Cambridge Assessment International Education

# Guide to planning practical science

## Contents

## Planning the accommodation[1]

This booklet is a guide to planning new laboratories and adapting existing facilities.

Science teaching needs a variety of areas including laboratories, stores, technician workshops or preparation rooms, resource areas and office space for teachers.

Siting all the science accommodation in one area is usually more economical in terms of both teachers' and technicians' time. This can also result in more efficient use of preparation and storage space, and reduce the overall equipment needs for science.

The following is a general guide when considering your particular requirements.

**Please note:** Endnote numbers relate to information in Appendix E on page 24.

### Number of laboratories

You will need to examine your school's curriculum, timetable and staffing when planning science laboratories. You should also consider possible future requirements.

Group sizes and the amount of curriculum time spent on science vary from school to school. The number of teaching periods will depend on the availability and deployment of science teachers. Decisions on this and on the proportion of learners' time to be spent on science will determine the average size of the teaching groups.

The efficient use of laboratories and other science teaching areas is important. However, because of the complexities of timetabling, schools will probably find it difficult to achieve a frequency of use higher than 90 per cent.

### Size of laboratory

If all the laboratories in a suite are the same size, there should be few constraints on timetabling them. You can enhance flexibility if all the laboratories can accommodate the likely maximum class size.

The size and shape of any existing laboratories will vary, but in general spaces of 85 $m^2$ are suitable for a maximum group size of 30 learners. However, in some situations, for example where a school has small class sizes, it may be appropriate to provide some small specialist laboratories.

The size of a new laboratory will depend on the maximum group size expected rather than the calculated average. You will also need to think about the range of activities being undertaken and the amount of storage available in the laboratory.

### Other teaching areas

Extra teaching areas can be valuable additions to the science suite where space allows, for example a small resources area. This space can provide a focus for the department, with displays of learners' work and a poster area illustrating new scientific developments. Common resources such as books and computers/laptops can also be kept here, avoiding duplication in each laboratory.

### Preparation and storage areas

Preparation and storage areas of around 0.5 $m^2$ per learner are needed to support the teaching. Where the laboratories are dispersed or on two floors, this figure may need to be increased to allow for some duplication of resources.

A shared staff office can be useful for meetings and preparation work, as well as the secure storage of paperwork such as learners' records and coursework.

## Planning principles[2]

There are two main types of arrangement:

1. linear
2. grouped around a central preparation room.

These arrangements are based on a number of principles that aim to make the best use of the space available:

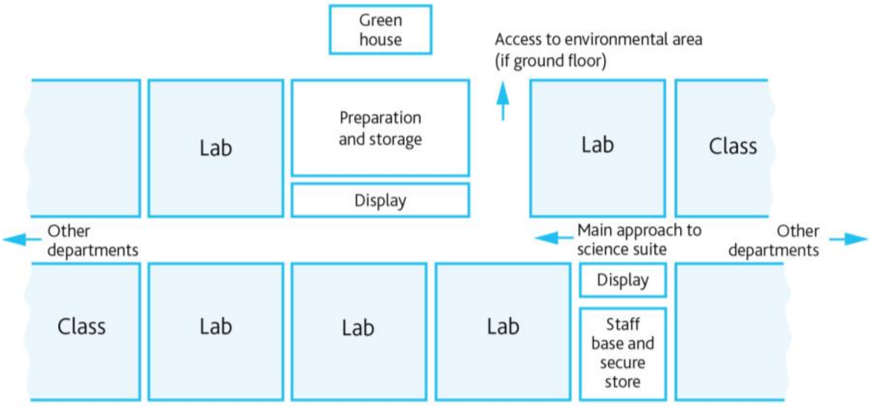
- Laboratories are grouped together on one or two floors to allow common resources to be shared and safer transportation of equipment.
- There is only one preparation area for each floor of laboratories. This provides a more economical use of space, equipment and technicians' time. If a preparation room is centrally positioned, distances to the laboratories are minimised.
- Other teaching areas are located for ease of access. The resource area or 'staff base area' is located to provide a focus for the department and to be easily accessed by the whole suite.
- The planned arrangement must allow for an exit door from each laboratory to the outside, if on the ground floor.

The key features of the two plan types are outlined on the next page.

## 1. Linear

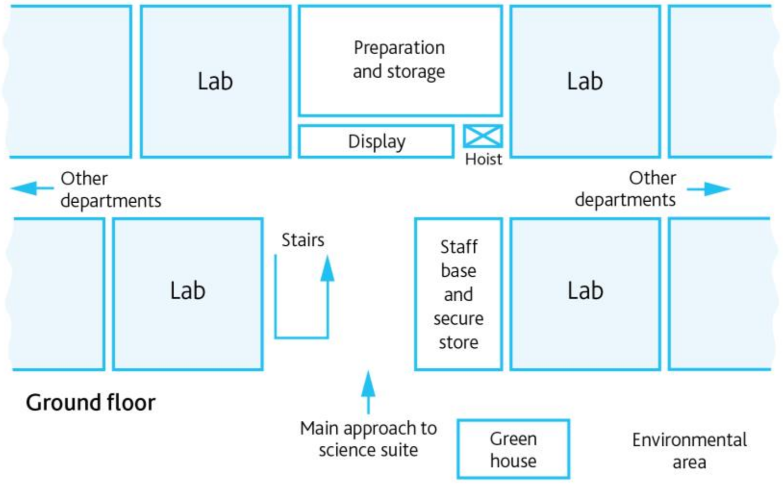
Where the number of laboratories is small (fewer than about six), a linear plan is suitable; the laboratories and other areas are close enough to give the science department a distinct identity. Staff can also easily reach all the working areas. With more than about seven laboratories, the distance between the preparation room and some of the laboratories makes the transfer of apparatus much more difficult.

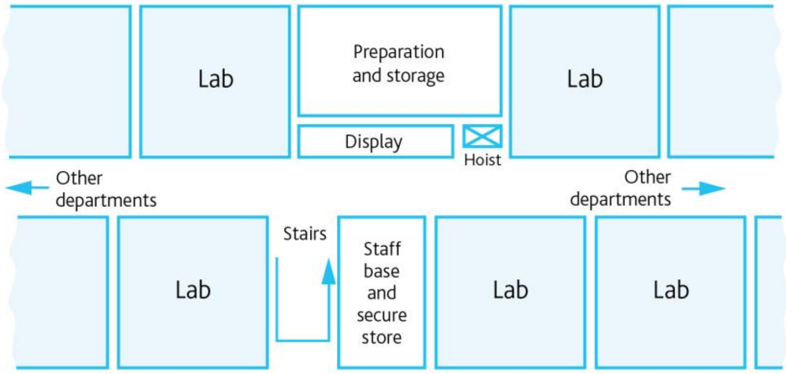
**Linear plan**




This layout may be modified with laboratories on more than one floor.

