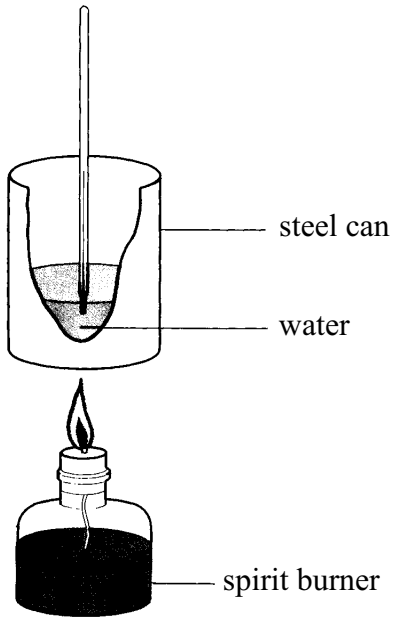
Investigating the heat of combustion of fuels

Background

It is useful to know how much energy is released when a fuel burns, as it can help us to choose the best fuel for a particular purpose. The diagram on the right shows a simple apparatus to measure the heat given out when a liquid fuel, like ethanol, burns. Heat from the flame warms the water in the steel can. If we measure the change in temperature of the water, we can work out how much heat went into the water from the burning fuel. The equation to do this is:



heat given out = mass of water x 4.2 x change in temperature

The units are:

- heat given out: joule, J
- mass of water: gram, g
- change in temperature: °C

It is helpful to know that 1cm^3 of water has a mass of 1g.

Your task

Your task is to plan, and carry out, an experiment to investigate the heat of combustion of different alcohols to find out which is the "best fuel". You will have access to spirit burners containing the alcohols shown in the table on the right.

methanol	CH_3OH
ethanol	C_2H_5OH
propanol	C_3H_7OH
butanol	C_4H_9OH

To gain high marks, your plan should include:

- a prediction of the relative amounts of heat produced by each fuel – this should be based on your scientific knowledge, and may be quantitative;
- a clear description of the method you will use (including details of all apparatus needed);
- details of what you will measure and any calculations you want to do;
- an explanation of how you will obtain reliable results, including how many measurements you intend to make;
- an explanation of how you will make it a fair test; and
- how you will carry out your investigation safely.

To gain the highest marks, you should do some background work first. You can:

- Look up information in books (make sure you write down the title and author) and **use** this information in your plan – don't just copy out, as you won't get marks for doing this.

Do preliminary experiments to work out the best conditions for your experiment – make sure you record what you do, what you find out, and explain how this helped you come up with your final plan.

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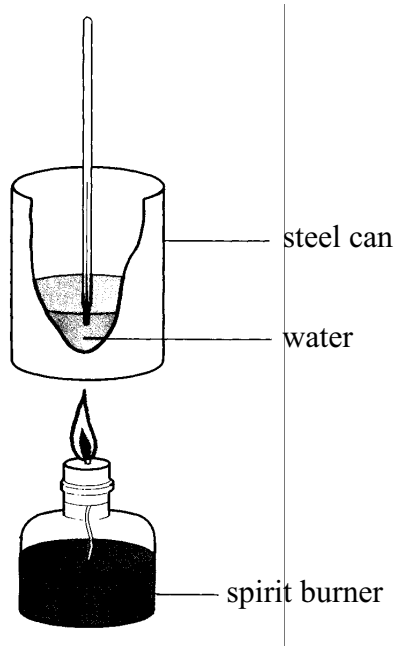
Emergency Plan

Aims

It is useful to know how much energy is released when a fuel burns, as it can help us to choose the best fuel for a particular purpose. The diagram on the right shows a simple apparatus to measure the heat given out when a liquid fuel, like ethanol, burns. Heat from the flame warms the water in the steel can. If we measure the change in temperature of the water, we can work out how much heat went into the water from the burning fuel.



If you haven't been able to come up with a working plan for any reason, you can use this Emergency Plan to get you going. You cannot get any marks for Planning of course, but you can still get marks for Obtaining, Analysing and Evaluating.

Apparatus

Goggles
Bench mat
Stand, boss, clamp
Thermometer
100cm^3 measuring cylinder
Steel can
Bunsen burner
Access to spirit burners containing methanol, ethanol, propanol or butanol
Digital balance

Method

1. Measure 100cm^3 of water in the measuring cylinder. Pour it into the steel can.
2. Record the temperature of the water.
3. Choose a spirit burner. Record the name of the fuel in it, and the mass of the whole burner (including the lid and fuel inside).
4. Clamp the steel can, and set it up so that the spirit burner will fit comfortably under it.
5. Light the wick of the spirit burner, and put it under the steel can.
6. Stir the water **gently** with the thermometer, and watch the temperature.
   When it has increased by 20°C, put the lid on the spirit burner to put the flame out.
   Record the new mass of the whole burner (including the lid and fuel inside).
7. Put fresh water into the steel can, and repeat steps 1–6 for each of the fuels.
   Try to do each fuel more than once.

If you are not sure what you are doing, ask for help!

Investigating the heat of combustion of fuels – *marking guidelines*

SPG

1	**Reasonable** accuracy in spg. **Limited range** of specialist terms used correctly.
2	**Considerable** accuracy in spg. **Good range** of specialist terms used with facility.
3	**Almost faultless** accuracy in spg. **Wide range** of specialist terms used correctly.

