Boiling of a Kettle assignment

Skill Area P – Planning

Hypothesis

Three factors which effect the boiling time of water is the volume of water being heated, the power of the heater used and the starting temperature of the water.

Predictions

If the volume of water being heated is doubled, the time taken to boil it will also be doubled. The time taken to heat the water would then be directly proportional to the volume of water being heated.

If the power of the heater is doubled, the time taken to boil the water will be halved. The time taken to heat the water would then be inversely proportional to the power of the heater used.

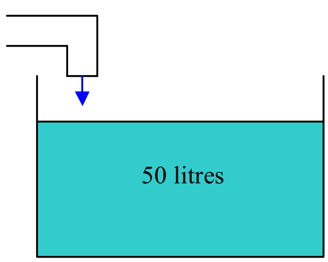
If the starting temperature of the water is increased, the time taken to boil it will be decreased. The time taken to boil the water depends on the difference between the starting temperature and the boiling temperature (100°C). This means that the time taken to heat the water is proportional to the difference between the starting and finishing temperature.

These proportionalities will not be valid when the temperature of the water reaches 100°C, because this is the boiling point of (pure) water. Water cannot be heated to more that 100°C, as when it reaches this temperature it turns into steam. Also, when the power of the heater is increased, more heat energy would be lost, reducing the efficiency of the experiment.

Reasons

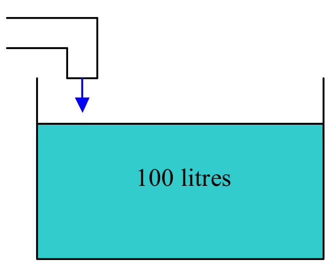
If the volume of water being heated is doubled, the time taken to boil it is doubled because the energy needed to heat the extra volume of water is the same as the original volume, so the time taken to boil the entire volume of water is doubled, assuming the starting temperature and power of the heater are the same. If the power of the heater is doubled, the time taken to boil the water will be halved because the heat emitted by the heater per second is doubled, so the same volume of water will boil in half the amount of time. If the starting temperature of the water is increased, the time taken to boil it will be decreased because the less heat would be needed to take the temperature up to boiling point, reducing the time of the experiment.

A good analogy to help us understand this is the bath analogy, and how long it would take to fill the bath with water. If the bath could hold twice the volume, then the time it took to fill the bath would double because the water needed to fill it would be twice as much. If there were two taps filling the bath instead of one, then the bath would be filled in half the time, because the rate of water flowing into the bath per second would be doubled. If the bath was already partially filled, then the time taken to fill it would be less, because the volume of water that had to be added would be less. These diagrams will help to explain this:



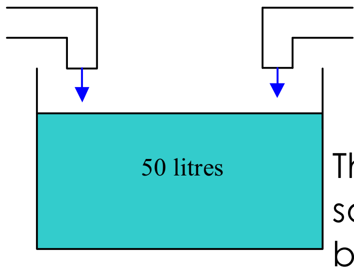
This is an ordinary bath, which had no water in when filling begun.

Time = 25s



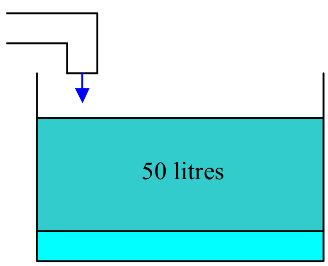
This bath had twice the volume capacity, and so time taken to fill it doubled.

Time = 50s



This bath had two taps instead of one, so the rate of water flowing into the bath doubled, and the time taken to fill the bath halved.

Time = 12.5s



This bath already had 10 litres in it when filling started, so filling time decreased by 5 seconds.

Time = 20s

Last year (year 10) I performed an experiment to measure the time taken to boil water in a kettle, with volumes of 500ml and 1000ml. Performing the experiments several times at each volume, the average results were boiling times of 87 seconds with 500ml and 170 seconds with 1000ml. With a margin of error of 0.05%, I have proven to an extent that boiling time doubles with the volume of water being boiled, so my prediction of this seems to be true. If this relation is indeed true, then the others will probably be too.

