4. That's cool!

1 hour

Children model an industrial heat exchanger and investigate the temperature changes that can occur during this heat transfer.

OBJECTIVES

- To understand that heat will move across a boundary separating hot from cold water, without the two sources mixing.
- To take measurements, using a range of scientific equipment, with increasing accuracy and precision, taking repeat readings when appropriate

RESOURCES

(Per group of 4 children unless otherwise stated)

- 5m flexible PVC tubing[1]
- 2-litre plastic drinks bottle (preferably transparent)
- 2 thermometers[2] (alcohol-filled, not mercury)
- Funnel
- 2 measuring jugs (about 500 ml)
- Source of hot and cold water
- Food colouring (to colour the cold water)
- Plastic bowl or bucket
- Activity sheet 12 or sheets 13-14

Safety note

Children need close adult supervision when performing this experiment. They should be warned about the dangers of hot water and scalds.

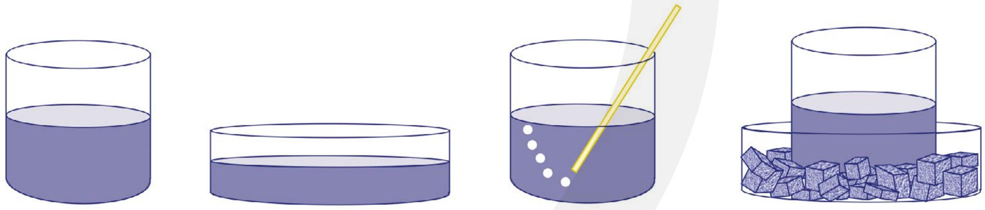
1 PVC tubing is available from educational suppliers. It is sold in a variety of lengths and bore sizes. The bore chosen will depend on the size of the funnel used.

2 Data-logging equipment (i.e. temperature probes linked to a computer) can also be used as an alternative to thermometers, if available.

CARRYING OUT THE ACTIVITY

To introduce the children to simple ways of affecting the cooling rate of water, they measure the temperature of a-d below at regular intervals.

Each jug has 200 ml of water at 60°C



The control will show the rate of cooling due to classroom conditions, e.g. temperature. The water in b, c and d cools faster than the water in a. In b and c the water is exposed to a larger surface area of cool air (provided by air bubbles in c), and in d the water is exposed to a colder surface. Allow the children to offer explanations of their results whilst ensuring that the discussion covers the factors mentioned above.

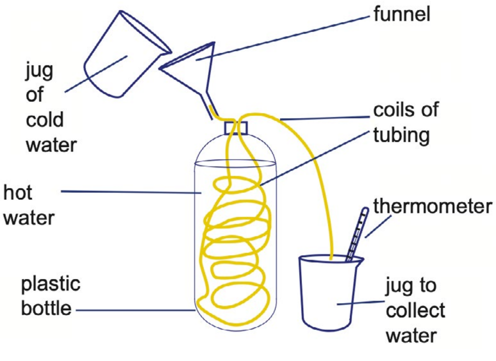
Activity sheet 12 provides an open-ended approach to heat exchange, challenging the children to find the quickest way to cool down a bottle of hot water. They are provided with the resources listed above and should be asked to think of a solution that does not involve removing the hot water. To do so would be unsafe, and would also provide an unrealistic method for industrial use, as the vessel shape and size are fixed and closed.

N.B. Whatever solution the children choose, they should be reminded to measure the temperature of the hot and cold water before and after cooling. They can be asked to measure the time taken for the water to reach a specific temperature, say 40°C.

Alternatively, the children carry out a more structured activity using Activity sheets 13- 14. This activity simulates the method used in industry to cool hot liquids. Using the equipment shown overleaf, a child holds one end of the tubing and pushes the rest of it into the plastic bottle, until about 30 cm of the tubing remains. The children fill a jug with tap water. The teacher fills the bottle with hot water, **which should be no hotter than 60°C.** With more able children, this procedure is repeated with a **control** bottle (see Appendix) to develop investigative techniques.

