Determinations of Specific and Latent Heats

Warin Poomarin: KVIS, Rayong Thailand

Calorimeters

The word *calorimeter* was coined (made up) by Antoine Lavoisier around 1780. A calorimeter is anything used to study the production or the exchange of heat. It could be a styrofoam coffee-cup, a small copper pot, or expensive cleverly built equipment. In school physics coffee-cups and thermometers are often used to find approximate specific and latent heats, and in chemistry to find approximate heats of reaction. The materials are cheap and easy to use, but the results are at best disappointing. Uncontrolled heat exchange with the surroundings introduces errors of 20-30%.

For the data collections below, coffee-cups are replaced by electric pots rated at 600 Watts (J/s). You are asked to compare your data with known values. The difference is NOT YOUR ERROR but the difference will help you to evaluate the apparatus and prompt you to think about improvements.

Fig 1 – pots, thermocouples and stirrers.

The steel and aluminium components of a pot have been weighed separately and the water *equivalent found* to be 80 grams. (By water equivalent we mean the amount of water that requires the same energy input to raise the temperature by one °C.) Pots could be lagged (insulated) with plastic foam etc. but in situations where two pots are used to make comparisons the results may be satisfactory when done on an open bench.

Preliminary data

Water (1.5 l) was added to two apparently identical pots. Both pots were plugged in for the same time with continuous stirring. The ratio of temperatures over time is shown in figure 1.

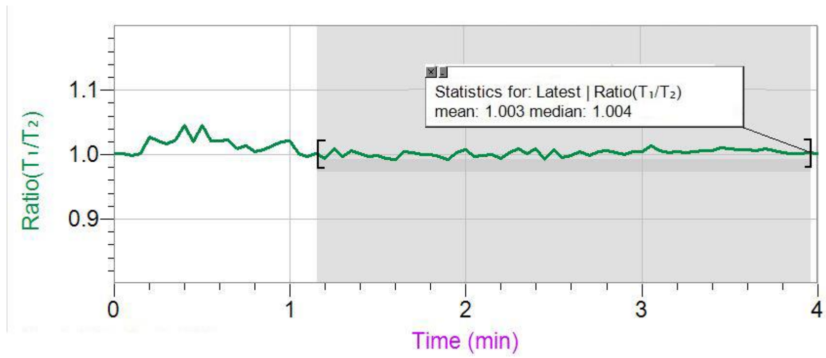

Fig 2 – ratio of temperatures measured during the heating of 1.5 li of water in two pots.

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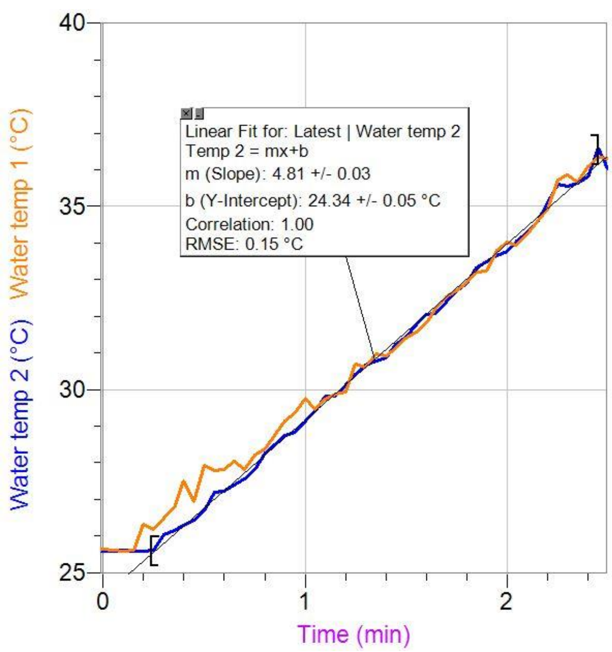


Fig 3 – temperature-time curves for heating 1.5 li of water in two different pots.

Taking the water equivalent of the pots as 80 g and the gradient of the heating curve for the water plus pot as 4.81 °C/min gives an estimate of the specific heat of water as 4700 J/(kg°C). The reader may verify this for themselves using …

$$Q = c_w\, m\, \Delta T$$

The estimate of specific heat is high by 10%, probably due to heat loss to the surroundings by evaporation, convection and some radiation.

Measurements

Set exercises are numbered **1** to **4**. *Please make a selection and/or substitute alternatives in consultation with your teacher.*

1 Determine the relationship between the mass of substance heated at a given rate and the rate of temperature rise using two hot pots.