**Linear on two floors**



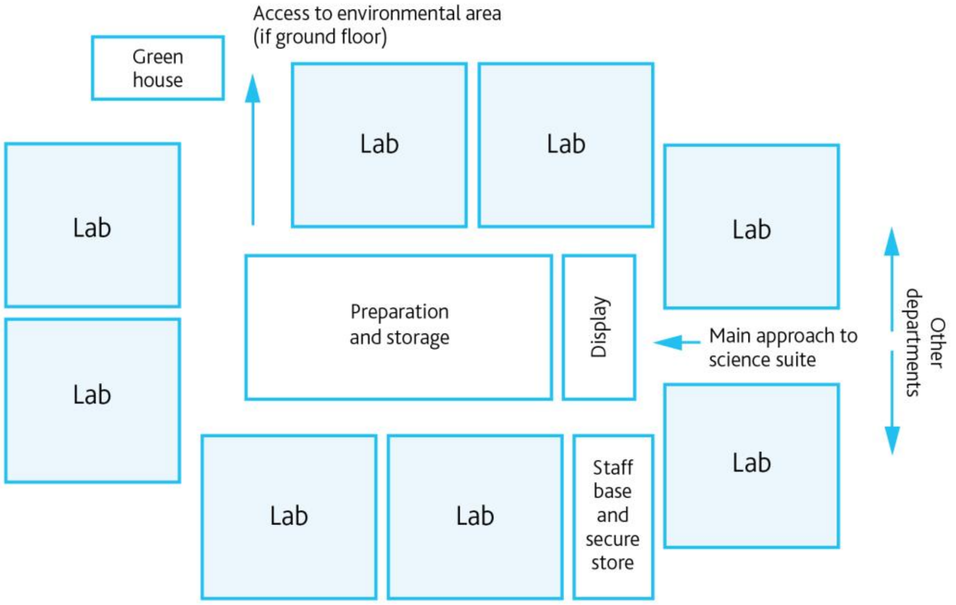




There may, however, be extra expenditure involved, for example you may need to install a lift or hoist for heavy items. Some resources may also have to be duplicated to avoid moving heavy or sensitive apparatus up and down stairs. Extra storage and resource areas may be needed.

## 2. Central preparation room

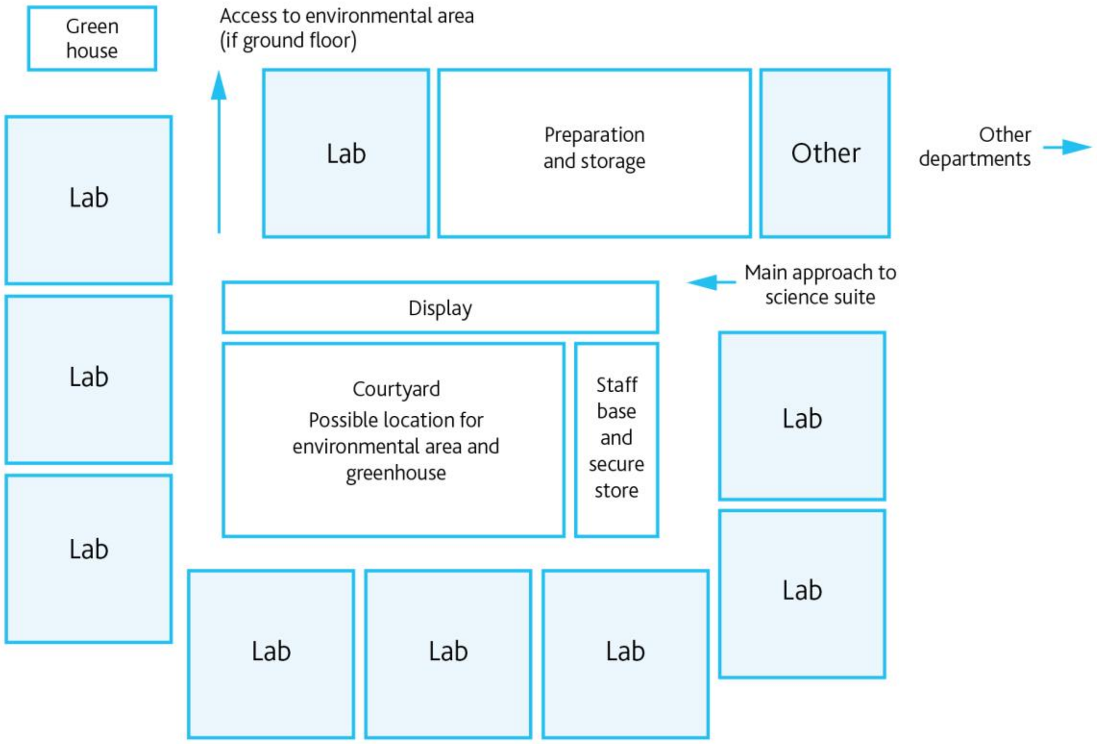
Locating the preparation room in the centre of the laboratory suite is suitable for schools with a larger number of laboratories. It is convenient for the technicians because the preparation room is central to the suite. Levels of natural light and views from the room, however, will be restricted.

**Central preparation room**




This plan may be modified with the laboratories around a central courtyard. This requires a greater area than the plan shown above, and there will be greater distances from the preparation room to some of the laboratories. The disadvantage of the above plan is reduced, and the courtyard may be suitable for some practical activities.

**Central courtyard**



## The laboratory[3]

A well-designed laboratory should be able to accommodate a wide range of scientific activities. The size of the space, the method of distributing services (gas and water) and the choice of furniture systems will all affect the way in which it can be used.

### Activities in the laboratory

Modern science courses place a much greater emphasis on practical work. The range of activities involved in these courses is diverse and will affect the way in which the laboratory is designed. Some of these activities are:

- teacher demonstration of experiments
- use of ICT and video
- learners' experimental work and investigations
- discussion and note-taking
- display.

#### Demonstration

Despite the increasing emphasis on learners' own practical activity, do not underestimate the use of the teacher demonstration of an experiment (real or simulated). Learners may need to group more closely around the teacher's bench or another area of the laboratory, such as the fume cupboard.

#### Use of ICT and video

You may have access to an interactive whiteboard, laptops, personal computers (PCs), tablet devices (for example, iPads) or videos/DVDs to illustrate particular aspects of the curriculum. Ethernet/wireless connection to the school network might also be preferable.

Make sure that the laboratory design allows learners to easily see screens without unwanted reflection.

Learners may also need to use PCs to access information from CD-ROMs or for use with data-logging equipment. A video-projector may be useful for class demonstrations.

#### Learners' experimental work and investigations

In many science courses, practical work can take a variety of forms, with learners working individually or in groups of different sizes.

It is essential that the laboratory provides sufficient space for learners to work safely, with access to the full range of appropriate resources. These may be fairly basic, such as Bunsen burners, tripods and mats, but will also include the necessary services. Investigations will often require practical work in more than one session. In this case, adequate space must be provided to store apparatus between sessions, while still allowing the laboratory to be used for other classes.

#### Discussion and note-taking

These activities can include writing up experiments, class discussion and learner presentations, perhaps using an interactive whiteboard, overhead projector (OHP), video/DVD or tablet devices (for example, iPads). For these activities you may need to reconfigure the furniture to allow for some group work.

#### Display

The science department and individual laboratories can be made much more interesting if well-mounted displays, perhaps of commercially produced posters or, better, learners' own work, fill the empty spaces on the walls. It is worth investing in a good pin board, painting it and screwing it to the wall.

