Safety Measures in Chemical Laboratories

Third Edition

National Physical Laboratory

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SAFETY MEASURES IN CHEMICAL LABORATORIES

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Preface to Third Edition

OPERATIONS in a chemical laboratory with noxious, inflammable or explosive materials are always attended with risks of personal injury or material destruction. The importance of a due regard for safe methods of work and of taking precautions against accidents, however unlikely, must be instilled as an integral part of the training of the young chemist.

Codes of regulations – to be strictly observed – may go some way towards reducing dangers inherent in chemical work, and compilations in book or chart form of the injurious action of various types of chemical are unquestionably useful. Yet it is from the precept and example of his more experienced colleagues that the new recruit will draw the surest guidance.

This booklet, compiled primarily to help the new entrant to the National Chemical Laboratory, contains much that even an experienced worker may be glad to know. The previous editions have, indeed, achieved a wide circulation in other laboratories and many letters suggesting amendments or additions have been received and considered. We would welcome any constructive suggestions for futher improvements.

1964

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Director
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Note

In April 1965 the National Chemical Laboratory was combined with the National Physical Laboratory to form one station.

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Contents

Introduction

THERE is always an element of danger present in chemical laboratories. This can be greatly increased or decreased by the attitude of the staff towards safety. Careful approach is necessary even in laboratories where small scale work or routine analytical procedures are carried out but extra care is essential in research laboratories where new chemicals and reactions with uncertain results are features. Newcomers should regard the first few months at least of the time they spend in a research laboratory as an apprenticeship in practical experience. A reaction they may have carried out confidently with small quantities in a school or college laboratory should be approached more carefully when the quantities of materials are appreciably increased, when conditions may be slightly varied and where perhaps a different type of apparatus is used.

Many industrial and in particular laboratory workers, have accidents involving injury during the early part of their employment. These sometimes arise from attempts to imitate the apparent casualness of older workers. The experience of the latter enables them to assess fairly accurately the risks involved and they have probably taken precautions which are not immediately obvious. Young people must learn to walk before they can run and to err always on the side of caution. They must remember that any form of carelessness in a laboratory may involve serious consequences for other people as well as themselves.

It is well known that certain chemicals can cause serious burns when in contact with the skin. These show us very quickly that they are harmful, but there are other chemicals which are more insidious in their effects and do not make known to us at once that they are just as dangerous. Anything in a chemical laboratory, unless you know definitely that it is harmless, should be treated with respect.

Probably nowhere is the adage "prevention is better than cure" more applicable than to accidents in a chemical laboratory. Success in any campaign to reduce accidents can only be achieved if three main aims are realized. First, to impress on senior staff that they have a great responsibility in that they must set a good example themselves and that they must try to obtain early development of safety-consciousness in their young workers. Secondly that some forethought on safety aspects must be given to all chemical experiments or even to routine preparations and thirdly that good housekeeping and tidiness are essential. With regard to the first, a letter, based on the Royal Society for the Prevention of Accidents "Letter to Foremen" has been sent to all senior officers at the National Chemical Laboratory. It reads: "Accidents, at the least, mean waste of time and spoilage of material or breakage of equipment. If there is also personal injury, then to the casualty it means pain and suffering and to his or her family it may even bring tragedy. By the very definition of the term there will always be some accidents, but much more can be done to reduce their frequency than most people realize. Our accident rate has been lower than that of Industry in general, for some years but nevertheless, after almost any accident which has occurred, it has been obvious that, with a little care and forethought, it need not have happened.

Rules and regulations can never be the complete answer; in a chemical research laboratory probably less so than in many other establishments. We are not working on production plants where set procedures can be observed. We are always facing variables and even unknowns and rules can never be devised to give complete coverage under such circumstances. Everything depends on the staff, in particular the younger members, developing a regard for safety and being made to accept that safety precautions are an integral part of any experimental work on which they may be engaged.

All members of staff bear the general responsibility of observing due care and precaution whilst carrying out their duties. The Safety Committee are strongly of the opinion that an even greater responsibility rests on the shoulders of the more senior members of the staff, not only in their supervision and training of junior members but also in the personal example they themselves set.

You, because of your authority and personal influence over people who work to your instructions can do far more than anyone else can hope to do in making N.C.L. as accident free as possible. It is true we have Safety Officers and a Safety Committee. That does not mean that accident prevention is their worry and not yours. They can help with training of staff, they can act sometimes in an advisory capacity or exercise supervision over any accident prevention scheme as a whole. When, however, we get to the laboratory and workshop benches, where the work is done, no-one can act as Safety Officer as well as you can. Try occasionally to see your laboratory from the point of view of new workers. What has become quite familiar to you may be rather puzzling to them and need a little explanation. Remember that new people not only need telling; they also need watching, and while it is obvious that you cannot always be at their sides, you can, however, put them under the observation of one of your more experienced workers until you are satisfied as to their ability to work unsupervised. Instructions are sometimes disobeyed because people do not understand the sound reasons which are behind them. You can make sure that any instructions you give have a care for safety included in them, are precise and completely understood. You can make it very obvious to the people under your charge that you do not regard safety as something to which lip service only should be paid, but as something in which you have a genuine belief and to which you wish to see attention given by all who work for you. You have the opportunity to do something for accident prevention in perpetuity, because as you train your juniors they will undoubtedly in the future train theirs."

