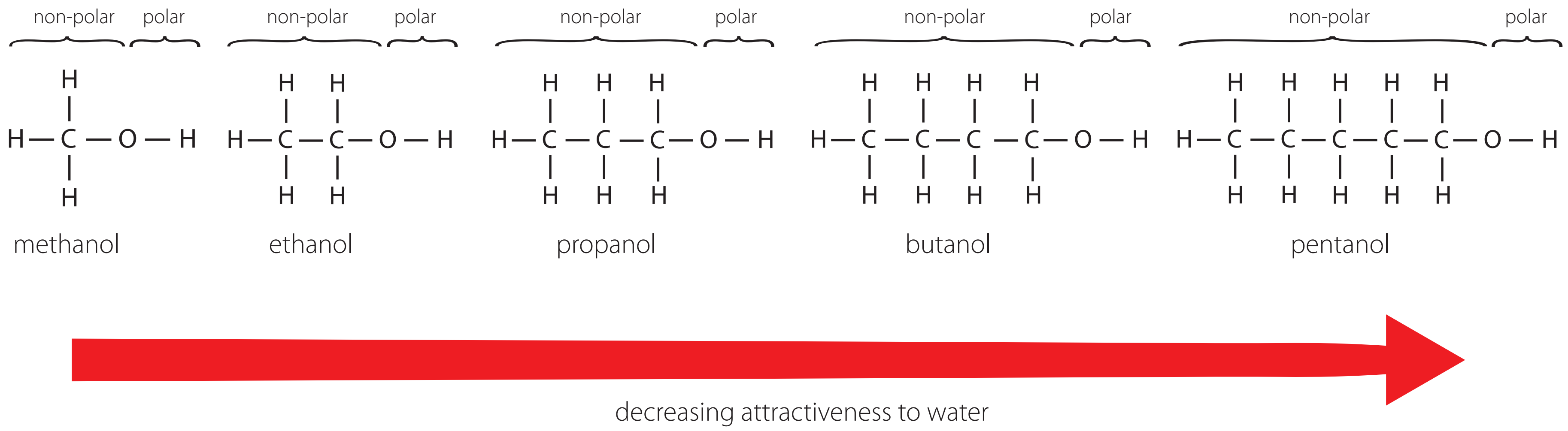
The combustion of alcohols is exothermic and in my experiment, I will use the energy released from burning a known mass of alcohol to heat a known amount of water. I can then compare the alcohols as fuels by calculating the quantity of energy transferred to the water. I will use the formula:

$$q = mc\Delta T$$

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)

The chemical structure of alcohols

Alcohols have a carbon chain and an OH group. The OH group is polar, which means that one part of the group is more positive/negative than the other. Polar groups are attracted to other polar groups, such as in water. The carbon chain is non-polar and will repel water.



So the greater number of carbon atoms in the alcohol, the less water it will absorb, making it better for car engines.

Burning alcohols

When they are burned, alcohols produce carbon dioxide and water:

CH_3OH methanol	+	$1½O_2$ oxygen	$\longrightarrow$	CO_2 carbon dioxide	+	$2H_2O$ water	$\Delta H = -726\ kJ\ mol^{-1}$
C_2H_5OH ethanol	+	$3O_2$ oxygen	$\longrightarrow$	$2CO_2$ carbon dioxide	+	$3H^2O$ water	$\Delta H = -1367\ kJ\ mol^{-1}$
C_3H_7OH propanol	+	$4½O_2$	$\longrightarrow$	$3CO_2$ carbon dioxide	+	$4H_2O$ water	$\Delta H = -2021\ kJ\ mol^{-1}$

C_4H_9OH butanol	+	$6O_2$ oxygen	→	$4CO_2$ carbon dioxide	+	$5H_2O$ water	$\Delta H = -2676\ kJ\ mol^{-1}$
$C_5H_{11}OH$ pentanol	+	$7\frac{1}{2}O_2$ oxygen	→	$5CO_2$ carbon dioxide	+	$6H_2O$ water	$\Delta H = -3329\ kJ\ mol^{-1}$
$C_6H_{13}OH$ hexanol	+	$9O_2$ oxygen	→	$6CO_2$ carbon dioxide	+	$7H_2O$ water	$\Delta H = -3984\ kJ\ mol^{-1}$
$C_7H_{15}OH$ heptanol	+	$10\frac{1}{2}O_2$ oxygen	→	$7CO_2$ carbon dioxide	+	$8H_2O$ water	$\Delta H = -4638\ kJ\ mol^{-1}$
$C_8H_{17}OH$ octanol	+	$12O_2$ oxygen	→	$8CO_2$ carbon dioxide	+	$9H_2O$ water	$\Delta H = -5294\ kJ\ mol^{-1}$

Values of heats of combustion from [7]

The combustion of alcohols is exothermic. ΔH is negative.

$\Delta H = H_f - H_i$

Energy is taken in to break the bonds in the alcohol and oxygen molecules and it is given out as the bonds are reformed when carbon dioxide and water are produced. In exothermic reactions, there is more energy given out than there is taken in.

Different alcohol fuels will therefore transfer different amounts of energy when they burn because of the different numbers of carbon atoms in the alcohol molecules.