## The size and shape of the laboratory

A laboratory of 85 $m^2$ is a suitable size for a group of 30 secondary school learners undertaking both practical and theory work. This size of laboratory will allow for enough local storage of basic items, provided that there is adequate central storage.

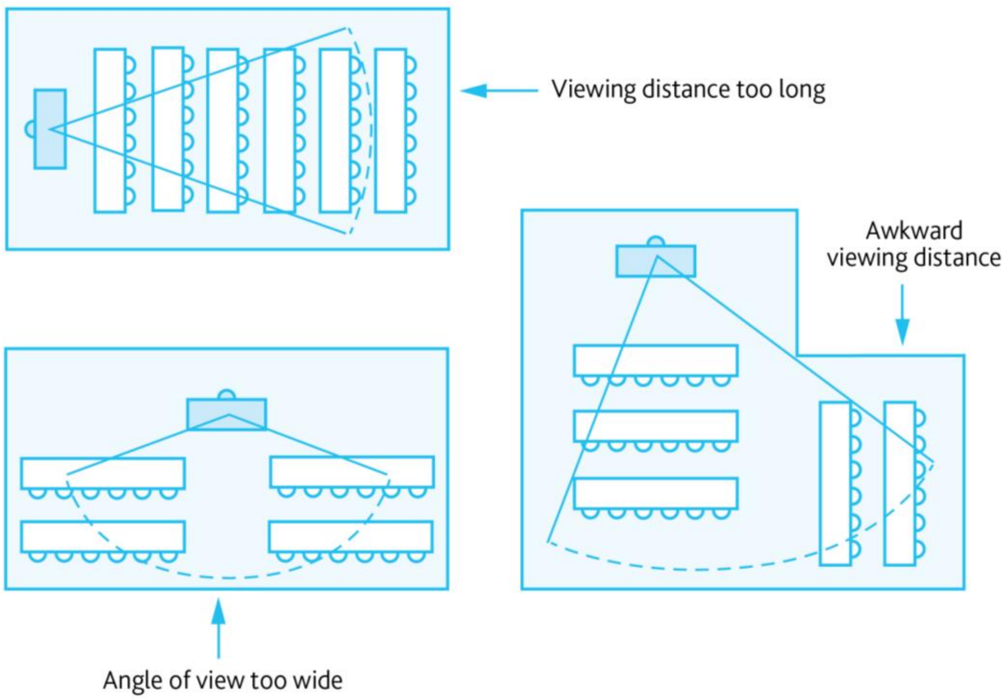
You may need to allow for more storage if the central store is small or inconveniently located.

Smaller spaces may restrict your choice of apparatus, and safety considerations may also become more significant.

A laboratory of less than 70 $m^2$ may only be useful for smaller groups of secondary school learners, or for sixth form groups. Space should also be allowed for the safe storage of learners' belongings, such as bags and coats.

The shape of the space is almost as important as its size. A simple rectangular shape allows for a flexible layout and good learner supervision.

Rooms that are too long and narrow are difficult to arrange. For example, if the teacher's bench and board are on the short side of the room the learners furthest away may have difficulty seeing the board and hearing the teacher.




## Planning guidelines

The following guidelines apply to a group of around 30 Cambridge IGCSE™/O Level candidates and may form the basis for evaluating laboratory designs.

- A work surface area of at least 0.3 $m^2$ is allowed for each learner.
- Each learner has good access to a full range of services, with a minimum of one gas tap (or portable Bunsen burners) and one socket outlet per two learners, and one sink per six learners.
- Learners face the teacher and the whiteboard whenever possible. Alternatively, learners should be seated around the teacher.
- For safety reasons, the fume cupboard should be positioned away from the fire exit or main circulation routes, but should have good access for groups of learners during demonstrations.
- Where possible, the main teaching wall is placed at 90° to the external wall, to allow good side lighting and to avoid direct glare from the window.
- A computer position is provided close to the teacher to enable supervision, and to maximise the potential of shared learner/teacher use.

- By placing the monitor screen at 90° to the window, problems of glare will be minimised.
- Storage of about 5 $m^2$ is provided for local resources and display, and is concentrated above and below the perimeter benching. There is a separate preparation area.
- There is adequate floor space at the perimeter for additional mobile storage units such as a general-purpose trolley.
- A clear area is provided to allow learners to gather for briefing sessions and the safe demonstration of fume cupboard experiments. It is important to consider each learner's ability to see and hear the teacher clearly.
- A clear floor length of around 3 m is allowed within the circulation route for runway experiments.
- An adjustable table for a wheelchair user positioned with a direct view of the whiteboard and near the door is preferable.
- A coat rack and bag storage area should be positioned away from the work areas.

It is important to allow adequate distances between furniture and equipment in laboratories. This will allow learners and staff to move around safely, especially during practical sessions.

## Services distribution

There are three main options for the distribution of services within a laboratory:

1. overhead
2. underfloor
3. perimeter.

Within each option there are variations, and sometimes two systems may be combined.

### 1. Overhead

In this option, services are distributed from a high level, for example through trunking attached to the ceiling or running above a false ceiling. Services are delivered to the benches by cables and pipes. Drainage is provided by the usual gravity method.

This system has advantages in that benches or islands can be serviced in a flexible manner – this has consequences for the arrangement of furniture. Maintenance is relatively straightforward.

However, the connections from the ceiling to the benches may appear untidy and obstruct the line of sight for some learners. The connections themselves may not be robust.

### 2. Underfloor

In this option, services may either be run in ducts set into the floor with varying degrees of accessibility or they may be located in the ceiling void of the room below. Services reach bench-top level via rigid or flexible connections, usually encased within furniture.

The advantages of an underfloor system are that most arrangements of benches can be serviced easily and the pipes and cables are all concealed. On the negative side, care should be taken to make sure that water services and electricity supplies are separated. Also, it may prove difficult to rearrange the furniture in the future if the service outlets are fixed.

If this kind of system is used, it is essential that access to the service ducts is as easy as possible. You should not need to dismantle a bench in order to gain access to a duct to add another electrical socket.

### 3. Perimeter

Perimeter service ducts are usually located at bench level (or just below it) with drainage at a low level. In this system, the service ducts are accessible yet discreet and the laboratory looks tidy. Modifications are reasonably easy to implement, but there are restrictions on the servicing of island workstations, which may require extra spurs.

## Health, safety and environmental issues

It is important that all relevant health and safety procedures are followed.

The main regulation affecting the handling and use of hazardous substances is found under the 2002 COSHH regulations (Control of Substances Hazardous to Health). This requires employers to prevent or control exposure to hazardous substances at work to prevent ill health.[4]

Full consideration must be given to any national or local regulations that differ from the regulations in the United Kingdom.

Schools and colleges can receive guidance from CLEAPSS[5] on storing and handling chemicals. This guidance is aimed at both meeting the legislative requirements and promoting good practice. It is also there to build on other guidance to improve the security and storage of hazardous chemicals.

Schools must keep an accurate inventory, and list approximate quantities of chemicals in stock and their location, as well as confirmation that they are stored appropriately. This will make sure that all chemicals can be accounted for at all times.

Teachers should perform a risk assessment for all practical activities. This normally involves noting any hazards and precautions in the lesson plan before starting the practical, highlighting any risks to learners and any special disposal requirements.

