TAP 607- 1: Measuring the specific heat capacity of a metal

The value of the specific thermal capacity of a material tells us how much energy is needed to change the temperature of one kilogram of the material by 1 degree. It is an important measurement for engineers and physicists who work with any material that changes its temperature or is designed to retain thermal energy.

In this activity you will make measurements to calculate a value for specific thermal capacity and consider some of the uncertainties in the measurements you have made.

You will need

* 1 kg blocks for thermal capacity
* 12 V immersion heater (typically 60 W)
* thermometer, 0 – 100 C
* power supply, 0 – 12 V rated to supply 6 A
* 4 mm leads
* two digital multimeters
* stopwatch

Basic experiment

* 1. Insert a thermometer and the immersion heater into their respective holes in the block. You may wish to drop a small amount of oil into the thermometer hole to improve the thermal contact between thermometer and block.
  2. Allow the thermometer to reach thermal equilibrium and then write down the temperature.
  3. Set up a suitable circuit that will enable you to measure the energy input to the heater.
  4. Turn on the current, noting the time if you are measuring energy using an ammeter and a voltmeter to record power.
  5. Energy = current  potential difference  time. Monitor and note the meter readings as the energy is supplied. They may change slightly as things warm up.
  6. Allow the block to heat up by about 10 C, then turn off the current and note the time again.
  7. At this point, keep watching the thermometer. The temperature at the turn-off time is **not** the appropriate final temperature to record. What do you think **is** the appropriate final temperature?
  8. Use E = m c  to calculate the specific thermal capacity, c, of your block. Compare your answer with a data book value.
  9. Was your calculated value of specific thermal capacity too high or too low? Which of the measurements you made is likely to be the one most in error? In which direction is it in error, and why might this be?

Slightly more sophisticated…

Energy losses are a problem in this experiment. The electrical energy measured going into the heater does not correspond exactly to the thermal energy actually delivered to the block itself (some of it goes to the immersion heater and to the surroundings) and so the temperature will increase less than you expect.

As a first improvement to the basic method, try cooling the block to about 5 C below room temperature (stand it in cold water for a while) and then warm it to about 5 C above room temperature.

Did this improve your value? How does this method help to reduce heat losses?

Outcomes

1. This experiment gives you a value for the specific thermal capacity of a metal. If others in your group have used different metals, compare your values. You may also have evaluated the specific thermal capacity for water. Is this value very different?
2. You have considered energy losses in this experiment and you may have worked hard to remove them. Generally, when devising your own experiments, try to be ingenious in removing or reducing unwanted effects.

Safety

Check the seals on the immersion heaters before use. Reject any that are obviously defective. In doubtful cases, any water which has entered during a precious activity can be removed by placing the heater in an oven for an hour at about 80 °C.

Practical advice

If you can provide a selection of different metals, it might be interesting to ask groups of students to use different blocks in order to compare results. The activity here assumes the use of an ammeter, voltmeter and stop-clock. Students using a joulemeter need only to take initial and final readings.

Some may still find setting up the electrical circuit demanding, and may need support.

It may be that the greatest source of error in this experiment is the lack of a smooth power supply. The meters do not read the correct average value of dc+ heavy ripple. If high current smoothing units are available they should be used. Better still would be 12 V car batteries.

Be safe

Impress on students the need to avoid running the immersion heaters outside the blocks, and not to cool them in water when hair-line cracks will draw water inside.

If 12 V car batteries are used, remember that they are often too heavy for one technician to lift.

Alternative approaches

A number of approaches may be used here depending on the abilities of the students. Certainly you should not feel constrained to use the proprietary blocks and immersion heaters if other equipment is already available. It might be possible with an able group to introduce a method of mixtures variant as a final piece of extension material but this would need careful treatment with a simpler method first.

Social and human context

The specific thermal capacity is an essential quantity to consider for any change of temperature. When materials are used for cooling purposes, for example, it is crucial to remove energy quickly and economically without the coolant changing its temperature too greatly. Water is, of course, ideal in this respect. But other materials are used too. In nuclear reactor technology, a variety of coolants are used to remove thermal energy from the reactor core, including liquid sodium. An additional property for reactor coolants is that they should not disturb the running of the reactor by absorbing neutrons. Hot water, close to boiling, when dropped on to the skin can cause great harm. It releases large quantities of energy into the tissues and, as every first-aider knows, the correct remedial treatment is to cool the affected part (i.e. to remove thermal energy from it) for a time of at least 500 s. This removes thermal energy from the underlying tissue as well. Storage heaters rely on the large mass and the high specific thermal capacity of the hot materials; the heater needs to retain the energy for a significant time for release into a room late into the day.

External reference

This activity is taken from Advancing Physics chapter 13, 220E