With regard to the second aim in accident prevention, forethought in chemical experiments, try to decide what could go wrong before you commence any preparation; think what your course of action would have to be in such an emergency and make sure that you have any necessary antidotes or safety equipment available. Do not carry out any reaction on a bench already over-crowded with apparatus. If an accident should occur it will probably be too late to start thinking which bottles on the bench contain inflammable or other-wise dangerous chemicals and which do not. Not many years ago radiant electric fires were all sold with open bowls and people who found them hazardous had to make and add their own guards from metal netting or rods. Now such fires are sold with guards devised at the design stage as an integral part of construction and they are obviously much safer in use. Thought given to safety at the initial stage of chemical work will avoid the necessity for make-shift precautions as the work develops.

The third aim in an accident prevention campaign, good housekeeping and tidiness, should not need any elaboration, except to say that apart from being essentials in any accident prevention scheme they will also bring other advantages. An occasional "spring cleaning" or stocktaking of cupboards and shelves will always result in finding bottles and equipment which can be dispensed with and where is the chemist who is not always wishing for more space? Finally, do not be under the misapprehension that in a chemical laboratory you only have to guard against chemical hazards. It will be found every year that the ordinary everyday accidents such as those caused by falls of people, falls of objects, use of machines and tools always predominate in numbers and more often than not in severity of injury.

Safety Organization and Safety Equipment

Although so much can be done by senior chemists to promote safe working within their own laboratories they do require and will appreciate some organizational support. We have no doubt at all that this is best provided by the appointment of a Safety Officer and Safety Committee for the Laboratory as a whole.

The Safety Officer must have a sound technical knowledge but need not be a practising chemist; he will be able to consult chemists with specialized experience in different fields. His main need is an enthusiasm for and a sincere belief in his job. He should be a man of tact and diplomacy, on good terms with all grades of staff, patient and not easily ruffled. The ability to lecture and write on safety matters is almost essential.

The prime consideration in setting up a safety committee is that the right people should be chosen to serve on it and that the number should be small. Safety committees often consist of one nominee from each group or section of the laboratory, but in a large establishment this can lead to an unwieldy committee and retard progress. The ideal number of members is six or seven including the Safety Officer. Since the Director of a laboratory knows more objectively than anyone else the qualities and suitability of his staff for such work he should appoint the members with but one exception; if there is a staff association it is desirable that one member should be its nominee. There are two important points here. One is that the Director, having appointed people in whom he has confidence, must take serious cognizance of any recommendations they make to him and the second is that, through its nominee, the staff association becomes associated with the consideration of questions of safety.

A safety committee will never be short of topics for consideration or investigation. Questions concerning the handling of chemicals are perennial and a logical approach is to begin at the beginning and consider – how do chemicals come into the laboratory: how are they stored and issued to the staff and what happens to unused quantities of any hazardous ones? Accidents have occurred with chemical residues which have been stored in cupboards and then forgotten. What should happen to chemical residues when a research topic has been completed or when a chemist leaves the laboratory? In such cases it may be found that hazardous materials have been kept for years unknowingly. One answer would appear to be the institution in every laboratory of a regular "spring cleaning". An annual combing out of cupboards and shelves is beneficial in more ways than may at once be apparent.

The correct method for safe disposal of waste chemicals should be a matter for consultation between the Safety Officer and the chemist concerned, or the advice of the Safety Committee should be sought.

Apart from the usual chemical storage problems such as the segregation of materials hazardous in juxtaposition, another point worthy of deliberation is whether or not some day to day scientific supervision should be given to chemical stores by a member of the scientific or technical staff, even if only on a part-time basis. Hazardous chemicals seem to be used more and more these days and yet it remains true that in most laboratories the post of storekeeper is considered a non-scientific one and the qualifications demanded are primarily clerical.

Provision, siting and use of general safety equipment or personal protective devices, consideration of safety in the night running of apparatus, issue of cautionary notices from time to time on new or old hazards and formation of rules and regulations are only a few of the topics for debate by the Safety Committee. Care should be taken not to make too many hard and fast rules. It may become necessary, exceptionally, to relax one of them and if once the impression is given that rules can be broken no-one will have any real respect for them. They are best kept to an absolute minimum but if, after much thought, some rule is made, it must then be strictly enforced.