Some schools assign a risk assessment level to all practical experiments based on a three-level scale from level 1 (lowest hazard rating) to level 3 (highest hazard rating). Learners would normally perform level 1 and 2 practicals, while level 3 practicals will be teacher demonstrations, normally carried out in a fume cupboard.

Teachers also need training so that they are aware of the location of main electrical switches, gas and water stopcocks, first aid kits, chemical-spill kits etc.

Supply staff and teachers providing cover for absent teachers must also be briefed on the locations of these controls. We strongly advise that non-science specialists should not be allowed to teach in laboratories on a regular basis.

The following checklist may be useful when considering health, safety and environmental issues.

### Ventilation[6]

Science laboratories must be designed to provide adequate ventilation, both for occupants and to dilute fumes and water vapour generated.

The DfEE (*Building Bulletin 90)* recommends two air changes per hour for chemical stores (and five air changes per hour for laboratories and prep rooms). Note that extraction will not work if the flow of air is not effective.

In most laboratories and preparation rooms some form of mechanical ventilation, such as a fume cupboard, will be required some of the time. This will help deal with the pollution loads, heat gain and water vapour produced by Bunsen burners.

Some questions to ask are:

- Is adequate ventilation provided with the windows and ducts that are available?
- Is the extraction system for the fume cupboard adequate, and does it discharge at a legal height?
- Is there an adequate source of fresh incoming air when the fume cupboard is switched on?
- Particularly in chemistry laboratories, is there sufficient ventilation to cope with all the learners doing chemical experiments at the same time?

You may need to consult local health and safety advisors for assistance in answering such questions.

### Lighting[7]

This aspect of laboratory design needs careful attention. A good general level of luminance (e.g. 300 lux) is recommended for all teaching.

Laboratories will usually need window blinds to significantly reduce daylight in the room.

Some questions to ask are:

- Is the lighting system flexible enough for the full range of activities that take place in the laboratory?
- Is extra lighting available at each workstation?
- Is the lighting system designed to minimise the effects of glare and reflection of boards, screens and benches?
- Can light levels be reduced to allow optics experiments to be carried out with ease?

One laboratory may need black-out facilities for light experiments; a dimming facility is also useful, which can provide enough light to allow learners to read instructions and record readings, with the main lights off and the blinds drawn.

### Heating and air conditioning

Another important consideration is that of the working temperature in the laboratory. Local regulations may prescribe a certain range of temperatures in the workplace.

Some questions to ask are:

- Can the laboratory be heated easily?
- Are radiators so enclosed that convection is restricted?
- Is the air conditioning system adequate to cool down the laboratory if the temperature rises during long experiments involving heating?

### Water

Each laboratory should have a manual shut-off valve for its water supply. Easy access to sink waste traps should be included at each sink. Also consider the insulation of water pipes.

### Electricity

All installations should comply with the latest local legislation.

Some questions to ask are:

- Is the system correctly wired and protected?
- Are all electrical items earthed properly?
- Is portable electrical equipment inspected and tested at intervals in line with current best practice and recommendations from the government or local authorities responsible for health and safety issues?
- Is a residual current device (RCD) used to protect the supply in each laboratory?
- Is this device easily accessible to the teacher, for example near the main entrance?

It may be appropriate to include extra electrical switching. For example, a single switch at the teacher’s desk may control a ring supplying all the low-voltage power supplies to the laboratory, so assisting in the control of experimental work. As with the installation and safe use of fume cupboards, you may decide to seek local advice.

### Gas

Each laboratory with piped gas should have a manual shut-off valve at the pipe entry to the laboratory. An automatic shut-off system can be used – this is activated in the event of a gas leak if the manual valve is not easily accessible.

Gas pipes should be installed in accordance with local legislation. If gas bottles/cylinders are used, these should be fitted in a secure cage outside the building.

The use of portable Bunsen burners is acceptable as long as safe storage is provided.

The use of spirit burners as a replacement for Bunsen burners is not acceptable as the temperature generated is insufficient for many experiments.

## Fire

Local building and fire regulations must be consulted so that extra exits are provided if necessary.

Suitable fire extinguishers and fire blankets should be provided in every laboratory and prep room. CLEAPSS guidance recommends two 2 kg carbon dioxide extinguishers are provided in each laboratory in addition to a fire blanket in a suitable container.[8]

Fire equipment inspections should be carried out in line with the local authority recommendations.

## First aid

A first aid kit should be stored in the laboratory and it should be easily accessible. This should include a dedicated system for washing eyes. See Appendix A. Eye goggles should be provided for every student.

### *General*

Accidents do occur but fortunately the majority are relatively minor. The most common injuries to pupils are minor burns (the picking up of a hot tripod for example) and skin contact with caustic chemicals. These injuries can often be dealt with on the spot by irrigating the damaged area with cold water; a sympathetic approach is always beneficial in these cases. See below for simple first aid advice.

### *Procedure for accidents*

- If there is an accident (injury, damage to equipment or spillage), assess the situation.
- If you feel that you can deal with it yourself then do so.
- Otherwise, stop the lesson and seek assistance from a colleague (you may need to contact the school first aid representative).

### *Emergencies*

- **Fire:** In case of fire, follow the normal school procedures (display details in each lab). **All staff must know how to deal with the situation when there is clothing on fire.**
- **Serious injury:** If you suspect a serious injury you should stop the lesson immediately, initiate any simple first aid measures and contact the school first aid representative without delay.

### *Immediate remedial measures*

This details the remedial measures that staff may carry out while waiting for first aid or professional remedial treatment. The following advice covers common laboratory accidents.

*Chemical splashes in the eye*
Immediately wash the eye under running water from a tap for at least 10 minutes. The flow should be slow and eyelids should be held back. Afterwards, take the casualty to the school first aid representative.

*Chemical splashes on the skin*
Wash the skin for 5 minutes or until all traces of the chemical have disappeared. Remove clothing as necessary. If the chemical adheres to the skin, wash gently with soap.

*Chemicals in the mouth, perhaps swallowed*
Do no more than wash out the casualty's mouth with water. After any treatment take the casualty to the school first aid representative. Do not make any attempt to apply an antidote.

*Burns*
Cool the burn under gently running water until first aid arrives. The casualty should then go to the school first aid representative.

*Toxic gas*
Sit the casualty down in the fresh air.

*Hair on fire*
Smother fire with a damp cloth.

*Clothing on fire*
Smother fire by pushing the casualty to the ground, flames underneath. Spread a thick cloth or garment on top if necessary. A fire blanket is ideal in labs but only use if very close by.

*Electric shock*
Take care for your own safety. Break contact by switching off or pulling out the plug. If you need to move the casualty clear while the supply is still on, use a broom handle or some such implement, or wear rubber gloves.

*Bad cuts*
There are gloves in all first aid kits; wear these. Apply pressure on or as close to the cut as possible, using fingers or a pad of cloth. Leave any embedded large bodies and press around them. Lower the casualty to a chair or the floor and raise the wound as high as possible.

*Splinters*
These are best removed by the school first aid representative.

**Service ducts, cables and pipes**
It is important that all the ducts are easily accessible and well ventilated, especially those carrying gas pipes. All cables and pipes need to be well supported or fixed to the walls, especially where the servicing system is flexible. You must follow electrical earthing regulations.