Planning the experiment

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:

$$q = mc\Delta T$$

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)

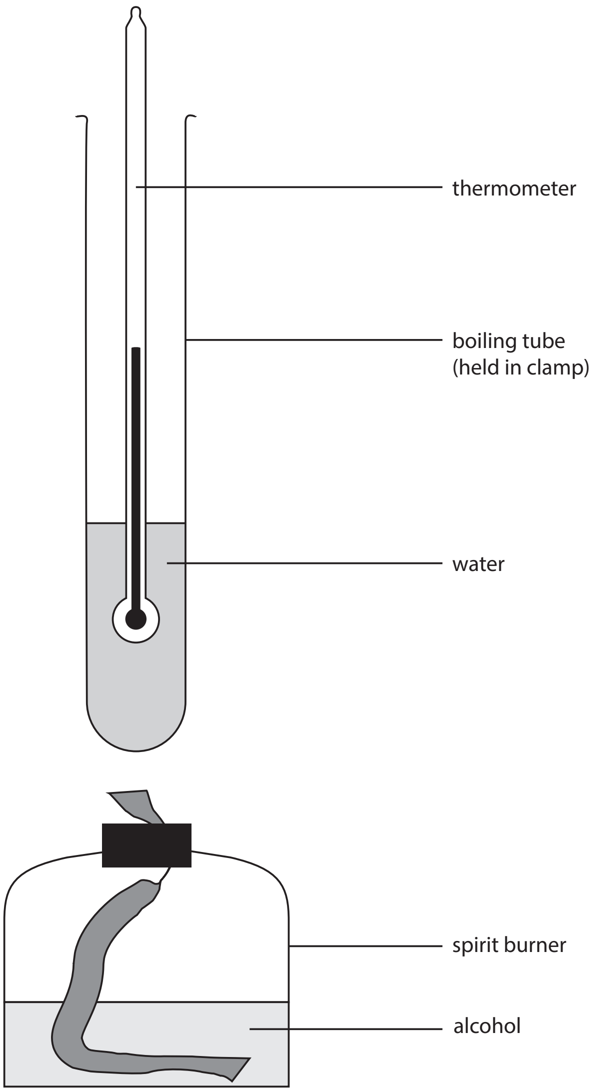
I will measure the energy transferred from different fuels when they are burnt and heat water. The energy transfer is Chemical energy to heat energy. Energy is also wasted as light energy.

Method

LO1 - MB3 bullet 1

After a group discussion I decide on the following method:

I will weigh the spirit burner without the lid before the practical. The spirit burner will contain 10 cm^3 of the alcohol investigated.



I will then add 10 cm3 of water to the boiling tube which I will clamp 10 cm above the top of the wick. I will use a 10 cm3 measuring cylinder as this is the smallest which can be used for most accurate results. I will also weigh the water as well (10 cm3 of water should weigh 10 g, but our measuring cylinders are grade B so they may not be very accurate). When measuring the water I will also make sure that the meniscus is at eye level and the bottom of the meniscus is at exactly zero.

I will then measure the start temperature of the water using the thermometer. We have alcohol glass thermometers but if I use a digital one it would be more precise.

I then need to light the spirit burner so that the flame is directly under the boiling tube. I will then let the fuel burn until the temperature of the water rises by about 40 °C. I will then put the lid on the spirit burner to put the flame out.

After this I will measure the end temperature of the water very quickly so that heat is not lost. It will be important not to touch the glass or you will be measuring the heat conducted by the water to the glass.

I will weigh the spirit burner without the lid as soon as the flame goes out. I can then calculate the heat of combustion of the fuel using the calculations given.

I will therefore measure the temperature change and the change in mass of fuel.

I will repeat each alcohol measurement at least three times until there is an insignificant variation between results. These are my dependent variables.

I will control the volume of water and fuel at the start of the practical. The accuracy of these measurements depends on the accuracy of the equipment used. The measuring cylinders are only B grade. The balance measures to 1 dp. I will control the distance between the wick and the bottom of the boiling tube. I will change the boiling tube in between use so that the glass is at the same temperature (room temperature) at the start of each investigation.

Variables

The dependent variable, which I will be measuring, is the temperature rise.

My independent variable is the alcohol/number of carbon atoms.

LO1 - MB3 bullet 2

My control variables are:

- the temperature rise of the water*
- volume of water to be heated†
- the same distance between 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

* I cannot control this exactly as the temperature might carry on rising after I've put out the flame, but I will make sure that I record the highest temperature reached. I will also stir the water with the thermometer to make sure I get as accurate result as I can

† I will measure the volume of water as accurately as I can, but I will be limited by the accuracy of the measuring cylinder. As the density of water is 1.0 g/cm^3, I will measure the mass of the water each time to make sure I get an accurate measurement.

Safety

The Health and Safety at work act 1974 gives responsibility to workers for their own safety and the safety of others around them. To follow this I will perform a risk assessment. This also means that I have to look at CLEAPSS on the p drive which tells us what we are allowed to do in school. We also look at HAZCARDS for information about the chemicals we use 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.

Our normal lab rules are displayed in the classroom. They include always wear a lab coat, tie your hair back and goggles. The environment is kept clear because all bags and coats are on the window sill. It would be better if we had coat hooks or lockers.

LO2 - MB3 bullets 1 and 2

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.
Lighter fuel	Flammable	Keep away form naked flames 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. This can be on the P drive. 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	

My results

My group collected three sets of our own results for one fuel. These were then shared across all the groups that did this investigation so that the final results were as reliable as possible.

I identified any outliers and excluded these when I calculated the mean heat of combustion for each alcohol.

Own results for octanol (octan-1-ol). Formula $C_8H_{17}OH$. RMM = 138.0

	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

Calculations

Calculate the heat of combustion for the fuel = Octanol.

