

Voltage values for **safe circuits**

We are now issuing the following advice on voltage levels for circuit building in schools:

- Pupils and students should carry out such work at no more than 30 V, irrespective of whether ac or dc is used.
- If there is a chance of touching an uninsulated conductor with wet skin, or of touching an uninsulated wet conductor, the limit becomes 15 V.

This is slightly different to what we said in an in-depth article about electrical safety in 2003 [1], though much of the information in that piece is still useful. We have based our advice around the concept of a “hazardous live”. According to the British Standard we use for guidance [2], if something is hazardous live it is capable of causing an electric shock or burn. The version of the standard in use in 2003 stated that smooth dc above 70 V could be considered hazardous live, as could ac or unsmoothed dc above 33 V. This was for dry conditions. The limits for wet conditions were half those for dry.

The latest version of the British Standard has set the dry limits lower, at 60 V and 30 V respectively. Having discussed the issue with our friends at CLEAPSS and ASE, we have decided on the 30 V ac and dc limit for the following reasons:

- There is no educational justification for carrying out circuit work at voltages between 30 V and 60 V dc.
- It is not always obvious whether a dc supply is smooth without testing it. Not every teacher or technician will be confident in applying the test, which would involve examining the output using an oscilloscope.

The advice also applies to the use of apparatus such as ray boxes, motors and heaters that students might connect to a power supply. There may be circumstances where a smooth dc voltage greater than 30 V (but not

60 V) for open circuit work can be justified. A specific example, gel electrophoresis, is described below. Please contact us to discuss any other activities you have in mind.

Gel electrophoresis

The National Centre for Biotechnology Education (NCBE) has developed activities on gel electrophoresis that feature on the SSERC website [3] and in some of our workshops. For the electrophoresis process to run in a reasonable time, it was common to connect 3 x 9 V batteries in series. NCBE then produced a 36 V dc power supply. We feel that we can justify student use of these voltages provided that:

- There is close supervision;
- All power supplies are switched off and unplugged from the mains while tanks are assembled and connections made.

For electrophoresis experiments using greater voltages, shrouded leads **must** be used and the equipment **must** have interlocks. An example of an interlocking system would be an electrophoresis tank where the power supply remains electrically disconnected unless a protective lid is locked in place.

You can read more about control measures when working with hazardous live voltages in Bulletin 253 [4] but note that the older voltage limits (e.g. 70 V instead of 60 V) are quoted in this article.

Smooth and unsmooth

Figure 1 shows how the outputs of different power supplies vary with time. Any dc that is not ripple-free is said to be unsmooth. The ripple may not necessarily be as pronounced as that shown in the middle image. >>