**Flooring**
Safety is the key consideration when choosing a floor surface. Old wooden floors must be sealed. Vinyl that is resistant to most chemicals and slip resistant is often a good choice. The number of joints in the flooring material should be kept to a minimum.

**Benching**
Badly stained benching can make a new laboratory look very unkempt very quickly, so it is worth choosing a material that will not mark easily.

Iroko wood, ideally from sustainable sources, is a good option, but it must be sealed and well maintained. Some synthetic materials, such as cast epoxy resin, are also suitable.

900 mm is generally considered a suitable height for a laboratory work surface. A working depth of 600 mm for benching and tables is recommended.

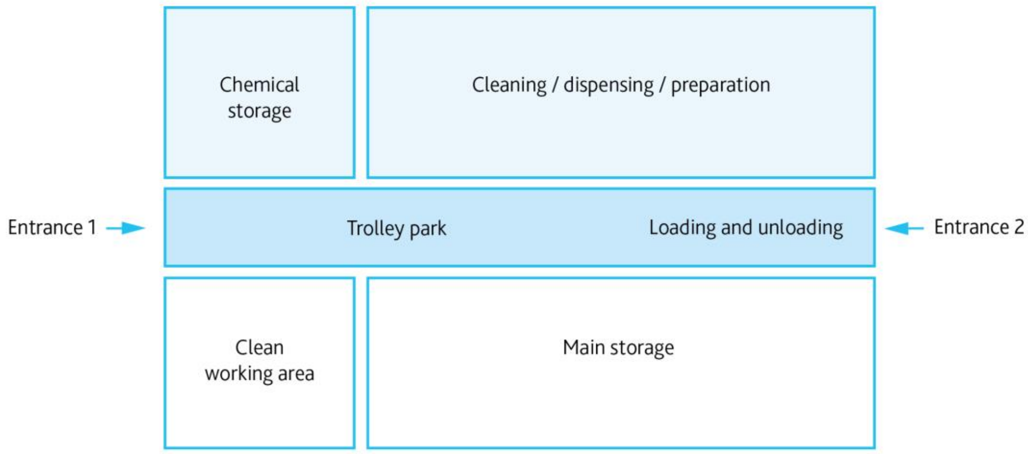
Stools should correspond to the height of the worktop. A measurement of 240–270 mm from the top of the stool to the underside of the worktop allows sufficient clearance for the learner to sit comfortably.

## The preparation room

The traditional design of science laboratories often includes separate preparation rooms for physics, chemistry and biology. While this has advantages, it does not always provide for the best use of technician time and resources, or allow for the best use of apparatus. A central preparation room can provide a better solution in many cases.

The preparation room can serve two main purposes: as the main storage area and as a workroom for the technicians. There are generally five main zones of activity in a prep room:

1. main storage
2. cleaning, dispensing and preparation
3. trolley park
4. clean working area
5. chemical storage.




The preparation room may also need to accommodate an autoclave, a distillation unit, a fume cupboard and a secure store for any radioactive materials. A fridge can be useful for storing ice.

The preparation room should also be equipped to allow for simple construction work in wood or metal and also for electrical repairs and soldering.

Assuming that there is virtually no apparatus storage in the laboratories, a floor area of $0.5\,m^2$ per learner can be taken as a guide to the size of preparation room required.

The preparation room in a school for 11 to 14 year olds only will be simpler than the room(s) described in this section. It will probably serve only one or two laboratories, but it may also be used to prepare trolleys of equipment for teaching younger learners in their normal classrooms.

You must consider local needs when planning the preparation room.

### The main storage area

The main storage area is best located in one place, preferably alongside the preparation and cleaning area. Equipment used frequently by all learners (such as tripods, Bunsen burners and goggles) is usually kept in the laboratory.

All other equipment is best kept centrally in the main storage area, where it can be checked regularly by a technician. Storage may be in the form of free-standing timber or metal racks providing flexible storage systems, which can be re-arranged to suit the available space. An alternative method of bulk storage is the rolling unit system sometimes seen in libraries. This system is economical in its use of space, but is expensive.

Storage systems need careful thought so that new staff can find items easily. One way is to number each shelf and add this location to the inventory.

Small items, such as lenses, can easily go missing. The simplest way to prevent this is to construct boxes with exactly 16 slots, one for each of the 16 lenses, so that the teacher can easily check apparatus at the end of the lesson. Technicians need to be warned never to put out incomplete sets of equipment. The same method can be used for the storage of compasses, screwdrivers, protractors, hand lenses and so on. Although this is time consuming to start with, the effort is worthwhile.

### The working area

This is where glassware is washed and equipment sorted after being returned on trolleys from lessons. In addition, practical experiments are prepared and small items of equipment are repaired in the working area.

Bench space needs to be provided to allow for:

- washing glassware
- drainage
- dispensing chemicals
- repairing apparatus
- constructing new apparatus.

The benching must be fully serviced with sinks, water, gas and electricity, paying due attention to health and safety, and to wiring regulations.

The preparation room should have shut-off valves/switches for electricity, gas and water services, in addition to a first aid kit and a variety of chemical-spill kits.

### The trolley park

The easiest way to move apparatus between laboratories is to use trolleys. As a guide, there should be two trolleys for each laboratory: one in use in the laboratory and one in the preparation room. There must be enough space to park the maximum number of trolleys and to allow circulation alongside. The best location for the parking area is between the main storage area and the working area.

### Clean working area

You will need shelving and desk space for books, CD-ROMs, DVDs, videos and other resources. You may also wish to provide a computer.

### Chemicals storage

It is important that all local regulations are strictly adhered to in this critical area of safety. Heads of science need to undertake regular reviews to make sure that, for example, prohibited substances are not being stored and that excess stocks are not being held. The store should be secure to prevent unauthorised access.

Bulk supplies are usually stored in the school grounds away from the laboratory complex, and away from areas frequented by learners. Then, only smaller quantities need to be kept in the preparation room, accessible to teachers and technicians only.

The chemical store must be well ventilated to the outside air, either by natural means or by mechanical extraction; full air conditioning is not necessary. The store requires protection from frost, and the door should open outwards. The flooring material should be impervious to chemicals.

Pressurised gas cylinders should be stored vertically, unless specifically designed to be used otherwise. Any storage area should be a secure, dry, safe place on a flat surface in the open air. If this is not reasonably practicable, store in an adequately ventilated area. Storage should always be in accordance with local regulations.

Shelves are best made of wood in case of leaks, and corrosive chemicals should be kept on the lowest shelves, at, or close to, ground level. Deep shelves can allow materials to become hidden at the back. High shelves (e.g. above shoulder level) should be avoided because there is a safety risk associated with lifting heavy bottles down from them.

In the preparation room, it is essential to have a locked cupboard for toxic chemicals and a fireproof cabinet for flammable liquids. The latter should be designed so that no chemicals will leak from the cabinet, even if all the contents are spilt.

It is important to keep an accurate inventory list and details of approximate quantities of chemicals in stock and their location, as well as confirmation that they are stored according to the 2002 COSHH regulations. This will ensure that all chemicals can be accounted for at all times.