With regard to safety equipment, laboratories will vary in their needs according to the nature of the work, although most proprietary equipment is intended for general laboratory use. As a broad guide, a list is appended of some items provided at the National Chemical Laboratory.

Respirators

At two easily accessible points in the laboratory there are provided two each of canister types of respirator to afford protection against toxic gases and vapours likely to be encountered in the work. Staff may take respirators in any emergency but after use they must be returned to the Safety Officer for cleansing, with some indication as to the concentration of gas they were used in and for how long. These are solely for emergency purposes and this practice is preferable to that of having respirators hung up in every laboratory and under no real supervision. Where the work being done could require frequent and instant availability of respirators they are provided. It should be remembered that no respirator will be of use where there is a deficiency of oxygen. Under such conditions respirators must be used which provide a supply of oxygen either from self-contained equipment (apparatus containing its own supply of oxygen or air), or by remote point intake of air through a long tube.

Winchester Carriers

These are in ample supply and Stores personnel are instructed that no Winchesters containing corrosive, volatile, or inflammable liquids are to be issued unless carriers are brought to receive them. Winchester carriers should preferably be of a type which will contain the contents of any bottle broken.

Safety Screens

These also are freely available and their use is strongly encouraged in addition to the use of goggles or spectacles. They are made from $\frac{3}{8}$in. or $\frac{1}{2}$in. acetate sheet or perspex and are held erect by dropping them into slots in two heavy metal feet in which they can then be tightened by a screw. They have the advantage that the feet can be placed at any part of the screen base to suit the apparatus and the slight gap between them and the bench permits the passage of tubing or flex. Some people prefer acetate sheet enclosed in metal frames, the base of the frame standing flush on the bench, with the idea of preventing spillage into the lap of an observer if breakage of the apparatus occurs.

Control of Water Flow to Condensers

Where water-cooled condensers are used in conjunction with electrical heating equipment such as heating mantles or hot plates a small apparatus is available which will turn off the electric power if water ceases to flow. The use of such apparatus is strongly advised for example where a chemical reaction under reflux is left running overnight.

Spillage Equipment

A cupboard near the centre of the building contains equipment for use in the event of any sizeable spillage from, or breakage of, liquid containers. If any inflammable solvent or chemical with an obnoxious odour is spilled it is important that it should not be allowed to enter the drains but should be removed as quickly as possible. Sand is therefore provided which can be used either to form dams or absorb liquids. Sawdust is also available, for where a chemical of unpleasant smell is spilled sawdust can be used to absorb it and afterwards burned, whereas sand would provide a disposal problem. Sodium bicarbonate is also provided for acid spillages. As an experiment these materials are now provided at the National Chemical Laboratory in thin plastic bags instead of in pails or other rigid containers. Several bags can be carried very easily and the contents poured out where needed or, if the bags are slashed, they can be lobbed from a short distance and the contents largely ejected on impact. Rubber boots, gloves, aprons and a squeegee are also available from the same cupboard.

Eye Wash Bottles

Eye wash bottles of approximately 1 litre capacity are provided in most laboratories at the National Chemical Laboratory. They are of the aspirator type and stand on wall brackets. A plastic tube from the base links to a soft rubber eye bath although in some cases it is better to detach this and wash with a jet. Where acid or alkali enters the eye it is important that there should be continuous irrigation of the eye with water for at least ten minutes before the casualty goes to a hospital. Several proprietary materials are available for addition to the water in minute quantity to prevent growth of algae.

Eye Protection

Goggles and safety spectacles should be provided in every laboratory. Many establishments now require staff to wear some form of eye protection during the whole working day, others at least during the time they spend at the laboratory benches or on other chemical operations. Laboratory workers should certainly have eye protection whilst engaged on any work which is hazardous or even possibly hazardous. Some form should always be used when making fusions, cutting sodium, breaking up solidified melts, chipping any hard material, opening certain cylinders of gas under pressure, when using grinding equipment, when carrying out any operation which contains a possibility of liquid splashing and when pouring liquid air, oxygen or nitrogen. The Safety Officer at the National Chemical Laboratory is charged to keep up to date with advances in this field and he has on display a dozen or so of the latest types of safety goggles, spectacles, face visors and dust respirators. People can examine and try these and determine with certainty which kind will serve their need most appropriately.

General Laboratory Operations

Handling Glass Tubing or Rod

Although ground glass joints are now almost universally used, serious injury still occurs as the result of treating with contempt such a simple operation as that of inserting glass tubing into a cork or rubber bung. The end of the tube should always be fire-smoothed to remove sharp edges and lubricated with glycerine or a trace of silicone grease. If the latter is used, it is possible, months later, to withdraw the tubing easily. The tubing should be held near to the point of insertion and the slight force necessary applied in a longitudinal direction whilst the tube is gently oscillated. Hold the cork or bung with the thumb and forefinger against a firm surface. Never hold it against the palm of the hand. After insertion the tubing should slightly protrude from the underside of the stopper because the hole may otherwise tend to get closed up by the action of solvents on the cork or bung.

