CONDENSATION

Experiments demonstrate clouds forming in the classroom

At a recent Institute of Physics/MMU secondary school physics and science teachers' conference, I was asked to present some classroom experiments that demonstrate the physics governing well known atmospheric phenomena. In this article a subset of these experiments, relating to the formation and characteristics of clouds, will be described.

Cumulus clouds with flat bases demonstrate many physical concepts, including condensation and evaporation, convection and the scattering of light. Image courtesy CloudBank image library of the Royal Meteorological Society.

Clouds in a bottle

The most stunning cloud-related demonstration is undoubtedly the production of a cloud in a bottle. Many sources of information and apparatus are available. However, through extensive research, we can recommend the following method for effectiveness, scientific accuracy and availability of materials. An old Schraeder-type bicycle inner-tube valve should be pushed through a rubber bung. This can then be attached to a foot or hand pump. Next, a small amount of hot water should be poured into a 2 l plastic drink bottle and swirled to wet as much of the internal surface of the bottle as possible. For safety, the bottle should be one that is designed for use with a sparkling drink—these will cope with pressures exceeding anything that could be achieved here—and should be checked for signs of damage. Air should be pumped into the bottle, maintaining a tight seal by using one hand to keep the bung pushed well into the bottle neck. The air should then be released suddenly by allowing the bung to pop out. At best, a faint cloud should form as some of the water vapour condenses. The cloud is faint because although the air in the bottle was supersaturated with respect to water vapour, there were no cloud condensation nuclei (CCN) present [1, 2, 3]. A little smoke should be added to the bottle (by gently blowing on a smouldering match) and the experiment repeated. A dense white cloud should now form in the bottle.

The experiment can be performed using ethanol rather than hot water. In this case, no smoke is required. Ethanol has a substantially greater vapour pressure than water, and such high levels of supersaturation can be achieved as to make nucleation possible without any CCN present.

If a thermometer is available, this could be put in the bottle. It will show that as air is added to the bottle, the temperature rises a few degrees, although because the air is added relatively slowly there is a flux of heat to the surrounding atmosphere. As the air is suddenly released from the bottle, both the pressure and the temperature fall abruptly. This can also be demonstrated by pointing an infrared thermometer at the bottle.

As well as being a powerful demonstration, this experiment demonstrates many applications of classroom physics at a variety of levels; from the water cycle to the Ideal Gas Equation and the fact that the rate of evaporation from a curved sur-

Creating a cloud in a bottle with Key Stage 2 students in Manchester.

face decreases with radius [1]. It is also possible to make 'negative smoke rings' in the bottle by gently squeezing out some of the 'cloud' from the bottle.

Clouds in a glass of beer

Another demonstration of the need for condensation nuclei can be shown using a glass of sparkling drink. Close inspection should reveal that bubbles do not form at random sites; the CO_2 changes phase (or nucleates) at places where there are imperfections or dirt on the surface of the glass. Some manufacturers now deliberately design glasses to promote bubble formation. If a small number of sultanas are added to the drink, they sink at first. Then, as bubbles nucleate on them, the upwards force slowly increases until the sultanas float to the surface, at which point the bubbles burst and the sultanas sink again. Adding salt to the drink similarly, and dramatically, increases the number of nucleation sites and produces noticeably more bubbles (small glass beads can be used instead to show that the release of CO_2 is not due to a chemical reaction with the salt). In effect, this creates a 'reverse cloud' in the drink, in the sense that there is a cloud of CO_2 gas in the main body of liquid [2, 3].

Why do rain clouds look black?

As an observer on the ground, we cannot tell whether this is because the water droplets in the clouds are absorbing or reflecting the incoming solar radiation. This can be demonstrated using an old-fashioned overhead projector, with two glass containers—one containing a little milk, the other a little black ink. Looking at them directly, it is obvious that the milk is reflecting the incoming light, whereas the ink is absorbing it. However, using the projector to observe the transmitted light produces two black images. It is only because we observe thinner, smaller clouds to be white, that we can deduce that they are mainly reflecting (scattering) light.

Using an infrared thermometer

Some infrared thermometers can be used to observe cloud temperatures, and hence relate the cloud characteristics to their level in the sky. For example, cloud base is always flat and occurs at the level at which the rate of condensation exceeds the rate of evaporation. Cirrus clouds consist of ice, which gives them their wispy appearance. Our infrared thermometer (cheaply obtained from Maplins) has an optical resolution of 8:1 distance to spot ratio, and responds to 6–14 μm (long-wavelength infrared)—this range is not affected by water vapour or CO_2 absorption. By integrating the Planck function over this range, the temperature of the dominant infrared source in the field of view may be obtained. The resolution is sufficient to determine the temperatures of high clouds (as well as surface objects), as well as allowing a rough estimate of the temperature of the Sun.

These demonstrations and many others are available to download from the internet. For more details visit www.MetLink.org.

References

[1] Knight S 2011 Cloud control *Catalyst Secondary Science Review* **21** 4

[2] Russell A, Ricketts H and Knight S 2007 Clouds *Phys. Educ.* **42** 457

[3] Bohren C F 1987 *Clouds in a Glass of Beer* (New York: Wiley) p 185

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