## Fume cupboards

The use of a fume cupboard is only required for schools offering Cambridge Upper Secondary programmes and above in a chemistry based subject. Fume cupboards may be either fixed or mobile. The main advantages of a mobile fume cupboard are ease of access and visibility for demonstration purposes, and economy of use, because one unit can be shared between a number of laboratories.

Mobile fume cupboards may be either ducted or recirculatory in nature.

- The ducted type must be attached to a fixed extraction system, whereas the recirculatory type (a self-contained unit) can be used anywhere, which is particularly useful in conversion schemes.
- Recirculatory fume cupboards contain filters that need to be changed at regular intervals. There may be a legal requirement to test them for saturation. You may need to seek independent advice regarding this and other maintenance matters.

To ensure flexibility, the overall size of a mobile fume cupboard may need to be checked against door opening sizes. You can find information on the types of fume cupboard available by searching online. It is important to adhere to local regulations regarding the use of fume cupboards.

## Radioactive materials[9]

The teaching of most combined science, co-ordinated science and physics courses is enhanced by demonstrations using radioactive sources. As with chemicals, it is essential to comply with all local regulations; in some areas it may not be possible to obtain such sources for school work.

The sources need to be stored in a locked, labelled cupboard away from any area regularly used by the same people. It is not a good idea, for example, to place this cupboard in the preparation room above the technician's workbench. Control access to the cupboard and its keys, and keep a log of all movements of the radioactive sources. The sources need careful maintenance and all staff need careful training in their use.

## Appendix A: Recommended first aid equipment

First aid boxes and travelling first aid kits should contain a sufficient quantity of suitable first aid materials and nothing else.

Replenish the contents of the boxes and kits as soon as possible after use so there is always an adequate supply of all materials. Items should not be used after the expiry date shown on packets. You must therefore check first aid equipment frequently to make sure there are sufficient quantities of items and that all are usable.

Keep the first aid equipment in a labelled, dust-proof, damp-proof container, which is used exclusively and specifically for the purpose of first aid in the workplace.

The standard first aid box should contain only the following materials:

- a card giving general first aid guidance
- **sterile** (unmedicated) dressings of various sizes (e.g. six 12 cm × 12 cm and two 18 cm × 18 cm dressings)
- individually wrapped adhesive dressings (minimum of 20)
- two sterile eye pads, preferably with attachments
- a minimum of four individually wrapped triangular bandages
- six safety pins
- several pairs of disposable gloves.

The quantities of each type of first aid material will depend upon the workplace and number of students and staff.

### Important advice

In places where mains water is not readily available for eye irrigation, sterile water or sterile normal saline (0.9 per cent) in sealed, disposable containers should be provided. Each container should contain at least 300 ml and should not be re-used once the seal is broken. At least 900 ml should be available.

Sterile first aid dressings should be packaged to allow the user to apply the dressing without touching the part which is to come into direct contact with the wound. This part should be absorbent. There should be a bandage or other fixture attached to the dressings – there is therefore no reason to keep scissors in the first aid box. Dressings, including adhesive ones, should be of a design and type appropriate for their use.

### Supplementary equipment

Disposable gloves, aprons and suitable protective equipment should be provided near the first aid materials and should be properly stored and checked regularly to make sure that they remain in good condition.

Plastic disposable bags should be provided for soiled or used first aid dressings. Used dressings must be safely disposed of in sealed bags in accordance with any local regulations.

Sharps bins are a good way of safely disposing of broken glassware, needles and scalpels, and may be a legal requirement in some countries.

# Appendix B: Apparatus

The type of apparatus found in a science department will be determined by a large number of factors, including the number of laboratories, the size of the school, the number and size of teaching groups being taught at the same time, as well as the level of funding.

## Physics

This list below details the apparatus expected to be generally available for examination purposes. The list is not exhaustive; in particular, items that are commonly regarded as standard equipment in a physics laboratory are not included.

Digital multi-meters often provide a cheap and flexible alternative to a range of ammeters and voltmeters.

**Cambridge IGCSE/O Level**

- ammeter: FSD 1 A or 1.5 A
- voltmeter: FSD 1 V, 5 V
- cells and holders to enable several cells to be joined
- connecting leads and crocodile clips
- d.c. power supply – variable to 12 V
- metre rule
- converging lens with a focal length $f$ = 15 cm
- low-voltage filament bulbs in holders
- a supply of masses and holder
- newton meter
- plastic or polystyrene cup
- modelling clay (Plasticine)
- various resistors, including a variable resistor (rheostat)
- switch
- thermometer: –10 °C to +110 °C at 1 °C graduations
- wooden board
- glass or Perspex block, rectangular and semi-circular
- measuring cylinder: 25 $cm^3$, 100 $cm^3$
- beaker: 250 $cm^3$
- springs
- stopwatch
- ray box.

**Cambridge International A Level**

Below is a list of the items that are regularly used in the practical test. The list is not exhaustive: other items are usually required, to allow for variety in the questions set.

- digital ammeter, minimum ranges 0–1 A reading to 0.01 A or better, 0–200 mA reading to 0.1 mA or better, 0–20 mA reading to 0.01 mA or better (digital multimeters are suitable)
- cells: 1.5 V
- lamp and holder: 6 V 60 mA; 2.5 V 0.3 A
- leads and crocodile clips
- power supply: variable up to 12 V d.c. (low resistance)
- rheostat (with a maximum resistance of at least 8 Ω, capable of carrying a current of at least 4 A)
- switch
- digital voltmeter, minimum ranges 0-2 V reading to 0.001 V or better, 0-20 V reading to 0.01 V or better (digital multimeters are suitable)
- wire: constantan 26, 28, 30, 32, 34, 36, 38 s.w.g. or metric equivalents
- long stem thermometer: –10 °C to 110 °C × 1 °C
- means to heat water safely to boiling (e.g. an electric kettle)

- plastic or polystyrene cup: 200 $cm^3$
- stirrer
- adhesive tape (e.g. Sellotape)
- balance to 0.1 g (this item may often be shared between sets of apparatus)
- bar magnet
- bare copper wire: 18, 20, 26 s.w.g.
- beaker: 100 $cm^3$, 200 $cm^3$ or 250 $cm^3$
- adhesive putty (e.g. Blu Tack)
- card
- extendable steel spring (spring constant approx. 25 N $m^{-1}$; unstretched length approx. 2 cm)
- G-clamp
- magnadur ceramic magnets
- mass hanger
- micrometer screw gauge (this item may often be shared between sets of apparatus)
- modelling clay (e.g. Plasticine)
- newton meter (1 N, 10 N)
- pendulum bob
- protractor
- pulley
- rule with a millimetre scale (1 m, 0.5 m, 300 mm)
- scissors
- slotted masses (100 g, 50 g, 20 g, 10 g) or alternative
- spring
- stand, boss and clamp
- stopwatch (candidates may use their wristwatches), reading to 0.1 s or better
- stout pin or round nail
- string/thread/twine
- vernier or digital calipers (this item may often be shared between sets of apparatus)
- wire cutters.

## Chemistry

The following list does not include items that are commonly regarded as standard equipment (such as Bunsen burners, tripods, glass tubing) but instead lists the specific equipment required for teaching at a particular level. A complete list of chemicals is not given as this will depend on the experiments taught, but a list of the common bench reagents required is given.