When breaking glass tubing into shorter lengths, first make the knife or file cut and then cover the tube with a cloth before applying pressure. If a cloth is not used it is advisable to hold the tube at waist level when the breaking pressure is applied.

Boring Corks

Cork borers should be kept sharp and the cork lightly rolled before it is bored. The end of the cork away from the cutter should be pressed against a piece of smooth wood, vulcanised fibre or similar material held on the edge of the bench. It is helpful, in the case of a rubber bung, to lubricate the cutter with a drop of glycerine and a smoother bore usually results if the cutting is done in one direction only, not alternately clockwise and anti-clockwise.

Glass Apparatus

Examine all apparatus for defects before any experiment. You are not expected to use cracked, badly chipped or otherwise dangerous glassware.

According to the degree of damage it should either be sent to the glass-blower for repair or discarded. Do not put broken glassware back into a cupboard. It should be put into proper receptacles, not into sinks and general rubbish or paper bins.

Dirty apparatus may be placed on a draining board but should never be allowed to accumulate in the sink itself which may be needed in such an emergency as someone being splashed with a corrosive acid.

Gas

Gas taps should be closed when the burners are not being used. If a small flame has to be left on, turn off the air so that the yellow flame can be seen. A fully-aerated Bunsen blue flame is invisible in sunlight and this, in addition to having caused many serious accidents, has resulted innumerable times in minor ones such as the burning of clothes.

The rubber tubing which carries gas to the burner should be kept in good condition. Prolonged heating causes embrittlement and cracking as well as producing a loose fit on to the burner. Make sure that you know where the main gas cock for your laboratory is situated. This should be in an easily accessible place and either clearly labelled or distinctively coloured.

Ice and Ice Crusher

Care should be taken to keep fingers out of the crusher. If glass should be broken into any crushed ice, discard the whole quantity. Glass cannot be seen in the ice and may cause badly injured fingers later on.

Fume Cupboards

Any work involving toxic gases or vapours should be carried out in a fume cupboard and not on the open bench. Make sure that the draught ventilation is in order before commencing any operation. Many young people come from school with the firm idea that fume cupboards are for work where unpleasant odours such as that of hydrogen sulphide are evolved. It is important that they should be given to understand early that fume cupboards are used to contain and remove toxic vapours and fumes and that odour alone is a secondary consideration. They can also, with advantage, be used for some other hazardous experiments, but should not be allowed to become a place for storing bottles and flasks which contain obnoxious or dangerous chemicals.

Chemical Apparatus

Many laboratory accidents occur because of attempts to get results in too great a hurry and by "taking a chance". This usually means slipshod assembly of apparatus – the inclusion of a bung which is not quite the right size but which may be "good enough"; a piece of glass tubing which looks as if it may have a flaw probably has a slight crack; a condenser which is not wide enough in bore and which blocks up very quickly if the distillate suddenly begins to solidify.

Always get the right equipment and put it together carefully. If you are using large flasks be quite sure that they are well supported by the right sizes of clamps, ring stands or tripods to hold them gently but securely. Never support thin glassware, such as beakers, by clamps attached to the edge or rim. If you have to carry large beakers or flasks make sure that the outsides of the vessel and your hands are free from slippery material. Use both hands for carrying, supporting the vessel from underneath, particularly if it contains heavy chemicals.

Vacuum Desiccators

Considerable damage can be caused by the sudden collapse of large desiccators. They should always be exhausted behind safety screens with a glass cloth over them or in cages. Do not use a large desiccator if a small one will do and discard any which show the slightest of cracks or heavy scratches. Sudden changes of temperature should be avoided and the desiccator should be placed on a rubber mat or even surface to avoid irregular pressure on the base.

Flasks under Pressure Greater or Less than Atmospheric

Any flask which is kept under pressure or vacuum will be subject to considerable strain and glassware to be used in this way should have no scratches or cracks. Erlenmayer or other thin-walled, flat-bottomed flasks must not be used. The normal type of suction flask is made of heavy glass to resist this pressure but if damaged in any way it may collapse violently. Remember too, that being made of thick glass, it is more liable to crack if hot liquids are poured into it.

Where a Gooch crucible is used the rubber holder should be of the correct size so that the crucible cannot be pulled through into the flask. The use of a specially shaped funnel for this purpose is recommended. Never cork tightly a vessel containing hot, volatile liquids. If it is necessary to exclude moisture a breather tube should be used; dust can be kept out by substituting a glass wool plug for the cork or a cap of filter paper.