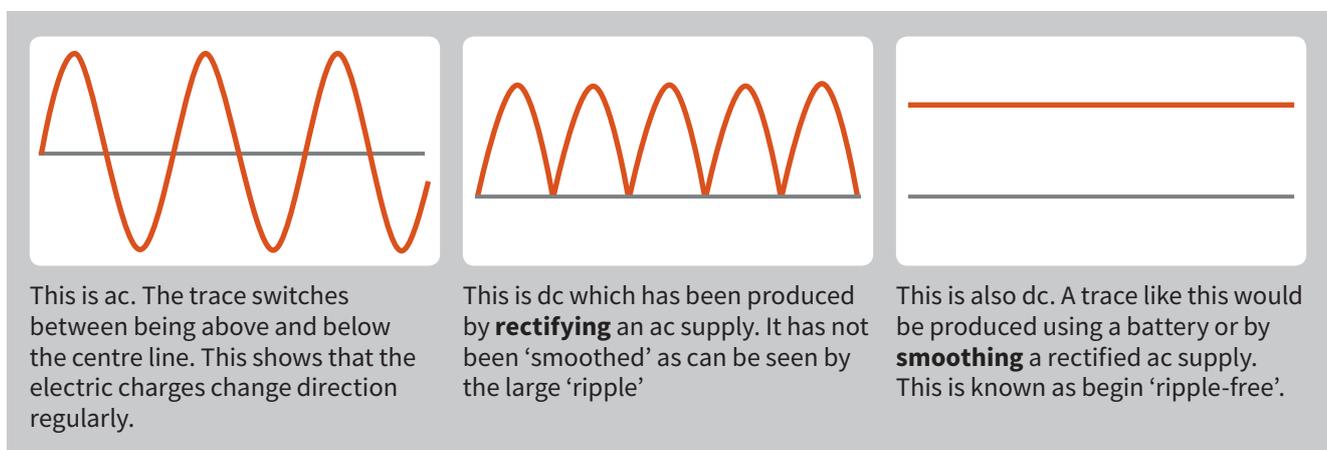


Figure 1 - Ac, unsmooth dc and smooth dc.

ac versus dc

Why are the limits for ac lower than for smooth dc? The effects of electricity on the body are complex, but we do know that the higher the current in the body, the greater the chance of harm. It is also true that if voltage increases, current increases. All materials have an electrical property called impedance. The lower the impedance, the higher the current for a given voltage. If you have studied physics to Higher level but not beyond, you might be thinking, "This impedance sounds just like what we called resistance." You would be partially correct, and a human body does indeed have a resistance. However, it also has a property called capacitance that contributes to a reduction in the body's overall impedance. This contribution depends on the frequency of the electrical source, i.e. how many times the output changes per second. Smooth dc is unchanging with time unlike ac

and unsmooth dc. The bottom line is that the body's impedance is less for unsmooth dc or ac than for smooth dc. For the same voltage, ac or unsmooth dc will cause a larger current in the body than smooth dc. This is one reason why the smooth dc voltage limit is higher. <<

References

- [1] SSERC Bulletin 208, Working with HT supplies, electrical safety.
- [2] BS EN 61010 Safety requirements for electrical equipment for measurement, control, and laboratory use.
- [3] <https://www.sserc.org.uk/subject-areas/biology/higher-biology/dna-and-gene-expression/> (accessed January 2019).
- [4] https://www.sserc.org.uk/wp-content/uploads/2018/10/SSERC_bulletin_253_p13-15.pdf (accessed January 2019).

Locust allergy

Allergy to locusts has been reported as an occupational allergy found in research staff working with repeated exposure to large breeding colonies of locusts. A proportion of these workers (invariably less than 50%) may become sensitised to locust allergens and of these a proportion may exhibit symptoms of asthma, rhinitis, dermatitis or conjunctivitis. There is some evidence that workers with previous allergies may be more susceptible. Such allergies develop slowly with prolonged contact with locusts. The major source of locust allergen is found in locust faeces arising from the epidermal cells of the mid-gut and ceca [1].

The key to reduce the risk of sensitisation to locust allergens is avoidance. For short-term studies (until the adults reach the end of their natural lives after a few weeks), the risk of allergic reactions is low. Locusts should not be maintained in continuous culture; it is safer to buy in locusts when needed rather than attempt to maintain a permanent culture [2]. Nevertheless, care must be exercised when cleaning out the cages to avoid raising dust. Cages should be constructed of material that is easily cleaned, is non-absorbent and is not perforated [3]. Simple plastic aquaria or vivaria can be suitably adapted to house small numbers of locusts. The sand tubes in commercial cages should not be used and the holes in the flooring should be blocked off. For the small stocks

of locusts likely to be encountered in schools gloves and a dust-mask covering mouth and nose should provide sufficient personal protection where it is required.