Skill Area P (Planning)

P.2a	Plan is safe. Plan is simple and likely to work.
P.4a	Makes a prediction (e.g. *xxxxanol will give out the most heat*). Plans a safe experiment which is a fair test, e.g. some indication of how it will be a fair test.
P.4b	Chooses suitable apparatus (especially look for appropriate measuring equipment).
P.6a	Makes a prediction and gives a scientific explanation (look for some reference to experiments done or graphs plotted from the worksheet data). Plans a safe experiment which is a fair test, and identifies the factors to control or vary. The factors **must** be stated, e.g. *I will keep the following variables the same to make it a fair test ...* The plan must show how this will be achieved.
P.6b	Chooses a suitable number and range of measurements, e.g. four fuels (repeated at least twice), starting/finishing temperatures and masses, volume of water, height of calorimeter.
P.8a	Makes a prediction and uses detailed scientific knowledge & understanding to explain it (i.e. calculates ΔH from supplied bond energies and converts to kJ/g). Plans a safe experiment giving full detail required to get precise and reliable readings. (Given the nature of this investigation, preliminary work should be involved to satisfy this).
P.8b	Shows that preliminary work has been done **as part of planning** to decide volumes, temperatures, etc. (this should be attached); or shows that secondary sources, e.g. bond energies have been used.

Skill Area O (Obtaining Evidence)

Note: Pupils should be observed to make sure that they carry out all practical work **safely**.
To get O.6a and O.8a, pupils must **select** the range of concentrations or temperatures to be used.

O.2a	Worked safely (annotate script to say this) and took some readings.
O.4a	Measured volumes, starting/finishing temperatures and masses, (times if appropriate), height.
O.4b	Records the results in a table.
O.6a	Makes accurate measurements and repeats them (e.g. 4 fuels with at least 3 readings for each – but check their graph to see if more repeats should have been done for a fuel or fuels).
O.6b	Records results clearly and accurately in a table, with correct units in the headings. Penalise if units are incorrect, e.g. for time in minutes watch out for 1.27 (they will think it's 1.27 minutes, but it's actually 1 minute 27 seconds – easy way to tell – there'll be no decimals >.59).
O.8a	Makes precise measurements and repeats them to make sure that the evidence is reliable (checks anomalous results if necessary). The range and number of readings should allow them to justify their prediction. Look at their processed results graph – award 8 marks only if the readings for each fuel are closely clustered (or repeated more frequently if variable) and a clear trend is there.

Skill Area A (Analysing)

A.2a	States what has been found out, i.e. what the results show. For example, *xxxxanol gave out the most heat* (any better statement in A.4b / A.6b would also count for A.2a).
A.4a	Results shown in a table or graph (i.e. some form of processing results). Note: If a table has been used for skill O, this counts for the mark in skill A.
A.4b	Identifies a trend or pattern in the results, e.g. *the more xxxxx atoms in the molecule the higher the temperature / lower time taken to heat the water / the lower the mass of fuel burnt.* Note: if their results don't form a pattern or trend, they can gain this marking point if they point this out.
A.6a	Draws a graph with a line or curve of best fit, and/or processes results in some way (e.g. calculates kJ/g, kJ/mol, average masses of fuel burnt, etc.). In a graph, watch that it is drawn properly with axis labels, accurately plotted points and a decent line of best fit. Note: a poor graph that does not merit A.6a does not stop candidates getting A.6a by processing their results.
A.6b	Draws a conclusion from the results in terms of heat released per gram (or per mole) of fuel burnt, e.g. *the more xxxxx atoms in the molecule the more heat produced per gram of fuel burnt*. Explains their conclusion using scientific knowledge and understanding (i.e. bonds broken/made).
A.8a	Draws a conclusion from a best-fit graph, or from processed results. This must match their results. Explains their conclusion using detailed scientific knowledge and understanding, e.g. clear discussion of net energy released due to bonds broken and made.
A.8b	Compares their results with their original prediction, quoting values from their graph (or from their processed results) to explain how their results support or undermine their original prediction.

Skill Area E (Evaluating)

E.2a	Makes a relevant comment about the method used and/or the results obtained.
E.4a	Comments on the accuracy of the measurements. Identifies anomalous results (if there are any).
E4b	Comments on the method used, and suggests changes to improve the reliability of the results.
E.6a	Recognises possible sources of error. Tries to explain any anomalous results. Discusses whether the evidence supports a firm conclusion.
E.6b	Suggests improvements or further work to give more evidence for the conclusion or to extend the investigation.

Annotations

- Remember that marking works from bottom up, i.e. there must be evidence for 2 marks before we can give 4 marks, etc. In cases where part of a description is met, consider awarding 3, 5 or 7 marks. If in doubt, you must refer to the syllabus guidelines. The bottom line is … would somebody else broadly agree with your judgement? Consider writing **why** you awarded the marks on the script.
- You should indicate clearly on each script the point at which the pupil gains, has some evidence for, or fails to gain, a certain mark in a skill. The convention should be (e.g. for P.8a):
  - ✓ **P.8a** if they get it … **(P.8a)** if there is some evidence for it … and … **X P.8a** if they don't get it.
- The final marks in each skill should be written across the top of the front page.
- It also helps in standardising if a couple of lines are added at the end to justify the overall marks.

Notes

A prediction **is** appropriate to this experiment, so we should look for one in Skills P and A.

If they get great results that lie beautifully on a curve (i.e. no anomalous results) don't bother looking to fulfil the "anomalous results" bits of O.8a and E6.a - they won't apply.