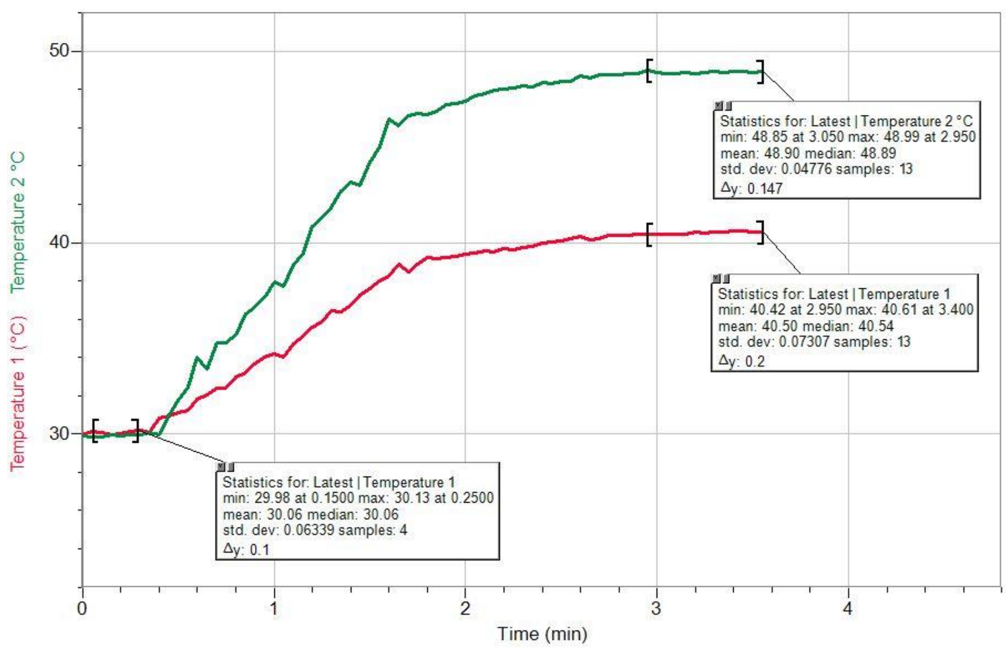
Suggested procedure

i Put 500 ml of water in one pot and 1000 ml in another.

ii Plug in both pots at the same time. Record temperature-time curves with continuous **stirring**, or, if using a thermometer, take the temperatures before, and after one minute or so of heating.

iii In a new calculated column in Logger Pro calculate and plot the ratio T_1/T_2 and comment on your findings.

Sample data



Note: the ratio of temperature increases is expected to be greater than 1 because the water equivalent to the pot effectively adds 80 g of water to each mass of water. The principle of the dependence of temperature rise on mass has been demonstrated approximately but it is apparent that there is greater heat loss to the room from the hotter pot. *How might more accurate measurements be made*?

2 Find the specific heat of steel by comparison with the known specific heat of water (4180 J/(kg°C).

Suggested procedure

i Add the same volume (around 300 ml) of palm-oil and water to two pots**.**

ii Plug in both pots at the same time and record temperature-time curves with continuous **stirring**, or if using a thermometer, take the temperatures before and after one minute or so of heating.

iii Using the known specific heat of water (4180 J/(li°C**)** find the *volume* specific heat of the oil in J/(kg°C), taking account of the water equivalent of the pots.

iv Given that the s.g. of most cooking oils including palm-oil is 0.92 write down the specific heat of the oil in J/(kg°C).

> **Notes:** *the specific heats and densities of water and cooking oil http://www.chempro.in/palmoilproperties.htm vary a little with temperature. These minor effects are less significant than errors due to incomplete draining of the bottles of oil and water, uncontrolled heat transfers by evaporation, insufficient stirring etc. and may be neglected.*

v *Return the oil to store and clean up your pots***.**

Sample data

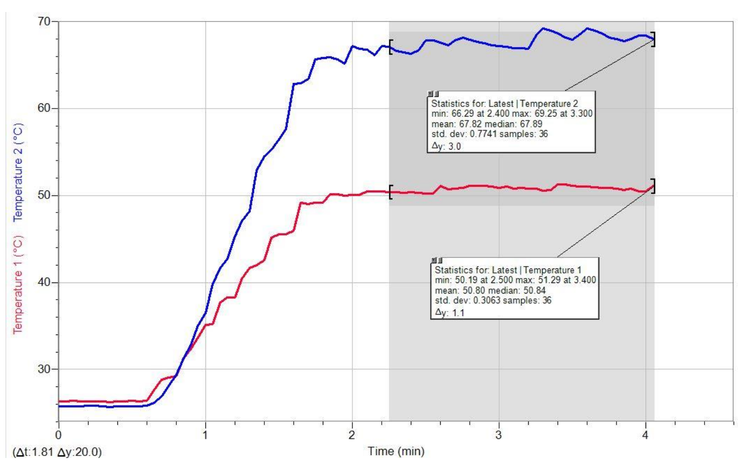


Fig 4 – temperature-time curves for 25O ml of palm oil and 250 ml of water heated with continuous stirring by supplying current for about one minute.