The following information should be useful in forming the control measures of a risk assessment:

- Determine if the pupil (or indeed teacher or technician who may be involved in handling locusts) has a history of allergic conditions and if so their relative severity.
- Do not attempt to set up a breeding colony of locusts. Rather buy in locusts as required. Maintain the locusts in a suitable container. Homemade wooden and muslin containers are not suitable.
- Avoid raising dust when removing locusts from the container for experimental purposes. You may wish to consider transferring locusts to a 'holding container' prior to experimental use. Handling locusts involves a low level of risk of allergic reaction or sensitisation. Wash hands immediately after handling locusts.
- When cleaning containers in which locusts have been maintained avoid raising dust, wear gloves and a dust-mask covering mouth and nose and work in a well-ventilated area.
- Consider if removing locusts to a 'holding container' for use and the cleaning of containers in which locusts have been maintained should be carried out by the pupil or by a technician/teacher. <<

References

- [1] Meir Paul Pener, (2014), Allergy to Locusts and Acridid Grasshoppers: A review, Journal of Orthoptera Research 23(1):59-67, <http://www.bioone.org/doi/full/10.1665/034.023.0105>.
- [2] Keeping and Housing Animals, L56, CLEAPSS. 2017, <http://science.cleapss.org.uk/Resource/L056-Housing-for-animals.pdf>.
- [3] Animal Allergy including that to Laboratory Animals - Policy and Guidance, University of Cambridge Health and Safety Division, 2004, <https://www.gurdon.cam.ac.uk/staffonly/forms/safety/biologicalsafety/UsefulInfo/Allergy>.

Involving students in safety

'Advanced Higher students carrying out project work can write their own risk assessments. True or False?'

This is a question we often ask at SSERC health and safety courses and most people answer, "True, but the risk assessments should be checked by a teacher." It's a good answer and one that often leads to discussion on how we can involve young people in risk assessment from an early age. Many teachers, perhaps subconsciously, do this from day 1. A secondary science teacher may, when running the first practical with a new S1 class, ask them what they think the hazards are in the activity and how the risk could be managed, though they might not use this language.

- What could harm you in this experiment?'
- How are you going to keep safe?'

Risk and risk management is specifically mentioned in CfE at all levels in Broad General Education:

'I am learning to assess and manage risk, to protect myself and others, and to reduce the potential for harm when possible.'

**HWB 0-16a/HWB 1-16a/HWB 2-16a/HWB 3-16a/
HWB 4-16a**

In addition, some courses such as Skills for Work: Laboratory Science at National 5 and Advanced Higher Chemistry require students to produce formal risk assessments as a part of the course. The following strategies, along with the aforementioned questioning, should help students develop skills in risk assessment and risk management. It helps if we make it clear to students that risk assessing is a process. The outcome of the process is a document, a risk assessment, which is a record of the process and which contains the control measures needed to carry out the activity safely.

Help students distinguish between hazards and risks

A hazard is something that can cause harm, like electricity. Risk combines the likelihood of something going wrong with the severity of harm should it do so. Use examples such as crossing the road. Whether you cross the school playground or the M8 motorway on a Saturday afternoon, the hazard is the same - being struck by traffic. However, there is usually very little traffic in the playground, so the chances of being hit are small, and vehicles generally move slowly, so any injury is unlikely

to be severe. Contrast this with the M8, where there is much more traffic and consequently a greater chance of being struck. The traffic tends to move so fast that any impact is going to result in a life-changing injury if not death. Starting with the same hazard, we have two vastly different risks, one which is easily reduced further by looking both ways, the other being intolerable no matter what control measures you put in place.

When we say that a risk is intolerable, we mean that there is no way to carry out the activity safely. Some risks are trivial - no control measures are required. In the middle ground are risks that are tolerable provided certain control measures are implemented.

"Move along, nothing to see here"

Emphasise that some activities have no significant hazards and that if this is the case, nothing more needs to be done. Nothing undermines Health and Safety more than the elevation of trivial hazards into significant risks, requiring all sorts of pointless control measures. Eye protection does not need to be worn when a trolley is rolled down a slope. There is a real danger of being seen to 'cry wolf'. If you insist on eye protection for all activities involving 'chemicals' then there is the danger that students will become blasé due to having to wear them for substances they know are harmless, vinegar or salt solution for example, and this could lead to them assuming that the eye protection simply isn't that important.