Vacuum Distillations

The distillation should be carried out behind a safety screen and should have the undivided attention of the operator. Some form of trap should be included between the distillation apparatus and the water or mechanical pump. Rapid release of vacuum should be avoided and you should make sure that vacuum has been released from all parts of the apparatus before disconnecting. Substances which have been heated to high temperatures should be allowed to cool before air is admitted to the system as many organic substances oxidise rapidly or even explosively at elevated temperatures. For the same reason the conventional air leak is not without objection and it is preferable to use a nitrogen leak with a mercury blow off in the connecting line.

Avoid heating the flask with a direct flame. Use an electric heating mantle or surround the flask with an air bath if high temperatures are necessary. This will give more even heating and also afford some protection if breakage should occur. Remember that systems under vacuum are potential sources of implosion or explosion if any part of the apparatus is hit or knocked hard enough to crack the glass. If you have to use rubber stoppers make sure they are the correct size and do not project too far into the neck of the flask. With continued heat they may soften and be pulled right in. Only use a water cooled condenser where the distillate vapour enters the condenser below a temperature of 115 °C.

Solvent Extractions

When making extractions and in shaking volatile solvents in separating funnels or other closed equipment, release the pressure frequently by inverting the funnel and opening the tap. This should be done particularly when extracting a slightly warm liquid with a volatile solvent or when washing acid material with bicarbonate solution. Sometimes in analytical extractions release of pressure through the tap is undesirable in which case the stopper should be removed cautiously.

Transfer and Storage of Inflammable Liquids

Transfer of large quantities of inflammable liquids from one vessel to another should not be done in a room where there are flames, electric heaters or other sources of ignition. Glass bottles larger than Winchesters should not be used for light petroleum, benzene or other inflammable solvents. Carboys should only be handled with the proper tipping or siphoning gear and carboys, drums and barrels should not be brought into laboratories. Solvent residue receivers should be of proper design. Avoid leaving bottles containing solvents in direct sunshine. Although different laboratories have different requirements for solvents it should, in every case, be the aim to keep laboratory stocks to a minimum.

Solvent Vapours

Many of the younger people do not know that the vapours from benzene and many other organic solvents are not only inflammable but when mixed with air can be violently explosive. They certainly do not realise, and many older chemists seem to forget, that most of them are also extremely toxic and often cumulative in action on the body when breathed in small concentrations over long periods. Cleaners should be given to understand very clearly that solvents should not be used at a sink where hot water is running.

Spillage and Residues

Mop up at once water or chemicals which may be spilled on the floor. A slip or stumble may be much more serious in a chemical laboratory than elsewhere, not only because of the chemical a person may be carrying but also because it is almost certain to be in a glass container. For the same reason keep the floor as clear as possible of equipment which is likely to impede the free passage of others.

If strong acids or other corrosive materials are spilled, a senior chemist should be called immediately to give advice. If you leave traces of corrosive material on ring stands or on rubber tubing it may cause irritation of the skin or serious burns to the next person who uses the equipment. Never leave apparatus containing corrosives such as oleum, sulphuric or nitric acids, phenol or alkalis, at the sink for washing. Always rinse out vessels before leaving them.

Pipettes

In using a pipette for any material be careful that no liquid is drawn into the mouth. Make sure that the tip of the pipette is kept well under the surface of the liquid. Never pipette by mouth cyanide or other poisons. The use of a vacuum line for pipetting dangerous materials is often recommended but there is always some difficulty in cutting off the suction at the right point and it is far better to use an aspirator bulb or a burette. Pipetting of hot solutions and volatile solvents is also dangerous because of the tendency to expel liquid from the tip when pressure develops in the confined air space at the top of the pipette. Corrosive liquids should never be pipetted. Use a measuring cylinder or a burette according to the degree of accuracy required.

Rubber Tubing and Bungs

Certain organic chemicals, particularly tar products and oils, have a deleterious effect on natural rubber equipment. Tubing and bungs should therefore be kept out of contact with such materials but where this is impracticable use should be made of the modern resistant polymers.

Wash Bottles

It is safe practice to use only your own wash bottles whether they are of the plastic "squeeze" bottle or the older glass flask type because if you pick up someone else's it may not contain the liquid you expected. If glass flasks are used there are also hygienic reasons.

Bottles and Other Containers

All containers should be clearly and correctly labelled and it is advantageous if any particular hazard such as "Poisonous", "Highly inflammable" or "Toxic vapour" is indicated. Make sure that all old labels are completely removed. Do not put any bottles containing dangerous materials on high shelves. Replace the stopper on any bottle immediately after use and return the bottle to its proper place as soon as you can. Never leave any bottle standing near the edge of the bench or on a draining board where it can easily be knocked over. Dispose carefully and separately of the contents of any bottles which cannot be positively identified after consulting the senior chemist in your laboratory. Bottles should not be carried by the neck and Winchesters in particular should only be transported in carriers which are provided.