Plan of Experiment – Investigation of the variation in boiling time with power

Apparatus

Method

The apparatus, consisting of a variable power source, a rheostat, an ammeter, a switch, a voltmeter, a heater, a thermometer, a thin can of water and several wires will be set up as shown above. Then the power will be varied by changing the potential difference (p.d) and the current (because power = p.d x current) using the variable power supply and the variable resistor. The temperature of the water will be measured every half minute during the experiment – this is instead of performing the experiment multiple times to get accurate results, because doing that would take far too long. After all of the readings for each power have been taken, a heating curve of the average times for each power will be plotted to calculate the time to heat the water at any power. This will increase the reliability of the results and any anomalous readings can be found. Before each experiment begins, the water and heater will be cooled down to a temperature under 20°C, then the heater will be activated, and the timer will begin. Because heating the water to boiling point at low powers will take a very long time, the experiment will stop when the water reaches 50°C. The average values of both of the experiments for a certain power will be averaged, so that one anomalous result won't make too much a difference to the final results. To make the results more accurate, a digital ammeter and voltmeter will be used, which give more accurate readings than analogue meters, making the current and p.d readings more accurate. The experiment will be performed at ten different powers by changing the supply voltage and rheostat settings (current), giving ten different sets of results.

Table of Readings

The results for each power experiment will be recorded onto tables like this:

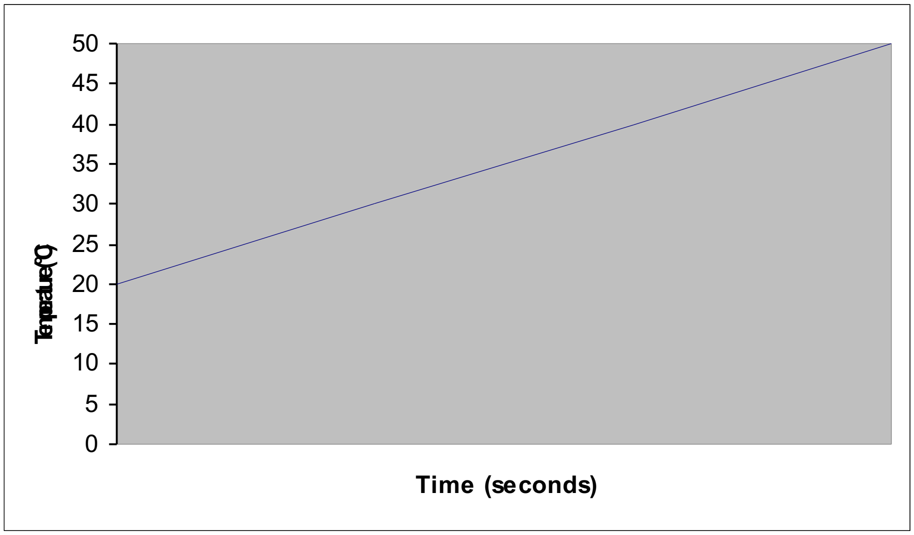
V= I=	P=
Time	**Temperature**
0	
30	
60	
90	
120	
150	

The table may be extended if the temperature of the water has not reached 50°C after 10 minutes (600 seconds), or the results will be extrapolated on a graph. When all results have been taken, the following table will be made for the heating curve graph and to see the energy involved in the reaction:

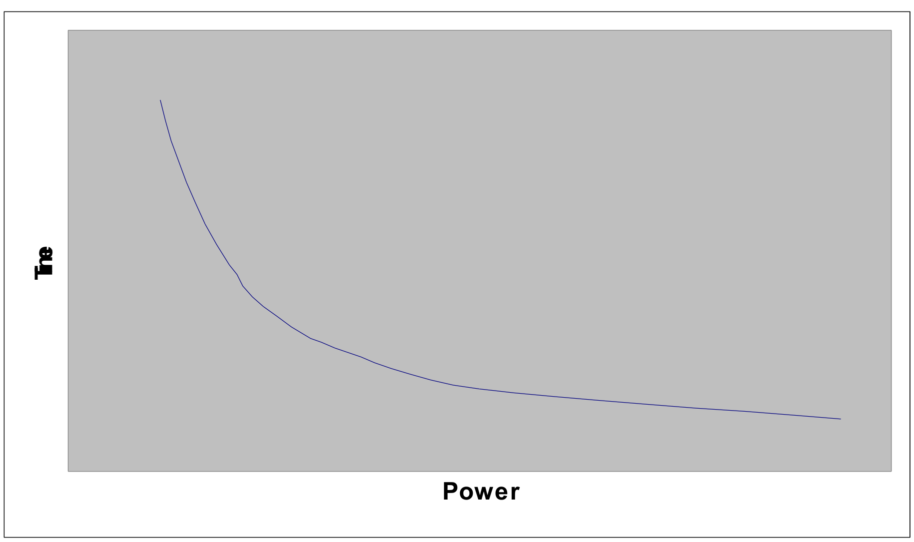
Power (W)	Heating time (s)	P x t

Graph

To make sure that the relationship between power and time is valid, the results for each set of results will be recorded on a graph, which should be like the one on the next page:



The line of best fit does not pass through the origin, because the heater would take time to heat up to 50°C, even if there was no water there. When all of the experiments have been performed and results extracted, a curve graph of heating time against power like the following will be plotted:



I will use this graph to test my prediction by checking that when a certain value of power doubles (marked P and 2P above) the time halves (marked T and $^{T}/_{2}$ above). If T does halve when P is doubled, then my prediction will be proven correct.

Fair Testing, Accuracy and Reliability

To ensure the experiment is fair, the same equipment will be used for every reading, because not all equipment is calibrated in the same way. Also, the volume of water will be kept the same for each reading. Because the water will only reach 50°C, the amount of evaporation will be negligible, so the water will not have to be replaced after each experiment.

Skill Area O – Obtaining Evidence

No changes were made to the experiment we planned out in Skill Area P. The tables of results, and the graphs of these, are on the following pages. The graphs were used to find the values for the summary table. If the line of best fit did not reach 50°C on the graph paper because the time was too long, then the value was calculated using the law of similar triangles. I also made a graph of the summary table values, which is after the summary table.

V=10.7v I=2.75A	P=29.4W
Time (s)	**Temperature (°C)**
0	12.5
30	14.5
60	16.5
90	19.0
120	20.5
150	23.0
180	25.0
210	27.0
240	29.0
270	30.5
300	33.0
330	34.0
360	36.0
390	38.5
420	40.0
450	42.0
480	44.0
510	46.0
540	47.0
570	48.0
600	49.0
630	50.5

V=9.7v I=2.5A	P=24.3W
Time (s)	**Temperature (°C)**
0	15.0
30	15.5
60	16.0
90	16.5
120	19.0
150	19.5
180	21.5
210	22.5
240	25.5
270	26.0
300	27.0
330	27.5
360	29.0
390	30.5
420	33.0
450	34.0
480	34.5
510	35.0
540	36.5
570	37.0
600	39.0

V=8.95v I=2.40A	P=21.5W
Time (s)	**Temperature (°C)**
0	15.0
30	16.0
60	17.0
90	19.0
120	20.0
150	21.0
180	21.5
210	22.0
240	23.0
270	24.0
300	24.5
330	25.5
360	26.0
390	27.0
420	27.5
450	28.0
480	31.0
510	33.0
540	35.0
570	38.0
600	39.0

V=7.9v I=2.00A	P=15.8W
Time (s)	**Temperature (°C)**
0	13.5
30	14.5
60	15.0
90	17.0
120	18.0
150	19.0
180	20.0
210	21.0
240	22.0
270	23.0
300	24.0
330	24.5
360	25.5
390	27.0
420	27.5
450	28.0
480	29.5
510	30.0
540	31.5
570	32.5
600	33.5