Model the behaviour you expect

Insisting that students wear eye protection then not wearing it yourself may suggest to students that eye protection is just a nag dreamed up by you to exercise your authority. Or perhaps they will feel they have been made to dress up as scientists.

Don't get students to dress up as scientists

If students require a lab coat or safety glasses in order to protect themselves, fine. If not, they should not wear them. Personal protective equipment is not a uniform that identifies someone as a scientist. Indeed, the Royal Society of Chemistry has resources based around the theme, 'Not all chemists wear white coats'. Work where lab coats must be worn represents only a subset of science. We have heard some primary teachers say that their children love wearing white coats (or a parent's old white shirt) for science, but we have to ask whether the same teachers would have their pupils wear artists' smocks when drawing with pencils. This is an area where we would genuinely like to hear your views. >>>

Teach older students to be systematic

There may be general hazards in an activity-slips, impact, cutting etc. It may help students to comprehensively cover other hazards by grouping them. For example:

- Fire
- Chemical - toxic, corrosive, flammable, irritant
- Electrical
- Radiation - ionising and non-ionising
- Biological - materials of living origin, microbiological

Talk about risk assessment and the workplace

Students should be aware that they must follow safety advice and if they don't, they cannot take part in practical

work. It is worth explaining to all students that in the workplace, risk assessments are carried out. Safety advice is then drawn up and communicated to staff. The consequences of failing to follow your employer's safety guidance could be disciplinary measures up to and including dismissal.

In school, in the workplace and in life in general it is impossible to eliminate risk. CfE recognises the importance of young people assessing and managing risk. In school science and technology departments, we have an unrivalled opportunity to develop their skills in this area. <<

Keeping in touch

Website access

Apologies to those of you who have fallen foul of a glitch in our system. You are supposed to be able to set/reset your own password but when attempting to do so while not logged in (having forgotten your password for instance) the link you have been sent to click on to confirm has been telling you it is invalid.

We think this has now been fixed. If you are still having problems accessing the website then do get in touch and we will sort it out.

Maintaining access

We have had the occasional request for the ability to make a printed version, particularly of the Hazardous Chemicals advice. The previous website allowed you to simply print the pages (a bit clumsy but it worked) but the new tabbed layout, while giving a much better browsing experience, makes this nigh on impossible.

So we have now produced a printable version of the Hazardous Chemical information from the pages. Note this does not contain the concentration calculator or the experiment guides but it will give you the necessary health and safety information.

This raises other issues. Such as why would you want to? To be fair, there are plenty of people who are happier seeking out the information on paper. That is perfectly reasonable.

We have come across a few cases where technicians are being told they have to have a paper copy - we assume as some sort of a backup. There are a few scenarios that could be put forward to justify this:

Scenario 1: the school does not have WiFi or wired internet access (or more likely it is not accessible in the Technician Base). Frankly, these days internet access for technicians is not a luxury: it is an essential. Technicians need access for a variety of aspects of their job so the school simply needs to sort this out.

Scenario 2: the internet has gone down. Possible but it is not very common and it is rare that the outage will last a long time. Given that our website is accessible by mobile device, the small amount of checking of safety information that may be needed during the outage can be done easily by phone or tablet.

Scenario 3: There is an incident in the prep room or elsewhere in the school. In fact this is an argument **against** using a paper version. Unless you remember to pick up the bulky file when evacuating or you have another copy elsewhere in the building then you will not have access. The internet will allow you to access our website at any time.

One more point is that as the website is being constantly updated, your paper copy may be out of date. It will be updated from time to time but realistically this will not happen more than annually at most.

So, if you want to print the Hazardous Chemicals advice, feel free, though you will be sacrificing several trees to do so (the document comes in at 550 pages!) but don't feel that you have to. <<

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



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

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.

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. >>



Figure 2 - A butane burner.

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.



Figure 3 - Homemade spirit burners.

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 than 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.



Health & Safety



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

- 3) Some solvents such as water can easily become superheated on 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 at 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. Care 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'.