If all the energy in the octan-1-ol is transferred to the water, the energy transferred = the heat of combustion

heat of combustion = specific heat capacity of water x mass of water x temperature increase

Where Specific Heat Capacity of water is 4.2 J g^{-1}

1st results

heat of combustion = 4.2 x 9.49 x 40

= 1594 J

= 1594 ÷ 1.69 J g^{-1}

= 943 J g^{-1}

2nd results

heat of combustion = 4.2 x 9.89 x 39

= 1620 J

= 1620 ÷ 1.63 J g^{-1}

= 994 J g^{-1}

3rd results

heat of combustion = 4.2 x 9.82 x 39

= 1609 J

= 1609 ÷ 1.68 J g^{-1}

= 958 J g^{-1}

Mean Heat of Combustion of octanol = $\frac{943 + 994 + 958}{3}$ = **965 J g^{-1}**

Results that I collected from another group

Results for methanol. Formula CH_3OH. RMM = 32.0

	Experiment		
	1st	2nd	3rd
Mass of water, g	11.13	9.43	11.70
Start temperature, °C	22	23	24
End temperature, °C	60	63	64
Temperature rise, °C	38	40	40
Start mass (fuel + burner) g	190.55	190.35	186.73
End mass (fuel + burner) g	188.02	187.53	184.04
Mass of fuel used, g	2.53	2.82	2.69

I wil do the calculations:

1st results

heat of combustion = 4.2 x 11.13 x 38

= 1776 J

= 1776 ÷ 2.53 J g^{-1}

= 702 J g^{-1}

2nd results

heat of combustion = 4.2 x 9.43 x 40

= 1584 J

= 1584 ÷ 2.82 J g^{-1}

= 562 J g^{-1}

3rd results

heat of combustion = 4.2 x 11.70 x 40

= 1966 J

= 1966 ÷ 2.69 J g^{-1}

= 731 J g^{-1}

Mean Heat of Combustion = $\frac{702 + 562 + 731}{3}$ = 665 J g^{-1}

Results for ethanol. Formula C_2H_5OH. RMM = 46.1

	Experiment		
	1st	2nd	3rd
Mass of water, g	10.54	9.95	10.18
Start temperature, °C	22	21	23
End temperature, °C	62	63	63
Temperature rise, °C	40	42	40
Start mass (fuel + burner) g	188.48	191.09	192.01
End mass (fuel + burner) g	186.13	188.71	189.62
Mass of fuel used, g	2.35	2.38	2.39

I wil do the calculations:

1st results

heat of combustion = 4.2 x 10.54 x 40

= 1771 J

= 1771 ÷ 2.35 J g^{-1}

= 754 J g^{-1}

2nd results

heat of combustion = 4.2 x 9.95 x 42

= 1755 J

= 1755 ÷ 2.38 J g-1

= 737 J g-1

3rd results

heat of combustion = 4.2 x 10.18 x 40

= 1710 J

= 1710 ÷ 2.39 J g-1

= 715 J g-1

Mean Heat of Combustion = $\frac{754 + 737 + 715}{3}$ = 735 J g^{-1}

Results for propan-1-ol. Formula C_3H_7OH. RMM = 60.1

	Experiment		
	1st	2nd	3rd
Mass of water, g	10.54	11.12	10.49
Start temperature, °C	22	22	24
End temperature, °C	62	64	49
Temperature rise, °C	40	42	25
Start mass (fuel + burner) g	188.29	190.99	191.78
End mass (fuel + burner) g	186.13	188.71	189.62
Mass of fuel used, g	2.16	2.28	2.16

I wil do the calculations:

1st results

heat of combustion = 4.2 x 10.24 x 40

= 1720 J

= 1720 ÷ 2.16 J g^{-1}

= 796 J g^{-1}

2nd results

heat of combustion = 4.2 x 11.12 x 42

= 1962 J

= 1962 ÷ 2.28 J g^{-1}

= 861 J g^{-1}

3rd results

heat of combustion = 4.2 x 10.49 x 25

= 1101 J

= 1101 ÷ 2.16 J g-1

= 510 kJ g-1

Mean Heat of Combustion = $\frac{796 + 861}{2}$ = 829 kJ g^{-1}

Results for butanol. Formula C_4H_9OH. RMM = 74.1

	Experiment		
	1st	2nd	3rd
Mass of water, g	10.09	10.82	9.99
Start temperature, °C	21	22	24
End temperature, °C	61	59	63
Temperature rise, °C	40	37	39
Start mass (fuel + burner) g	190.00	179.37	185.79
End mass (fuel + burner) g	188.02	177.53	184.04
Mass of fuel used, g	1.98	1.84	1.75

I wil do the calculations:

1st results

heat of combustion = 4.2 x 10.09 x 40

= 1695 J

= 1695 ÷ 1.98 J g^{-1}

= 856 J g^{-1}

2nd results

heat of combustion = 4.2 x 10.82 x 37

= 1681 J

= 1681÷ 1.84 J g^{-1}

= 913 J g^{-1}

3rd results

heat of combustion = 4.2 x 9.82 x 39

= 1609 J

= 1609 ÷ 1.75 J g^{-1}

= 919 J g^{-1}

Mean Heat of Combustion = $\frac{856 + 913 + 919}{3}$ = 896 J g^{-1}

Results for pentanol. Formula $C_5H_{11}OH$. RMM = 88.2

	Experiment		
	1st	2nd	3rd
Mass of water, g	10.22	10.94	10.09
Start temperature, °C	23	23	24
End temperature, °C	62	74	66
Temperature rise, °C	39	51	42
Start mass (fuel + burner) g	188.06	190.71	191.47
End mass (fuel + burner) g	186.13	188.71	189.62
Mass of fuel used, g	1.93	2.00	1.85

I wil do the calculations:

1st results

heat of combustion = 4.2 x 10.22 x 39

= 1674 J

= 1674 ÷ 1.93 J g^{-1}

= 867 J g^{-1}

2nd results

heat of combustion = 4.2 x 10.94 x 51

= 2343 J

= 2343 ÷ 2.00 J g^{-1}

= 1172 J g^{-1}

3rd results

heat of combustion = 4.2 x 10.09 x 42

= 1780 J

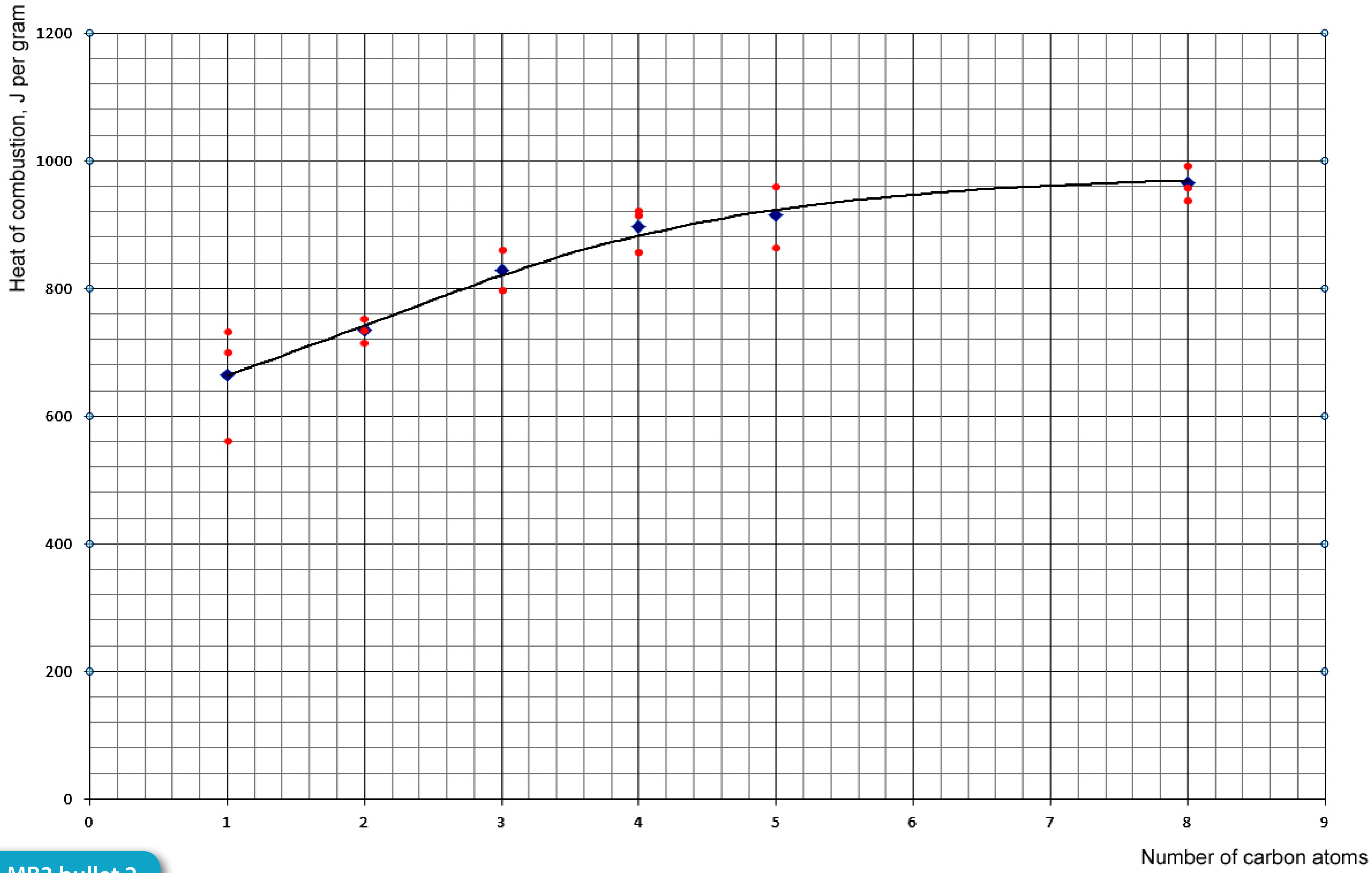
= 1780 ÷ 1.85 J g^{-1}

= 962 J g^{-1}

Mean Heat of Combustion = $\frac{867 + 962}{2}$ = 896 J g^{-1}

Summary of all the results

Alcohol	Formula	Number of Carbon atoms	Mean heat combustion, J per gram
Methanol	CH_3OH	1	665
Ethanol	C_2H_5OH	2	735
Propan-1-ol	C_3H_7OH	3	829
Butan-1-ol	C_4H_9OH	4	896
Pentan-1-ol	$C_5H_{11}OH$	5	915
Octan-1-ol	$C_8H_{17}OH$	8	965



LO3 - MB3 bullet 2

Conclusion

In this practical we used many different alcohols. The alcohols we used were octan-1-ol ($C_8H_{17}OH$), pentan-1-ol ($C_5H_{11}OH$), butan-1-ol (C_4H_9OH), ethanol (C_2H_5OH) and methanol (CH_3OH).

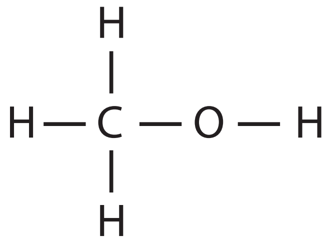
The trends on the graph show that as the number of carbon atoms increase, more energy per mole of fuel is released. It is a directly proportional relationship. We use the energy per mole for comparison instead of energy per gram so that we are comparing the same number of molecules of each fuel.

Combustion is the reaction of fuels with oxygen:

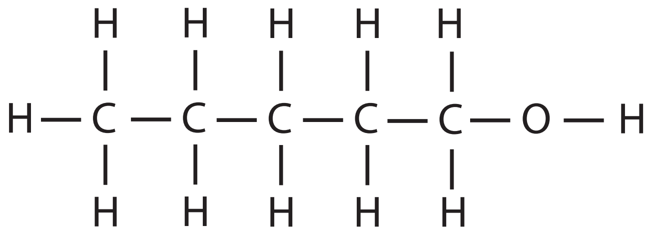
$$C_2H_5OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

My experimental heat of combustion increases with number of carbon atoms. On the alcohol graph I can also see that as the number of Carbon atoms increases the experimental heat of combustion per mole also increases.