**Cambridge IGCSE and Cambridge O Level**

- balance, single pan, direct reading: 0.1 g or better, weighing to 200 g
- beaker, squat form with lip: 100 $cm^3$ and 250 $cm^3$
- boiling tubes: approximately 150 mm $\times$ 25 mm
- burette: 50 $cm^3$
- clocks (or wall-clock) to measure to an accuracy of about 1 second
- conical flasks within the range 100 $cm^3$ to 250 $cm^3$
- filter funnel
- measuring cylinder, 50 $cm^3$ or 25 $cm^3$ and 10 $cm^3$
- pipette: 25 $cm^3$
- pipette filler
- polystyrene, or other plastic beaker: approximate capacity 150 $cm^3$
- spatula
- stirring rod
- teat/squeeze/dropping pipettes
- test-tubes (some of which should be Pyrex or hard glass): approximately 125 mm $\times$ 16 mm
- thermometer: –10°C to 110°C at 1 °C
- wash bottle.

**Cambridge International A Level (in addition to the list given for Cambridge IGCSE and Cambridge O Level)**

- beaker, squat form with lip: 100 $cm^3$, 250 $cm^3$
- dropping pipette
- evaporating basin, at least 30 $cm^3$
- measuring cylinders: 10 $cm^3$, 25 $cm^3$ and 50 $cm^3$
- pipette: 10 $cm^3$
- porcelain crucible: approximately 15 $cm^3$, with lid
- thermometers: –10 °C to 100 °C at 1 °C and –5 °C to 50 °C at 0.2 °C
- volumetric flask: 250 $cm^3$
- side-arm conical flask with bung and delivery tube.

**For qualitative analysis**

***Bench reagents***

- aqueous ammonia (approximately 2.0 $mol/dm^3$)
- aqueous barium nitrate or aqueous barium chloride (approximately 0.1 $mol/dm^3$)
- aqueous potassium dichromate(VI) (approximately 0.1 $mol/dm^3$)
- aqueous potassium iodide (approximately 0.1 $mol/dm^3$)
- aqueous potassium manganate(VII) (approximately 0.02 $mol/dm^3$)
- aqueous silver nitrate (approximately 0.05 $mol/dm^3$)
- aqueous sodium hydroxide (approximately 2.0 $mol/dm^3$)
- hydrochloric acid (approximately 2.0 $mol/dm^3$)
- limewater (a saturated solution of calcium hydroxide)
- nitric acid (approximately 2.0 $mol/dm^3$)
- sulfuric acid (approximately 1.0 $mol/dm^3$)
- aqueous iodine (approximately 0.01 $mol/dm^3$ in 0.2 $mol/dm^3$ potassium iodide)

***Other material***

- aluminium foil
- red and blue litmus paper or universal indicator paper.

For testing carbon dioxide, delivery tubes are not necessary. Students can either pour the gas carefully into a test-tube containing limewater and shake, or use a dropping pipette to sample the gas and bubble it through some limewater in a test-tube.

***For inorganic analysis***

- the carbonates (where they exist), sulfates, nitrates and chlorides of the cations listed in the ‘qualitative analysis’ notes
- the sodium and potassium salts of the anions listed in the ‘Qualitative analysis’ notes.

***For organic analysis***

- the reagents needed to perform the reactions of alcohols (primary, secondary, tertiary), aldehydes, ketones, halogenoalkanes, carboxylic acids and esters listed in the theory syllabus.

**For quantitative analysis**

***Acid/base titration***

- common laboratory acids (hydrochloric acid, sulfuric acid, nitric acid)
- a weak acid such as ethanoic or propanoic acid
- sodium hydroxide
- sodium carbonate
- methyl orange or screened methyl orange, thymol blue, bromophenol blue, thymolphthalein

***Permanganate titration***

- potassium manganate(VII)
- hydrogen peroxide
- iron(II) sulfate or ammonium iron(II) sulfate
- sodium nitrite
- ethanedioic acid or its soluble salts.

***Iodine/thiosulfate titration***

- potassium manganate(VII)
- hydrogen peroxide
- potassium iodate(V)
- starch indicato.r

***Gravimetric, thermometric, rates and gas collection***

- copper(II) sulfate
- Group 2 carbonates
- iron, magnesium, zinc metals
- potassium iodide
- potassium peroxydisulfate
- sodium thiosulfate
- solid hydrated barium chloride and magnesium sulfate.

## Biology

This is a list of basic materials and apparatus that a well-equipped biology laboratory would contain. Many of these items are regularly used in the practical test. The list is *not* exhaustive. Other items may be required to allow for variety in the questions set.

**Cambridge IGCSE and Cambridge O Level**

- beakers or other containers
- test-tubes and large test-tubes, bungs, test-tube racks and test-tube holders
- hard glass test-tubes
- funnels
- droppers or teat pipettes or glass dispensing bottles
- dishes such as Petri dishes
- means of measuring small and larger volumes of liquids such as syringes, graduated pipettes and measuring cylinders
- glass rod
- capillary tube
- thermometers (covering at least the range 0–100 °C; any range starting below 0 °C and ending above 100 °C is suitable)
- means of heating, such as Bunsen burner
- glass slides and cover-slips
- white tile or other suitable cutting surface
- visking tube
- hydrogen carbonate indicator (bicarbonate indicator)
- iodine in potassium iodide solution (iodine solution)
- Benedict’s solution (or an alternative such as Fehling’s)
- Biuret reagent(s) (sodium or potassium hydroxide solution and copper sulfate solution)
- ethanol/methylated spirit
- cobalt chloride paper
- pH indicator paper or universal indicator solution or pH probes
- litmus paper
- glucose
- sodium chloride
- aluminium foil or black paper
- rulers capable of measuring to 1 mm
- mounted needles or seekers or long pins with large head
- means of cutting biological materials e.g. scalpels, solid-edged razor blades or knives
- scissors
- forceps
- means of writing on glassware (e.g. wax pencil, water-resistant marker, small self-adhesive

labels and pencils).

**Desirable apparatus and materials**
Microscope with mirror and lamp or with built-in light, at least low-power (×10) objective; optional high-power (×40) objective will greatly increase the range of cellular detail that can be resolved.

Chemical reagents in addition to those listed above:
- copper sulfate (blue crystals)
- dilute (1 mol $dm^{-3}$) hydrochloric acid
- source of distilled or deionised water
- eosin/red ink
- limewater
- methylene blue
- potassium hydroxide
- sodium hydrogen carbonate (sodium bicarbonate)
- Vaseline/petroleum jelly (or similar)
- mortar and pestle or blender.