Opening Chemical Containers

Nowadays bottles are much more effectively sealed than was formerly the case and it is well to open them with caution. It is no more trouble to hold the bottle behind a transparent screen while the stopper is removed than it is not to do so. Many should be opened with really strict precaution and your senior chemist will tell you about these. In particular, sealed ampoules require great care and gloves and goggles or a face shield should be worn in addition to using the screen. Even ampoules of materials which have been opened many times before and found to give no trouble can be dangerous if there is a variant batch. We had two ampoules of such a chemical to open and the usual procedure was followed of placing the ampoule in a refrigerator for several hours, making a scratch on the neck and applying a hot glass rod. There was a violent explosion. Before opening the second, the batch number was noted on the label and the contents scrutinized carefully. At the bottom of the ampoule a tiny bead of free water was observed. The same opening routine was followed and again there was an explosion. The manufacturers of the chemical were informed and we were shortly afterwards notified that the material had not been properly dried and that they had therefore destroyed all ampoules from that batch.

Even within the same batch there can be differences. One bottle of bleaching powder blew up in a man's face when the cap and insert were removed. Another bottle, with the same batch number, gave no trouble. This may be puzzling but is nevertheless a fact.

Polyethylene Containers

Polyethylene and similar inert materials have been used with great advantage to make many items of laboratory ware. It should be remembered, however, that these materials have a low coefficient of friction and vessels such as gas jars can easily slip through the hands, particularly if wet. If a glass beaker containing corrosive liquid slips from the hands into a sink the glass will break and although there may be some splashes, most of the liquid will remain in the sink. If a polyethylene vessel is similarly dropped it will bounce slightly and much of its contents will be ejected upwards, perhaps into the face. Where such vessels are not provided with handles, a few very shallow grooves machined into the outside of the casing or just one thin strip of similar material welded on to the outside circumference would do much to reduce this hazard.

Use of Hand Tools

The increasing use of metal framework for apparatus and panels of metal or other materials has led chemists and their assistants to use shaping and construction tools to quite a large extent. Many accidents occur which could have been avoided. Most of these are due to two factors:

(a) *Misuse of tools:* Screwdrivers used as chisels or levers, pliers used as spanners, adjustable spanners incorrectly fitted and pulled away from instead of towards the jaw opening, power tools left on at the main switch and unattended and soldering irons left on and not in a proper stand.

(b) *Defectiveness of tools:* Spanners used with splayed ends, chisels with burred or even mushroomed heads, tools without handles or with handles improperly fitted or split or splintered, and power tools not wired and earthed properly and trailing leads allowed to become a hazard.

Avoid accidents by selecting the proper tools and sizes for the job and see that they are inspected regularly and maintained in good order.

Some Dangerous Chemicals

Aluminium Chloride

Bottles should be opened with extreme caution and a face shield or goggles worn. This is particularly necessary if the contents have been stored after partial use. The substance is liable both to cause stoppers to stick and to develop pressure by formation of hydrogen chloride. Bottles have been known to burst. Only small bottles should be stored on open shelves and in larger quantities the vessels should be fitted with breather tubes filled with a drying agent. The breathers should be inspected at fairly frequent intervals as they are liable to choke.

Benzene

Benzene is very inflammable and also forms explosive mixtures with air. In addition it is extremely toxic as an acute or chronic poison. The maximum allowable concentration which can be breathed over a long period is only 25 parts per million of air and this is less than the concentration which can be detected by odour.

Beryllium Compounds

It is now recognized that the handling of beryllium and its compounds can be an extremely hazardous occupation unless the workers are protected by a carefully designed system of health surveillance and the areas in which they work are continuously monitored to ensure that the levels of contamination of the atmosphere and of surfaces are below an accepted tolerance level. Such compounds produce a type of dermatitis as a result of absorption through the skin but the effect of their inhalation as air-borne dust is likely to be a far greater hazard to health. The nature of the various forms of acute and chronic beryllium diseases is fully and excellently discussed in "Toxicity of Beryllium Compounds", Tepper, Hardy and Chamberlain, published by Elsevier, Amsterdam and London, 1961. Dr. K. Williams has contributed a study of the medical aspects of beryllium disease (Williams, K., A.E.R.E., MED/R. 2854).

Medical supervision will include clinical and X-ray examinations, blood counts and checks of variation in body weight. In the laboratory, the highest possible standards of care and cleanliness in all manipulations are essential. Much valuable information on chemical and physical methods of analytical control is contained in "The Analytical Chemistry of Beryllium", *Proceedings of a Symposium*, Blackpool, 1960, PG Report 171. U.K.A.E.A. Production Group, Risley, Warrington, Lancs., 1961.

C[illegible] air-borne dusts, smears and other sources of contamination are fully described in "The Determination of Beryllium: Handbook of Chemical and Radiometric Methods for its Determination in Ores, Concentrates and Low-grade Sources," H.M.S.O., London, 1963.