In the alcohols there is covalent bonding. This means that the electrons are shared between the atoms. The alcohols have C-C bonds, C-H bonds and a C-O bond and an O-H bond. The OH bond is very hard to break. More heat energy is needed to break this bond. Energy is used to break the C-C and C-H bonds, but then released as new bonds form between C and O and H and O. Longer chain alcohols release more energy because they have more bonds to break and new ones to form.



methanol



pentan-1-ol
In this molecule, there are more bonds to break and reform

The evidence from our investigation and the discussions about properties of fuels with different numbers of carbon atoms support the hypothesis. The conclusion is that the more the number of carbon atoms then the more energy can be released.

Evaluation **LO4 - MB3 bullets 1and 2**

I drew a line of best fit on the graphs and on the first graph plotted all the data points to show the spread of data. The spread of data was quite narrow as I had excluded results that were obvious outliers. Some of the groups in the class had results that showed a significant variation within the temperature readings. Some groups had continued till there was less that 5°C variation over the temperature readings. Others (propanol and pentanol groups) left their's in. I only included the results I thought weren't outliers in my calculations. The group that did propan-1-ol had a very low reading (25°C). The pentan-1-ol group had a high reading. I counted this as an outlier, but I wasn't as sure about this result. I could have included it. It meant with these alcohols I only had two results to calculate the heats of combustion instead of three, so my results would be less reliable. The results were close together however. my table shows my range of results.

Alcohol	Mean heat combustion, J per gram	Range
Methanol	665	562 - 731
Ethanol	735	715 - 754
Propan-1-ol	829	796 - 861
Butan-1-ol	896	856 - 919
Pentan-1-ol	915	867 - 962
Octan-1-ol	965	943 - 994

From the graph and the above table, you can see that the results for methanol showed the greatest range, and the lowest repeatability, but the graphs showed a good trend, especially when I calculated the energy per mole. I think then that my results were quite accurate.

I looked up the heats of combustion of different alcohols (references [7], [8], [9] and [10]). There was a variation in the figures from website to website, but I used the Doc Brown figures because this is a trusted website (the values were also the same as on [8]). When you compare my results with the results from the Doc Brown website though, mine were way out.

Alcohol	Mean heat combustion, kJ per mole	Website [7] value for heat combustion, kJ per mole
Methanol	665	562 - 731
Ethanol	735	715 - 754
Propan-1-ol	829	796 - 861
Butan-1-ol	896	856 - 919
Pentan-1-ol	915	867 - 962
Octan-1-ol	965	943 - 994

My results are consistently about 2.5% of the actual results.
The main reason for the results varying, and some groups getting outliers was due to the technique used. The energy transfer between the burning fuel and the water wasn't good. We could have made a lid for the boiling tube to stop heat loss. Some of the energy in the fuel was also transferred to light energy. This practical assumes that **all** the energy is converted to heat.

We might also have got incomplete combustion. This leads to the formation of carbon monoxide which is toxic, and carbon particles. It means that all the energy is not released from the fuel.

LO4 - MB3 bullet 1

Some other reasons for outliers and variation in the results:

Problem	Solution
1. The wick was dirty and not easy to light because it was covered in soot from previous experiments.	New one will allow the wick to absorb fuel evenly and burn evenly and be easier to light.
2. The height of the boiling tube was different for each test.	Measure exactly 50 mm from the top of the wick to the bottom of the tube each time.
3. The direction of the boiling tube had to be altered for each fuel positioning for maximum benefit because the direction of the flame was different once it was lit but this took time and could have affected the results as fuel burned away.	Keep the boiling tube in the same direction but also make sure that the wick is cut directly across rather than at an angle.
4. If at a different direction than vertical the boiling tube glass leaned against the clamp stand. Heat energy was then wasted as heat energy was conducted to the metal of the clamp stand	Position the boiling tube away from the clamp stand so that heat energy is not wasted.
5. The volume of water was not being exactly 10 cm3, due to incorrect reading of the measuring cylinder caused by a parallax /meniscus.	Make sure that the meniscus is at eye level and that the measuring cylinder is on a level horizontal surface.
6. It was difficult to keep to a 40 °C temperature rise in the water. There was still a variation of the temperature in the water after the flame had been put out.	Use a larger volume of water than 10 cm3 in a conical flask.
7. General movement of air meant that the flame not constantly on boiling tube due to air flow. Heat energy from the flame was then lost by convection	Do it by myself in room with just me and keep all the windows and doors shut.
8. Errors in thermometer readings.	Use digital or data logger for more accuracy. The readings on some groups' thermometers varied before we started the investigation (they weren't precise).
9. Errors in thermometer readings.	There might have been some variation in the temperature in different parts of the boiling tube. We could have stirred the water with the thermometer to make sure the temperature was even.
10. Wick not exactly the same size so the volume of fuel would be different as there is a longer wick for more fuel to vaporise along as it reaches the flash point.	Trim wicks exactly 10 mm each.
11. Incomplete combustion of the fuel.	Burn the fuel in pure oxygen.

The results were not accurate as they were shared across the groups. There were limitations by equipment error. Next time we would weigh the water to start with exactly the same volume, use grade A glassware, a digital thermometer and a different boiling tube for each test.

It would be good to extend the investigation. We had no hexanol or heptanol, so there was a gap in the results. We had to base our graph on these figures.