**Cambridge International A Level (in addition to the list given for Cambridge IGCSE and Cambridge O Level)**
- bungs with delivery tube to fit test-tubes/boiling tubes
- specimen tubes with corks
- syringes and plastic tubing or rubber tubing to fit syringes
- filter funnels and filter paper
- spotting tile or similar with space for 12 separate drops
- conical flasks
- capillary tubing
- soda glass tubing
- paper towelling or tissue
- cotton wool
- solid glass rods
- spatulas
- hand lenses (not less than ×6, preferably ×8)
- forceps
- scissors
- cutting implement, such as solid-edged razor blade/knife/scalpel
- microscope and lamp/inbuilt illumination with high-power and low-power objective lenses (one each or one between two)
- eyepiece graticules and stage micrometer scales
- haemocytometers
- bench lamp with flexible arm
- balance (to 0.1 g)
- water baths (thermostatically controlled) or means to supply hot water
- cork borers
- stopclock/timer showing seconds
- simple respirometer – can be ‘homemade’
- pipe cleaners/other suitable aid to demonstrate mitosis and meiosis
- culture bottles, autoclave
- inoculating loops/wires
- tape for sealing dishes
- cultures of live yoghurt
- appropriate cultures of microorganisms, such as *Escherichia coli, Bacillus subtilis.*

**Stocks of:**
- iodine in potassium iodide solution
- Benedict's solution
- Biuret reagent/potassium hydroxide and copper sulfate solution
- ethanol (for fats test)
- methylated spirit (for extraction of chlorophyll)
- sucrose (Use AnalaR (AR) for non-reducing sugar test. Some types of table sugar do not contain glucose.)
- glucose
- starch
- albumen (or egg white)
- potassium hydroxide
- sodium hydroxide
- sodium chloride
- dilute hydrochloric acid
- hydrogen carbonate indicator (with air pump to equilibrate to atmospheric carbon dioxide)
- sodium bicarbonate/sodium hydrogen carbonate
- limewater
- hydrogen peroxide
- distilled/deionised water
- universal indicator paper and chart
- litmus paper
- eosin/red ink
- methylene blue, thymolphthalein, bromothymol blue
- Vaseline/petroleum jelly (or similar)
- DCPIP (dichlorophenol-indophenol)
- ascorbic acid (vitamin C)
- Diastix/Clinistix/Albustix for testing glucose concentration
- enzymes: amylase, trypsin (or bacterial protease)
- materials for preparing immobilised enzymes: calcium chloride, sodium alginate
- plant sources of catalase, e.g. sweet potatoes, mung beans, potatoes
- wheat, barley or similar as a source of starch
- non-competitive enzyme inhibitor (e.g. copper sulfate – hydrated)
- stains for preparing slides to show mitosis – e.g. acetic carmine, toluidine blue
- apparatus/chemicals for water cultures to show effect of Mg and N on growth
- nutrient broth, nutrient agar and technical agar (not nutrient)
- appropriate disinfectants.

**Apparatus for sampling animals**
- beating tray ('homemade')
- pooter ('homemade')
- sweeping net (muslin)
- plankton net and dip net (if aquatic environment is being sampled)
- pitfall trap/jam jar; suitable cover to prevent water entry
- trays for hand sorting.

**Slides for Cambridge International AS Level**
- mitosis
- TS stem, TS root and TS leaf of, for example, dicotyledonous mesophyte (such as *Ligustrum* or *Prunus* or local equivalent), maize, rice, sorghum, wheat, xerophyte leaves
- LS stem, LS root to show xylem vessel elements and sieve tube elements and companion cells
- TS trachea, TS bronchus, TS bronchioles
- TS lungs to show alveoli
- TS artery, TS vein

- blood smear
- animal and plant cells; Protoctista (e.g. *Amoeba*, *Euglena* or local equivalents, for example from a culture made with water and hay to stimulate single cell organisms).

**Slides for Cambridge International A Level**

- meiosis
- TS anther, TS ovule
- pollen
- stamen and stigma of wind-pollinated and insect-pollinated plants
- VS maize fruit
- TS kidney
- TS spinal cord
- examples of organisms representing the three kingdoms; Protoctista (e.g. *Amoeba*, *Euglena* or locally available equivalents); Prokaryotae (e.g. bacterial smear, cyanobacteria); Fungi (e.g. yeast, *Penicillium*).

## Appendix C: Chemical and equipment suppliers

- Better Equipped Educational Supplies Ltd: **www.betterequipped.co.uk**
- DJB Microtech Ltd: **www.djb.co.uk**
- Fisher Scientific UK Ltd: **www.fisher.co.uk**
- Philip Harris Ltd: **www.philipharris.co.uk**
- Scientific & Chemical Supplies Ltd: **www.scichem.com**
- Scientific Laboratory Supplies Ltd: **www.scientificlabs.co.uk**
- Sigma-Aldrich Ltd: **www.sigmaaldrich.com**
- Timstar Laboratory Suppliers Ltd: **www.timstar.co.uk**

## Appendix D: Safety in the laboratory

Centres are responsible for safety matters. We draw your attention to the following UK associations, publications and regulations.

Associations:

CLEAPSS is an advisory service providing support in practical science and technology.
**www.cleapss.org.uk**

The Association for Science Education promotes excellence in science teaching and learning.
**www.ase.org.uk**

Publications:

*Safeguards in the School Laboratory*, ASE, 11th edition, 2006
*Topics in Safety*, ASE, 3rd edition, 2001
*CLEAPSS Laboratory Handbook*, updated annually (available to CLEAPSS members only)
*CLEAPSS Hazcards*, updated annually (available to CLEAPSS members only)
*Hazardous Chemicals*, an interactive manual for science education, SSERC, 2002 (CD)

UK Regulations:

Control of Substances Hazardous to Health Regulations (COSHH) 2002
**www.legislation.gov.uk/uksi/2002/2677/contents/made**

You can find a brief guide at: **www.hse.gov.uk/pubns/indg136.pdf**

European Regulations:

The European Chemicals Agency, ECHA, publishes a ‘candidate list’ of chemicals that are scheduled to require authorisation under EU chemicals legislation and are therefore unsuitable for use in schools:

**www.echa.europa.eu/web/guest/candidate-list-table**

## Appendix E: Endnotes

Guidance and recommendations for the UK can be obtained from the publications listed below. Schools outside the UK may also find these guidelines helpful when planning science practical work. However, all practical work should always be carried out in accordance with the health and safety legislation of the country in which it is done.


1 *Science Accommodation in Secondary Schools (2004) (Building Bulletin 80),* DfEE Her Majesty's Stationery Office (HMSO) ISBN 0 11 271039 5. **http://science.cleapss.org.uk/Resource/Building-Bulletin-80.pdf**

2 *Science Accommodation in Secondary Schools (2004) (Building Bulletin 80),* DfEE Her Majesty's Stationery Office (HMSO) Section 1, pages 5–9.

3 *Science Accommodation in Secondary Schools (2004) (Building Bulletin 80),* DfEE Her Majesty's Stationery Office (HMSO) Section 2, pages 10–32.

4 *Control of Substances Hazardous to Health Regulations (COSHH) 2002* **www.hse.gov.uk/coshh**

5 **www.cleapss.org.uk**

6 *Ventilation (1999) (Building Bulletin 90),* DfEE Her Majesty's Stationery Office (HMSO).

7 *Lighting Design for Schools (2006) (Building Bulletin 101),* DfEE Her Majesty's Stationery Office (HMSO).

*8 CLEAPSS guide: L14 Designing and Planning Laboratories, Section 6 (2000)*

9 *Managing Ionising Radiations and Radioactive Substances in Schools and Colleges (2019), L93,* CLEAPSS: **www.cleapss.org.uk**