> **Note:** after the heating currents were removed at around 1.6 minutes in figure 4 the temperatures continued to increase a little as the base of the pots and the liquids come to equilibrium at a uniform temperature

3 Find the specific heat of steel by comparing the heating curve for nails and water with the curve for the same mass of water.

Suggested procedure

i Put a known mass of iron nails in one of two pots, Add water to each. Suggested quantities. Pot 1: 300 g nails and 600 ml of water. Pot 2: 900 ml of water.

ii Plug in both pots at the same time and record temperature-time curves with continuous **stirring**, or, if using a thermometer, take the temperatures before and after one minute or so of heating.

iii Remembering that the water equivalent of a pot is 80 g and that the energy supplied is the same to each, write down an equation containing the temperature differences ΔT_1 and ΔT_2, the specific heat and effective mass of water, and the specific heat and mass of the mass of nails. Solve for the specific heat of steel.

iv Compare your result with the known specific heat of steel [0.49 J/(kg°C)]. *Discuss possible sources of error and how accuracy might be improved.*

Sample data

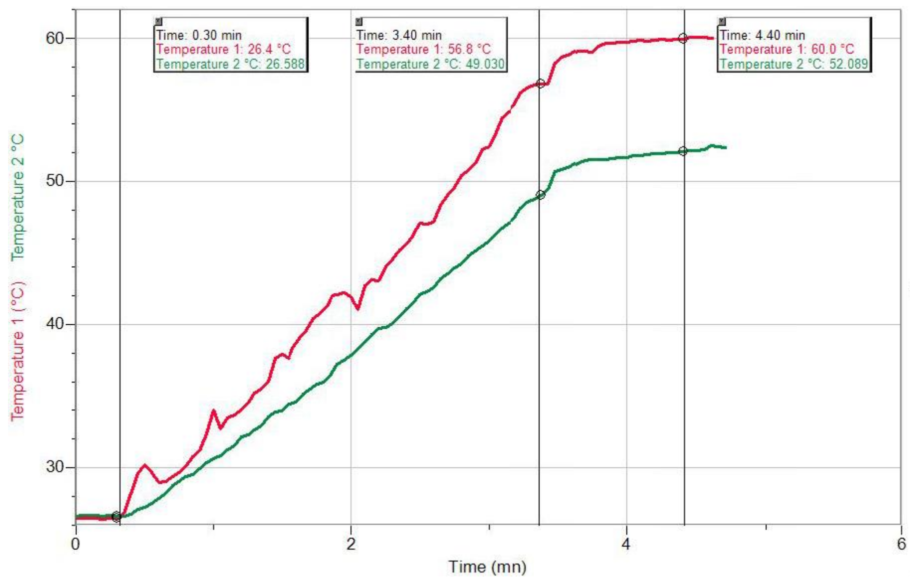


Fig 5 – temperature-time curves for water (green) and the same total mass of water and nails (red).

Note: measured temperature continues to rise for some time after the power has been removed (at 3.40 min) as the base of the pot and the water come to equilibrium at a uniform temperature.

4 Estimate the latent heat of melting for ice by melting a measured mass of ice in water at zero degrees C.

Suggested procedure

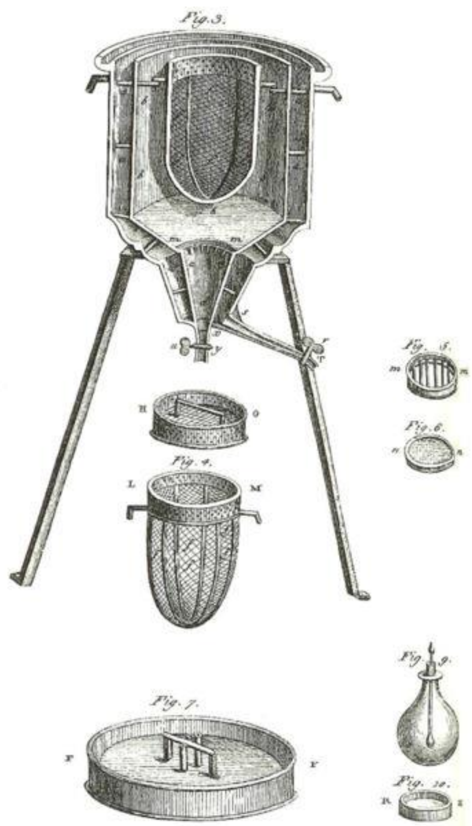
i Put a quantity of ice in the pot.

ii Plug in the pot and find the time required to melt the ice.

iii Estimate the latent heat of melting per kg.

v Compare your result with the known latent heat of melting for ice. *How might you modify your procedure to be more reliable?*

Something to think about



An "ice calorimeter" said to have been used by Lavoisier in 1780 to measure the amount of heat coming from a small animal in the inner chamber, by collecting water from melting ice in the outer chamber that dripped from the tap.

What do you think? Was that a good idea? How accurate might his measurements have been and how would you do this (measure the heat output from a mouse in J/s) with the equipment we now have?