We also have used alcohols with more carbon atoms to see if the relationship carries on after octan-1-ol. But we might have had to modify the experiment to do this. The fuel ignites when it becomes volatile (vaporises). This is called the flash point. There is a link between flash point and the number of carbon atoms. The lower the number of carbon atoms then the lower the flash point. This is because of less intermolecular forces between the molecules with lower numbers of carbon atoms. This suggests that some long chain alcohols will be difficult to light, and they may not burn properly.

Some alcohols also have slightly different structures. The alcohols we had to choose from included propan-2-ol. This means that the OH group was at a different position in the alcohol. We should test some of these different alcohols to see if our finding still stands.

It may also be difficult to transfer our results to the real world. Fuels are not usually pure chemicals but mixtures (for instance alkane fuels). It is likely that alcohol fuels are mixtures of alcohols and not pure. We do not know from the new methods of production of alcohol fuels ([5] and [6]) how pure the alcohols for the fuels will be (and mixtures may be better).

Methanol has the lowest combustion energy, but it also needs the least oxygen to burn (see page 6). It therefore has the lowest chemically correct air-fuel ratio, so an engine burning methanol would have the most power [1]. But alcohols with fewer carbon atoms might be a problem on a hot summer's day or at high altitudes. From butanol upwards, the alcohols are relatively insoluble in water, and will attract less, making them better for engines.

Review of health and safety

There were no problems or accidents when I did the practical.

I was careful when lighting the wick of the spirit burner, and used matches instead of walking around the lab with a lighted splint. I was careful not to tilt the burner when lighting the wick so as not to get any of the alcohol outside the burner.

References

[1] J.L. Smith and J.P. Workman. Alcohol for Motor Fuels. Colorado State University. Fact Sheet 5.010. 2012.
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[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] Science Daily. Ethanol fuel. 2012.
http://www.sciencedaily.com/articles/e/ethanol_fuel.htm

[4] US Department of Energy. Ethanol. 2012.
http://www.fueleconomy.gov/feg/ethanol.shtml

[5] Science Daily. Efficient Biofuel Made From Genetically Modified E. Coli Bacteria. 2008.
http://www.sciencedaily.com/releases/2008/01/080106202952.htm

[6] Science Daily. 2012. Highly Efficient Production of Advanced Biofuel by Metabolically Engineered Microorganism
http://www.sciencedaily.com/releases/2012/10/121023091032.htm

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

[8] N. Saunders. Combustion of alcohols. 2000
http://www.creative-chemistry.org.uk/gcse/documents/Module7/N-m07-24.pdf

[9] Slideshare. Heat of combustion of various alcohol. 2010
http://www.slideshare.net/sweemoi/heat-of-combustion-of-various-alcohols

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

UNIT RECORDING SHEET

OCR
RECOGNISING ACHIEVEMENT

Science

OCR J815 Unit R073 Level 1/Level 2
Cambridge National Certificate in Science
Unit Recording Sheet

Please read the instructions printed at the end of this form. **One** of these sheets, suitably completed, should be attached to the assessed work of **each** candidate.

Unit Title	**How scientists test their ideas**	**Unit Code**	**R073**	**Session**		**Year**	
Centre Name						**Centre Number**	
Candidate Name	**Burning fuels L2 Distinction**					**Candidate Number**	

Criteria			**Teacher Comments**	**Mark**	**Page No**
LO1: Be able to plan a scientific investigation			There is a comprehensive plan. An appropriate choice of equipment has been made. Repeats have been carried out, but could have been more (two or three measurements only). The range was limited by the range of alcohols in the centre. A good discussion of variables. A wide range of information sources has been used, though there is limited justification of why these were used.	13	
MB1: 1 – 6 marks	**MB2: 7 – 11 marks**	**MB3: 12 – 15 marks**			
• **Limited** plan includes equipment and techniques to be used • Plan provides a 'fair test' • Identifies how **some** errors will be minimised • **Some** sources of secondary data/information identified **[1 2 3 4 5 6]**	• Plan gives **sufficient detail** for investigation to be repeated, including choices of: o equipment, including instrumentation o range and number of data points o number of replicates o control of variables to result in the collection of data of an appropriate quality • **Some** explanation of how errors will be minimised • **Range** of **relevant** sources of secondary data/information identified **[7 8 9 10 11]**	• **Comprehensive** plan shows scientific understanding in making appropriate choices of: o equipment, including instrumentation o range and number of data points o number of replicates o control of variables to result in the collection of accurate data to address the scientific problem • **Detailed** explanation of: o how errors will be minimised o variables which cannot be controlled • **Wide range** of **relevant** sources of secondary data/information identified and selection of **appropriate** sources justified **[12 13 14 15]**			

<table>
<tr><th colspan="3">Criteria</th><th>Teacher Comments</th><th>Mark</th><th>Page No</th></tr>
<tr><td colspan="3">LO2: Be able to collect scientific data</td><td rowspan="3">All significant risks discussed, and appropriate measures taken. Investigation carried out totally independently.

All risks managed successfully – no incidents or intervention required.

Recording of data excellent.</td><td rowspan="3">9</td><td rowspan="3"></td></tr>
<tr><td>MB1: 1 – 4 marks</td><td>MB2: 5 – 7 marks</td><td>MB3: 8 – 10 marks</td></tr>
<tr><td>• Basic understanding of risks in procedures with only standard laboratory safety precautions identified
• Significant teacher intervention required to ensure safety or help set up equipment
• Results recorded clearly
[1 2 3 4]</td><td>• Some risks in procedures identified and some specific responses suggested to reduce risks
• Most risks managed successfully with no significant incidents or accidents and no requirement for teacher intervention
• Little support required to set up equipment
• Results tabulated to include all data collected, including use of correct headings
[5 6 7]</td><td>• All significant risks in the plan evaluated and reasoned judgements made to reduce risks by use of appropriate specific responses
• All risks managed successfully with no incidents or accidents and no requirement for teacher intervention
• Measurements taken and recorded to appropriate accuracy and precision using an appropriate format, including use of correct units
[8 9 10]</td></tr>
<tr><td colspan="3">LO3: Be able to analyse scientific information</td><td rowspan="3">Excellent calculations. Appropriate graphs drawn. Excel used, but lines of best fit added by candidate.