The accepted tolerance level of beryllium contamination in the atmosphere, during a normal 8-hour day, is 2μg Be/m^3 of air. It has been stated* that 45μg of beryllium fluoride, inhaled over a period of 20 minutes, produced an acute form of beryllium disease within three days. The concentration of beryllium in the atmosphere should never exceed 25 μg/m^3, even for very brief periods.

The toxicity of beryllium compounds varies according to their composition and preparation. There is no record of any health hazard associated with the handling of naturally-occurring ores in which the beryllium-containing mineral is beryl (beryllium aluminium silicate).

Tolerance levels, accepted by both U.S.A.E.C. and U.K.A.E.A., are discussed by R. O. R. Brooks, A.E.R.E. R/3000.

Bromine

Bottles containing bromine fracture easily because of the mobility and high density of the element. The vapour, as well as the liquid, can cause unpleasant burns and is extremely dangerous to the lungs and eyes.

Carbon Disulphide

One of the most inflammable of common solvents. The flash point is —30 °C and the vapour can be ignited by a hot steam pipe or electric bulb. The vapour is also very toxic and the liquid can be absorbed by the skin to produce systematic effects.

Ethers

Diethyl ether is extremely inflammable. The vapour ignites very easily and also forms explosive mixtures with air. Electric hotplates are a frequent source of ignition. Diethyl, isopropyl and higher ethers may form explosive peroxides on storage, as may branched chain and unsaturated hydrocarbons and compounds with an ether link like dioxan and tetrahydrofuran. These are all best kept in dark bottles and a dark cupboard and should be tested periodically for peroxides with acidified potassium iodide. If peroxides are present they should be removed by washing with ferrous sulphate solution.

*EISENBUD, M., BERGHOUT, C. F. and STEDMAN, L. T., *J. Ind. Hygiene*, 1948, 30, 281.

Liquid Nitrogen

Liquid nitrogen is often handled very carelessly in laboratories. Goggles or face shields should be worn when transferring to Dewar vessels from the tanks and these tanks should only be used on the proper tilting stands. The Dewar vessels, unless enclosed in metal cases, should be wrapped on the outside with overlapping windings of adhesive tape. When making the transfer, a small quantity of liquid nitrogen should first be introduced and the vessel then rotated a few times to prevent local thermal shock before charging is continued to the required level. Do not cork or in other ways stopper the Dewar vessel.

Metal Hydrides

Most of these are used as suspensions in mineral oil. They are very reactive to water and even to moisture in the air, evolving hydrogen. Some will ignite spontaneously, particularly if the particles in suspension are very small. Care should be taken when opening any tins of metal hydrides as there may be pressure inside. Face shields and gloves should be worn. Lids should not be left off the containers for any length of time and before any tin is re-sealed it should be purged with dry nitrogen to displace any moist air. Dry powder fire extinguishers should be available in any laboratory where metal hydrides are used.

Mercury

Metallic mercury has a definite vapour pressure and few people realise that this vapour is toxic, particularly over a long period in very slight concentration. When spilled it tends to form small droplets which present a very large surface area for evaporation. These droplets should be picked up as quickly as possible by means of a glass capillary tube attached to a filter flask and water pump. If it is necessary to leave a surface of mercury in any vessel exposed to the air it can often be covered by a layer of water or other non-toxic liquid. Apparatus where mercury is constantly employed and where there is any possibility of breakage or spillage should be stood in some form of tray from which the mercury can be more easily collected. Poor floors, which contain joins or cracks, prevent picking up of many spilt droplets. Where this is so, estimations of mercury vapour in the atmosphere should be made and, if necessary, the floor treated with a lime and sulphur wash to form the sulphide.

Methyl Silicate

Should be used with great care as the vapour can cause serious eye injury or even blindness.

Perchloric Acid

Perchloric acid is an extremely powerful oxidising agent and contact with organic materials is potentially dangerous. Fires, explosions and detonations have occurred from such contact. Glass joints should be used in experimental apparatus; rubber bungs or corks and grease, including silicone types, should be avoided. The 60–70 per cent acid can be stored safely but concentrations above 85 per cent may explode spontaneously. Even slight spillages must be avoided, as combustible materials which have been wetted with dilute acid, may, after drying, be ignited by heat, friction or impact. Mixtures of perchloric acid and acetic anhydride are sometimes used for metallurgical cleaning and although procedures have been devised for *relatively* safe handling it must be stressed that the behaviour is still unpredictable. Before perchloric acid in any form is used, the senior chemist in a laboratory and the Safety Officer must be consulted.

