The heat is on

One of the core activities in chemistry at all levels is heating substances. This is usually done with little fuss and few accidents. The presence of naked flames and hot objects or substances is, however, a significant hazard so a review of methods and techniques for heating chemicals seems timely.

Burners

The most common method of heating in the school chemistry laboratory remains the use of the Bunsen burner or using some other type of burner.

Bunsen burners

The means used overwhelmingly more than any other in a chemistry laboratory is the Bunsen burner. Despite having been in use since 1857, it has not really been bettered. The presence of a hot, naked flame though does raise a few issues that need to be addressed for its safe use:

1) Ensure you purchase the correct type of burner for your gas supply. The two types of gas require different size jets and ratios of oxygen to burn efficiently and it can be dangerous to use the wrong type.
2) Use appropriate tubing.
   a) The traditional orange rubber tubing is fine but it perishes on exposure to hydrocarbons and should be closely inspected at least annually and damaged tubing replaced.
   b) Thick-walled nitrile tubing (usually black) will not perish but is quite rigid and in use the tension in the tubing can result in the Bunsen burner being overturned.
   c) The best option is thinner walled, more flexible, nitrile tubing which is usually grey.
   d) There is no need to have the reinforced end pieces. If they are fitted, be careful not to remove the pipe from the gas taps by pulling on the tubing as this can cause the end piece to work loose.
3) A naked flame is not suitable for heating flammable substances, such as ethanol or propanone. If these need heating, other methods should be used such as a water bath.

Other gas burners

It used to be possible to get attachments to fix to camping gas cylinders that would allow them to be used as Bunsens.

These have never been a good idea but recent changes to regulations mean that they should not be used in the laboratory. They should not be available from any reputable school supplier but are still to be found on Amazon and Ebay and from overseas. If you have any, they should be disposed of.

Figure 1 - Attachment for camping gas cylinder. NOT to be used in schools (image Lilly_M under Creative Commons license 3.0).

It is possible to purchase properly designed portable butane burners (see Figure 2) these have a heavy base making them perfectly stable and are a good alternative if you are working in a room without a gas supply or perhaps out doing fieldwork.

Spirit burners

These are simple glass jars with a wick that typically burn ethanol (usually in the form of methylated spirits).

They can be purchased from most suppliers or you can make your own from mini jam jars (see Figure 3).

The safety issue here is that there is a reservoir of highly flammable liquid that could spill in the event of being knocked over. With moderate care, though, this is not likely as both designs are quite stable.

The size of the flame is determined by the wick rather than the amount of fuel in the burner's body so it is best if this is kept as low as required for the session.

If the burners are being stored for any length of time, they should be emptied of fuel. When being stored in the short term, a lid is a good idea to reduce evaporation of the ethanol; for safety as well as for reducing the need for refilling.

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Figure 2 - A butane burner'.

Figure 3 - Homemade spirit burners.

Electrical heaters

These are very useful in situations where the presence of a naked flame is dangerous - especially when working with organic solvents which are often highly flammable.

As electrical devices, it is important that these are PAT tested at appropriate intervals and that before use they are given a quick visual inspection to ensure they seem safe.

Hot plates - These heaters consist of a flat hotplate that flasks and beakers can be placed on. They are often combined with a magnetic stirrer - a very useful facility. In theory, they claim to heat up to 300°C or more. In practice it is difficult to get this high due to heat loss from the beaker/flask to the surroundings.

Heating mantles - these are more specialised heaters, designed for use with round-bottomed flasks particularly during organic chemistry. Again, there can be issues with heat loss to the environment preventing high temperatures being achieved.

TIP

If you wrap aluminium foil around your flask on either a hotplate or a heating mantle, it will reflect back much of the heat and allow you to achieve a higher temperature.

Electric 'burners'

Unlike other electric devices, these 'burners' produce a high intensity stream of heat and can be used to replace a Bunsen burner - apparently achieving temperatures of 900°C.

With these sorts of temperatures, great care should be taken to avoid things such as overheating of substances (e.g. oils), ignition of flammable solvents etc.

Ovens - a laboratory oven can be set to heat a substance for a set period of time at a set temperature. They are designed to maintain the temperature more accurately than domestic ovens but are less widely used than might be the case as it is not possible to observe any changes taking place within the oven. They are, however, invaluable for drying solids for accurate making up of solutions or for other preparations. Incubators work in a very similar way but at lower temperatures, mainly for incubation of microorganisms.

Hairdryers - while not used much for actual heating, they are often used for drying things such as chromatograms. They can also be used for some heating experiments such as that of the cobalt chloride mixture in the demonstration 'equilibrium and Le Chatelier'. Care should be taken when purchasing cheap hairdryers to ensure they are of a suitable standard: for instance, those that have a switch between 110 and 220 V and not suitable for use in schools.

Microwaves - while not widely used in schools, microwave ovens are growing in use in laboratories. They are not suitable for all purposes but can be used to heat certain substances much more rapidly that might be the case otherwise. There are a few specific issues to be wary of:

1) Metal items, including spatula, aluminium foil etc., should not be placed in a microwave under any circumstances. They can rapidly heat and ignite causing serious damage.
2) Non-polar substances are not affected by microwaves so cannot be heated this way.

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Figure 4 - A heating mantle wrapped in foil to help achieve higher temperatures.

3) Some solvents such as water can easily become superheated un a microwave, meaning that when disturbed they can instantly boil and may deposit boiling water over your hand.
4) Flammable substances produce vapour when heated and this is trapped in the microwave chamber. Ethanol, for instance has a flashpoint of only 13°C and so the slightest spark can easily ignite the vapour potentially causing an explosion. Unless you are certain of your solvent, stick to just using the microwave for aqueous mixtures.

'Baths'

Heat can conveniently be applied to substances by immersing their container in a fluid of an appropriate temperature. In all cases, care must be taken to ensure that hot liquids are not spilled as they can cause nasty scalds and burns - especially oil.

Water baths are the most commonly encountered. For longer heating or large quantities, commercial water baths should be purchased: These are filled with water and the water is heated and maintained as a specific temperature by a thermostatic control. They are particularly useful for biological experiments.

On a small scale, you can simply heat a beaker (or other container of water) remove the flame and then place a test tube of your substance in the water - for removing chlorophyll from a leaf for instance.

Oil baths work in exactly the same way but as oils can be safely heated to over 200°C higher temperatures can be achieved. Can should be taken to avoid overheating and hence a fire.

Sand baths are most commonly used in conjunction with a hotplate. If the hot sand is piled up around the beaker/ test tube, it ensures the heat comes from the sides as well as the base and this can speed up the reaction as there is less reliance on convection to distribute the heat.

Conclusion

The main risk from all of these techniques comes from the heated substance itself: either simply by exposure to hot liquid/solid and getting a burn/scald or perhaps from properties of the chemical itself due to flammability of solvents such as ethanol or potential explosivity of things like ammonium nitrate. In addition, when heated some substance will emit dangerous fumes; in these cases, the heating should be carried out in a fume cupboard.

So as well as ensuring you know the dangers associated with the technique you have chosen, it is also vital that you are aware of any hazards from the chemicals you are using. If you are unsure, contact us here at SSERC for advice. <<

Figure 5 - An electric 'burner'.

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