Trends in data described and explained. Explanations, eg bond-breaking and making, could have been extended.</td><td rowspan="3">11</td><td rowspan="3"></td></tr>
<tr><td>MB1: 1 – 5 marks</td><td>MB2: 6 – 9 marks</td><td>MB3: 10 – 13 marks</td></tr>
<tr><td>• Some evidence of processing of quantitative data:
o data presented as simple charts or graphs
o use of a simple mathematical technique where appropriate
• Some trends/patterns in the data identified
[1 2 3 4 5]</td><td>• Graphical and mathematical techniques used to reveal patterns in data:
o charts or graphs used to display data in an appropriate way
o correct use of simple mathematical techniques where appropriate
o appropriate qualitative treatment of the levels of uncertainty in the data, including identification of any anomalous results
• Main trends/patterns in the data described with reference to quantitative data
[6 7 8 9]</td><td>• Appropriate graphical and mathematical techniques used to reveal patterns in data:
o appropriate scales and axes used in graphs and data plotted accurately, including where appropriate, use of lines of best fit
o correct use of complex mathematical techniques where appropriate
o appropriate quantitative treatment of levels of uncertainty in the data
• Main trends/patterns in the data described in detail and interpreted correctly with reference to quantitative data and relevant scientific understanding
[10 11 12 13]</td></tr>
</table>

Criteria			Teacher Comments	Mark	Page No.
LO4: Be able to evaluate scientific information			Some quantitative treatment of spread of data. Detailed evaluation, with sources of error discussed and explained (could have used more terminology). Suggestions for improvement made and explained. Conclusion provided but could have been more detailed (see above in LO3). Applied skills from Unit 1 when discussing obtaining energy from fuel.	12	
MB1: 1 – 5 marks	**MB2: 6 – 9 marks**	**MB3: 10 – 13 marks**			
• **Limited** comments made about the quality of the data and the methods used • **Simple** conclusion given which is consistent with the data collected and shows **limited** scientific understanding • There is **limited** application of skills/knowledge/understanding from other units in the specification **[1 2 3 4 5]**	• **Some relevant** comments made about the quality of the data including accuracy and sources of error, linked to the methods of collection: o limitations in the methods of data collection identified and suggestions for improvements given • Conclusion given and **justified** based on an analysis of the data, showing **sound** understanding of the underlying science • Applies skills / knowledge / understanding from other units in the specification in a way which is **mostly relevant** **[6 7 8 9]**	• **Detailed** and **critical** consideration given to the data and methods used to obtain them: o sources of error and quality of data **discussed** and **explained**, including accuracy, repeatability and uncertainty o limitations of the method identified and suggestions for improvements **justified** • Conclusion given and **justified** based on **critical** analysis of primary and secondary data, clearly linked to **relevant** scientific understanding o identification of conflicting evidence o what further evidence is needed to make the conclusion more secure • Applies skills / knowledge / understanding from other units in the specification in an **effective** relevant way **[10 11 12 13]**			
LO5: Be able to communicate scientific information			Information clearly organised; report well-structured. Scientific terminology and conventions used effectively. GPS excellent – few errors. Diagrams and graphs used appropriately; more could have been added, eg release of energy as bonds broken and remade.	8	
MB1: 1 – 4 marks	**MB2: 5 – 7 marks**	**MB3: 8 – 9 marks**			
• **Limited** use of scientific, technical and mathematical language, conventions and symbols • **Some** errors in grammar, punctuation and spelling • **Limited** use of diagrams, graphs, flow charts and pictures **[1 2 3 4]**	• Information is presented in a **structured** format • **Sound** use of scientific, technical and mathematical language, conventions and symbols • **Occasional** errors in grammar, punctuation and spelling • **Some appropriate** use of diagrams, graphs, flow charts and pictures **[5 6 7]**	• Information presented is **clear**, well organised and structured, and in a **coherent** format • Scientific, technical and mathematical language, conventions and symbols are used **effectively** • **Few**, if any, errors in grammar, punctuation and spelling • Diagrams, graphs, flow charts and pictures are used **appropriately** and accurately **[8 9]**			
			Total/60	**53**	

URS143 Devised July 2012 **R073/URS**

Oxford Cambridge and RSA Examinations

MODERATORS COMMENTS

<table>
<tr><td colspan="3">R073 How Scientists test their ideas: Burning fuels L2 Distinction</td></tr>
<tr><td colspan="3">LO1: Be able to plan a scientific investigation</td></tr>
<tr><td>MB1: 1 – 7 marks</td><td>MB2: 8 – 13 marks</td><td>MB3: 14 – 18 marks</td></tr>
<tr><td>• Limited plan includes equipment and techniques to be used
• Plan provides a 'fair test'
• Identifies how some errors will be minimised
• Some sources of secondary data/information identified</td><td>• Plan gives sufficient detail for investigation to be repeated, including choices of:
- equipment, including instrumentation
- range and number of data points
- number of replicates
- control of variables to result in the collection of data of an appropriate quality
• Some explanation of how errors will be minimised
• Range of relevant sources of secondary data/ information identified</td><td>• Comprehensive plan shows scientific understanding in making appropriate choices of:
- equipment, including instrumentation
- range and number of data points
- number of replicates
- control of variables
- to result in the collection of accurate data to address the scientific problem
• Detailed explanation of:
- how errors will be minimised
- variables which cannot be controlled
• Wide range of relevant sources of secondary data/ information identified and selection of appropriate sources justified</td></tr>
<tr><td colspan="2">The report includes a very good plan, with a good discussion of variables (including variables that cannot be controlled). Ways of minimising error are incorporated into the method, but not designated as such.