The empty jug is placed beneath the tubing outlet and a thermometer is placed in the jug. The children measure the temperatures of the hot and cold water and record these on Activity sheet 14. They complete the prediction boxes, giving reasons for their choices.

The cold water (coloured to show it does not mix) is poured slowly down the funnel and through the tubing coiled in the bottle. When the cold water has stopped flowing, the temperatures of the hot and cold water are taken again, and recorded on Activity sheet 14.



The temperature differences of the hot and cold water are compared. A space is provided on Activity sheet 14 for the children to record the differences. Typical results, with a starting temperature of 60°C, would show a rise of about 15°C for the cold water and a drop of about 5°C for the hot water.

If the bottle is to be used again immediately, the tubing should be removed and stretched out over a sink to release trapped water. If this is not done, water trapped in the tubing will mix with the next cooling water to pass through, and will increase the apparent temperature difference of the cooling water.

The illustration on Activity sheet 2 is not an exact representation of an industrial

site, but children can discuss which vessel is used for heat exchange. The best suggestions would be one of the two vessels the water passes through before flowing into the river.

DISCUSSION QUESTIONS

- What has happened to the temperature of the cooling water that has been poured through the tubing? Why?
- What has happened to the temperature of the water in the bottle? Why?
- In industry, cooling water often flows through many thin tubes in a container of hot liquid. What difference might this make?

BACKGROUND INFORMATION

The water passing through the tubing shows a marked temperature rise, as heat has transferred from the hot to the cold water. The percentage of cold water in contact with hot water is greater than the percentage of hot water in contact with cold water, as there is three times more hot than cold water. Therefore the cold water's temperature rise is greater than the hot water's temperature drop.

In industrial cooling systems, the surface area of contact between the two liquids

is maximised by putting hundreds of cooling tubes inside a vessel called a heat exchanger. The flow rate of water is controlled (either manually or automatically) to obtain the desired temperatures. For safety reasons, there must always be a flow through a heat exchanger, as a build-up of hot materials can result in high pressure and pipe rupture.

Water is not the only coolant used in industrial heat exchangers, air is also used. Cool air can be blown over exchanger tubes using large fans.

EXTENSION ACTIVITY

There are many factors which affect the rate of cooling which children can investigate, including the length of tubing coiled inside the bottle, coiling the tubing around the outside of the bottle and the diameter or thickness of the tubing. Only one variable should be varied during an investigation, to ensure fair test conditions are maintained.

Appendix: Using a control during heat exchange

The extra resources required are:

- 5m flexible PBC tubing
- 20 litre transparent plastic drinks bottle
- 2 thermometers
- Source of hot water

A control can be used alongside the test bottle, to ensure fair test conditions. This control is set up in exactly the same way as the test bottle, so that as many factors as possible remain constant. *The control bottle will monitor any temperature changes that occur due to the surrounding conditions* (e.g. the room temperature). The difference between the two bottles is that cooling water is poured through the tubing in the test bottle, but not the control bottle.

N.B. *It is not possible to obtain the same 'pattern' of coils in each bottle. The effects of this on the surface area of contact between the tro liquids can be discussed with ore able children.*

The variables to be controlled (i.e. kept the same) are: Size, shape, material of the bottle

Length, diameter, material of the tubing

Volume of hot water

Position of the thermometer in the water

Timing of the readings of the test and control water

The control of variables should be discussed with the children before carrying out a controlled experiment.

The children can predict what they think will happen to the temperature of the control water as well as the test water, using the space provided on Activity sheet 14.

Comparing the resuslts for the test bottle with those for the control will show any change in the cooling rate of the hot water due to the presence of the cooling water passing throug the coils. For example, a typical temperature drop for the control water is 1-2 oC and the hot water in the test bottle will drop about 5-6 oC over the same period of time.

If no control has been used, there would be no way of knowing how much heat was lost to the surroundings and how much to the cooling water. It could therefor be argued that none, or little, of the temperature difference was due to the cooling water.

RECORDING RESULTS

An empty row has been left in the table on Activity sheet 14 for children to add temperture readings for a control bottle, and make comparisons