Can a *MaxChill™* sports bottle really cool a drink to below ambient temperature without adding ice? – Teachers' Guide

Cooling by the process of evaporation is not an immediately obvious one, even though it is commonly used today by gardeners owning greenhouses where they often spray water on their floors to cool them down on very hot days. Indeed the idea is by no means new, the population of the hottest parts of India are known for many centuries to have poured water onto their house roofs to cool them and to have hung wet mats at door and window openings to cool the inside as the wind blows. On a much larger scale, power stations utilise the process of evaporation in their giant cooling towers to cool water prior to recycling it back to the boilers to turn it into steam to drive the turbines. If you have a power station with cooling towers nearby then a visit to it would be useful, not just to see the evaporative cooling, but also the generating and transmission of electricity.

For the students to appreciate why evaporation produces cooling they will need an introduction to kinetic theory. With ideas of molecules in motion and the concept of a distribution of speeds of motion, it is not difficult for them to understand that hotter liquids will have more higher speed molecules than cooler ones, though both will have some low speed molecules too. For molecules to escape from a surface they are likely to surmise that they will be the faster ones, so leaving the slower ones behind, hence a cooler liquid.

Unfortunately the cooling of the *MaxChill™* bottle by evaporation is more complex than just dealing with the evaporation of water from the floor of a greenhouse and you will need to deal with the energy transfer between the contents of its outer cover, the plastic of the bottle, and the water inside.

Further discussion could focus on why evaporation is quicker from a thinly spread film of liquid than from a beaker containing the same amount. The effect of a breeze needs to be broached, explaining that few escaping molecules will then get bounced back by the air molecules and so the cooling is more effective. Whilst the activity does not look at liquids varying in volatility, that also could be discussed, noting how cohesive forces are lessened in more volatile liquids. The effect on the rate of evaporation with temperature can also be looked at, this being greater with rising temperature as more molecules will have enough energy to escape. Finally the difference between evaporation and boiling needs to be addressed, the former taking place at all temperatures and the latter only at the liquid's boiling point.

Demonstrations with marble trays and the 3-D kinetic theory apparatus in which ball-bearings are put into motion in a tube will help to give students a picture of what is going on and the fact that it is in collisions between molecules that energy is transferred. Some might like to make up a 'flick book' to illustrate molecular motion in gases, or indeed to model evaporation from a liquid.

This activity also gives an opportunity to deal with different temperature sensors and, although the sensor used here is a ntc thermistor, other thermal sensors could be discussed and demonstrated, together with the concept of thermal capacity and its effect on response time.

Whilst one could organise the activity to be conducted on a bicycle (as illustrated in the initial photograph), it is likely that this might well be distracting to the rider unless *LabQuest's* display screen is deliberately covered during the ride.

Typical results

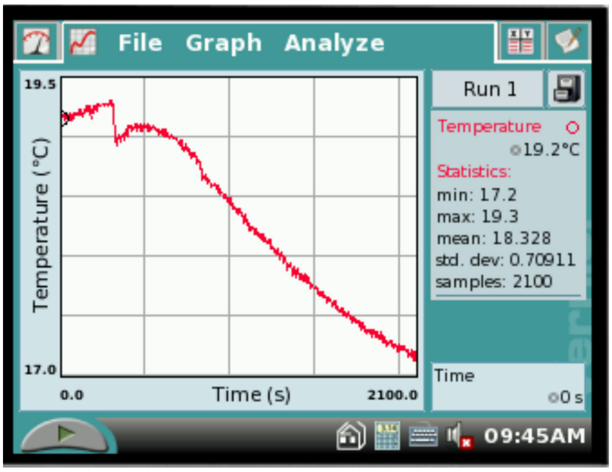

Figure 1 Graph of Temperature against Time and statistics for the cooling of the *MaxChill™* sports bottle

Answers to questions

Q1 It would stay at or go to whatever the ambient temperature was.

Q2 There should be negligible change of temperature

Q3 It may have decreased a little.

Q4 It decreased by approximately 2°C.

Q5 The students' answers should make mention of faster and more energetic water vapour molecules being able to escape from the outer cover leaving the slower ones behind, hence making it cooler. They also need to mention that there must be an energy exchange by collisions between the molecules within the bottle, the bottle wall itself, and the outer cover.

Q6 The process is evaporation and takes place at all temperatures whilst boiling only occurs at the boiling point.

Q7 This is sweating or perspiring.

Useful websites

Chem4Kids – Evaporation of Liquids
http://www.chem4kids.com/files/matter_evap.html
There is a simple description here, accompanied by a picture, of the process of evaporation.

Evaporation
http://hyperphysics.phy-astr.gsu.edu/hbase/kinetic/vappre.html
This Hyperphysics website has some excellent diagrams illustrating the difference between evaporation and boiling. There are also links within this website dealing more generally with kinetic theory.

Let Physics Cool Your Drink!
http://www.maxchill.com/Home.html
This is the homepage of the *MaxChill™* Sports Bottle.

Temperature Sensor – The Thermistor
http://www.facstaff.bucknell.edu/mastascu/elessonshtml/Sensors/TempR.html
There is a lot of useful information here on thermistors and links to more on both thermocouples and band-gap sensors.

Useful book

Practical Electronic Sensors. Owen Bishop. Bernard Babani (publishing) Limited. 1991. ISBN 0 85934 218 2.
This inexpensive paperback looks at a large range of sensors and how they work. In some cases it also provides circuits in which to incorporate a sensor for a particular application.