Numbers of repeats are satisfactory (though just; no additional measurements are included where there are outliers), and the range is suitable.

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

[13]</td><td></td></tr>
</table>

LO2: Understand the risks and benefits related to the applications of nuclear radiation		
MB1: 1 – 4 marks	**MB2: 5 – 7 marks**	**MB3: 8 – 10 marks**
• **Basic** understanding of risks in procedures with only standard laboratory safety precautions identified • **Significant** teacher intervention required to ensure safety or help set up equipment • **Results** recorded clearly	• **Some** risks in procedures identified and **some** specific responses suggested to reduce risks • **Most** risks managed successfully with no significant incidents or accidents and no requirement for teacher intervention • **Little support** required to set up equipment • Results tabulated to include all data collected, including use of correct headings	• All significant risks in the plan **evaluated** and **reasoned** judgements made to reduce risks by use of **appropriate** specific responses • All risks managed successfully with no incidents or accidents and no requirement for teacher intervention • Measurements taken and recorded to appropriate accuracy and precision using an appropriate format, including use of correct units
The risk assessment is of a very high standard; however, only methanol is specified. The centre has indicated that the practical was carried out independently. The taking and recording of data was excellent, though in instances where outliers were obtained, no additional measurements are included (though this was dependent on other groups having taken the measurements). Correct units are provided throughout. [9]		

LO3: Be able to analyse scientific information		
MB1: 1 – 5 marks	**MB2: 6 – 9 marks**	**MB3: 10 – 12 marks**
• **Some** evidence of processing of quantitative data: • data presented as **simple** charts or graphs • use of a **simple** mathematical technique where appropriate • **Some** trends/patterns in the data identified	• Graphical and mathematical techniques used to reveal patterns in data: - charts or graphs used to display data in an **appropriat**e way - correct use of simple mathematical techniques where appropriate - **appropriate qualitative** treatment of the levels of uncertainty in the data, including identification of any anomalous results • Main trends/patterns in the data **described** with reference to quantitative data	• **Appropriate** graphical and mathematical techniques 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 - correct use of complex mathematical techniques where **appropriate** - **appropriate** quantitative treatment of levels of uncertainty in the data • Main trends/patterns in the data described in detail and interpreted correctly with reference to quantitative data and **relevant** scientific understanding
The calculations have been carried out and presented in an exemplary fashion. The centre has indicated that the two graphs have been drawn in Microsoft Excel but lines of best fit added by the candidate. The first graph incorporates all data points, illustrating the spread of data. For the first graph, better use could have been made of the space available. There is some quantitative treatment of levels of uncertainty in the data when comparing measured with actual heats of combustion from the literature. Main trends/patterns in data are described and interpreted correctly. [11]		

LO4: Be able to evaluate scientific information		
MB1: 1 – 5 marks	**MB2: 6 – 9 marks**	**MB3: 10 – 13 marks**
• **Limited** comments made about the quality of the data and the methods used • **Simple** conclusion given which is consistent with the data collected and shows **limited** scientific understanding • There is **limited** application of skills/ knowledge/ understanding from other units in the specification	• **Some relevant** comments made about the quality of the data including accuracy and sources of error, linked to the methods of collection: • limitations in the methods of data collection identified and suggestions for improvements given • Conclusion given and **justified** based on an analysis of the data, showing **sound** understanding of the underlying science • Applies skills/knowledge/understanding from other units in the specification in a way which is **mostly relevant**	• **Detailed** and **critical** consideration 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 - limitations of the method identified and suggestions for improvements **justified** • Conclusion given and **justified** based on **critical** analysis of primary and secondary data, clearly linked to **relevant** scientific understanding - identification of conflicting evidence - what further evidence is needed to make the conclusion more secure • Applies skills/knowledge/understanding from other units in the specification in an **effective** relevant way
A table is provided indicating the range of data collected for each alcohol, and there is some discussion of the spread of data, and its repeatability and accuracy. Limitations of the procedure have been indicated, along with suggestions for improvement and how the investigation could be extended to make the findings more secure. There is a good conclusion, but perhaps the ideas about the release of energy (or uptake) being the result of breaking and making bonds could have been developed further. There is a good discussion of the use of alcohol fuels in energy 'production' drawing on knowledge and understanding from other units. [12]		

<table>
<tr><th colspan="3">LO5: Be able to communicate scientific information</th></tr>
<tr><th>MB1: 1 – 4 marks</th><th>MB2: 5 – 7 marks</th><th>MB3: 8 – 9 marks</th></tr>
<tr>
<td>• Limited use of scientific, technical and mathematical language, conventions and symbols
• Some errors in grammar, punctuation and spelling
• Limited use of diagrams, graphs, flow charts and pictures</td>
<td>• Information is presented in a structured format
• Sound use of scientific, technical and mathematical language, conventions and symbols
• Occasional errors in grammar, punctuation and spelling
• Some appropriate use of diagrams, graphs, flow charts and pictures</td>
<td>• Information presented is clear, well organised and structured, and in a coherent format
• Scientific, technical and mathematical language, conventions and symbols are used effectively
• Few, if any, errors in grammar, punctuation and spelling
• Diagrams, graphs, flow charts and pictures are used appropriately and accurately</td>
</tr>
<tr><td colspan="3">There is excellent use of scientific language throughout the report.

There is the occasional 'typo', but there are few errors in GPS.

The graphs are very good, and excellent use has been made of other diagrams. Perhaps the diagrams on page 22 could have been annotated to show how the release of energy is dependent on bond breaking and making?
[8]</td></tr>
</table>

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Email cambridgenationals@ocr.org.uk

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