V=1.5v I=5.85A	P=8.8W
Time (s)	**Temperature (°C)**
0	14.0
30	14.5
60	15.0
90	15.5
120	15.5
150	16.0
180	17.5
210	19.0
240	20.0
270	21.0
300	22.0
330	23.0
360	23.5
390	24.0
420	24.5
450	25.0
480	26.0
510	27.0
540	27.5
570	28.0
600	29.0

V=6.2v I=1.25A	P=6.5W
Time (s)	**Temperature (°C)**
0	14.0
30	14.5
60	15.0
90	15.0
120	15.5
150	16.0
180	16.5
210	16.5
240	16.5
270	17.0
300	19.0
330	19.5
360	20.0
390	20.5
420	21.0
450	22.0
480	23.0
510	23.5
540	24.5
570	25.5
600	26.0

V=3.4v I=0.83A	P=2.8W
Time (s)	**Temperature (°C)**
0	13.5
30	13.5
60	14.0
90	14.5
120	14.5
150	15.0
180	15.5
210	15.5
240	16.0
270	16.6
300	17.0
330	17.0
360	17.5
390	18.0
420	18.0
450	18.5
480	19.0
510	19.5
540	19.5
570	20.0
600	20.5

Summary table

Power (W)	Heating time (s)	P x t
29.425	474	13947.45
24.25	702	17023.5
21.48	786	1688.28
15.8	882	13935.6
8.775	1050	9213.75
6.5	1368	8892
2.882	2412	6806.664

Skill Area A: Analysis

From the final graph, we can see that the heating time increases as the power decreases, and the shape supports our original prediction. As the power is doubled from 10W to 20W, the boiling time decreases from 1000s to 780s. This is a decrease factor of $^{780}/_{1000}$ = 0.78, not half (0.5) as predicted. There is a difference of 0.78 – 0.5 = 0.28.
% difference from my predicted value = $^{0.28}/_{0.5}$ x 100 = 56%
I have definitely not proven my prediction to be correct! This is partly because of human error, and also because of having inaccurate measurements due to heat losses. The can had no way of stopping heat from escaping to the surrounding air, so some heat was not used in the water, making the results inaccurate. Also, notice that using lower powers, the energy supplied to the water (using energy = power x time to calculate this) was much less than that supplied to the water at higher powers. This means that a lot of heat energy escaped the water to the surrounding area, making the results inaccurate. If I could stop this heat escaping, then I would be able to prove my prediction to be correct.

Skill Area E: Evaluation

My results were not sufficiently reliable enough to test my prediction, giving an accuracy of !56%. This could be because the thermometer can only be read to !0.5°C, and the 0-5A range on the analogue ammeter that we used is not as accurate as the 0-1A range. The digital voltmeter used, though, was more accurate than an analogue voltmeter.

Because of the lack of time to perform the experiment, a graph was drawn to average readings instead of repeating the experiment and averaging readings. Readings were taken using high powers and low powers, as well as several in between, so the graph had a wide range of readings. However, the readings were not taken systematically, though they were reasonably equally spaced out. Any anomalous results have been circled on the graphs and ignored. These were probably due to human error, or perhaps the thermometer accidentally touched the heater, which would be hotter than the water, making the readings too high. The stopwatch was accurate to !0.01 seconds, and any reaction time delay in starting the stopwatch would be equal to the reaction delay for reading results from the stopwatch, so the time readings were accurate. The measuring cylinder was accurate to !2ml, so the accuracy of the volume readings could be improved.

To improve the accuracy of our results, a digital ammeter and thermometer could be used, which give more accurate readings – the digital thermometer is accurate to !0.1°C, 5 times more accurate than the mercury thermometer. To improve the reliability of the evidence, each experiment should be repeated several times, then the average used, or a wider range of powers could be used. Also, results could be shared with other groups, and then the class average results worked out, which would be more accurate than group results.

To back up my prediction, further experimentation could be used. For example, datalogging could be used to take many readings for the same experiment. Several experiments can be performed at the same time using one datalogging computer. There is no human error, and the temperature is read to !0.1°C. Also, an experiment using a digital ammeter and thermometer (see above) would be useful for improving the reliability of the results if the experiment was repeated.