Sodium and Phosphorus

Sodium, which should be stored under paraffin or naphtha, should not be kept near phosphorus, which is stored under water since confusion could lead to serious consequences. Inconspicuous fragments of sodium are often left in flasks or bottles after it has been employed as a drying agent or as a reactant and these constitute a danger to anyone who is required to clean the vessel. Complete disposal of all traces of the metal should be carried out or at least arranged by the person who has used it. Sodium residues quickly become coated with a film of hydroxide or carbonate and are all the more dangerous on this account. Residues should always be destroyed with alcohol. Sodium and potassium metals will explode violently when dropped into chlorinated hydrocarbons, e.g. carbon tetrachloride.

Solid Carbon Dioxide (*Dry Ice*)

The usual danger is that of "burns" or severe frost bite. Gloves should be worn when handling it or special tongs used. These and any other implements used should have wooden handles. In a confined space it can generate sufficient gas to cause asphyxiation by oxygen deficiency. Pieces of dry ice must never be placed into stoppered containers or explosion may result. If it is added to organic solvents to provide a cold bath round any vessel it must only be added in small pieces or the solvent may splash out and cause "burns" to the skin or eyes.

Sulphuric Acid and other Corrosive Materials

Although most people in laboratories are aware of the dangerous properties of sulphuric acid it remains a very common cause of accident. When sulphuric acid is used as a drying agent, usually in a desiccator or bubbler, its presence is apt to be forgotten and injuries may occur when cleaning such apparatus or clearing up breakages. Acid splashes on the skin should be thoroughly washed with water before bicarbonate solution or other neutralizing solutions are used. The acid should not be stored on high shelves.

Bottles of strong nitric and hydrochloric acids and also ammonia should be opened carefully with a cloth over the neck and stopper before the latter is loosened. Safety carriers should always be used to transport Winchesters of corrosive materials and such chemicals must not be handled in large, fragile containers such as 4-litre beakers without provision of another receptacle to catch the contents in case of collapse.

Fire Risks and Burns

"Good housekeeping" is a most important factor in actual fire prevention in chemical laboratories and also in preventing small fires developing into really serious ones. Inflammable solvents in particular should be handled carefully and quantities kept in laboratories reduced to the minimum necessary. Even small bottles of such solvents should be replaced on their shelves as soon as they have been used and never allowed to accumulate on the benches. Solvents, if spilled, should be cleaned up immediately and not allowed to get into the drains. Solvent residues must not be poured into the sink but collected in suitable residue cans or bottles. Disposal of all waste materials should be a matter of some care. Different types should be segregated and placed in separate covered containers. Fires have often been started by spontaneous combustion developing in waste containers and have sometimes spread either because the container had no lid or, if it had one, the lid had not been replaced. For this reason, metal bins with foot-pedal operated lids are useful containers for most types of waste. They are not usually very large but this may be an advantage as frequent emptying is required. The length of time waste is allowed to remain undisturbed and develop heat is important in spontaneous combustion, so it is sound policy to empty all bins towards the end of each day. The period of greatest danger is obviously the week-end and bins should certainly be emptied every Friday afternoon. Do not throw still-glowing matches into waste bins. Flint lighters are preferable to matches for lighting gas burners.

Hot plates should not be placed against walls and these or other heating apparatus such as gas-heated crucibles and metal or oil baths should be insulated from the bench by two sheets of asbestos board separated by an air space. Open flames should only be employed after a survey of neighbouring apparatus and materials has been made. Gas tubing to burners should be inspected periodically and, if it shows signs of thinning, cracking or becoming hard, should be replaced. Gas burners should never be left on overnight. It is wise to have gas turned off at the building's main valve when the day's work is finished. It should be the duty of the last person leaving a laboratory at night to see that no electrical apparatus has been left switched on unless it has a card, signed by a responsible officer, attached.

Experiments involving very inflammable materials can often be conducted with advantage inside a fume cupboard so that any small fire occasioned can be more easily confined and extinguished. If the bench of the fume cupboard is provided with a raised edge to prevent the running out of any spilt inflammable liquid, the risk of fire spreading will be reduced. If a fire does occur, room windows and doors should be closed if it is possible to get at them, the fire attacked with appropriate extinguishers and the fire brigade called.

Fires have sometimes been caused by the "magnifying glass" effect of wash bottles or other globular flasks filled with liquid and left exposed to the direct rays of the sun. The danger is increased if dusters or other easily combustible materials are also habitually left on benches. Particular care should be observed during the summer months, especially at week-ends and if the windows of the room are facing south.

FIRE EXTINGUISHERS

Soda acid type. These discharge a dilute solution of sodium sulphate. They can be used for all fires such as paper and wood but must not be used for fires where any live electrical circuits are exposed or for fires involving sodium, potassium, magnesium and such metals. They can be used for water miscible solvents such as alcohol or acetone but not for solvents or oils which are not miscible. These extinguishers do leave a mess after use and in many places have been replaced by containers which discharge a spray of water when a capsule of carbon dioxide is broken.

Foam type. Foam extinguishers should be used on immiscible solvents lighter than water, e.g. petrol, oils or benzene, particularly in bulk. They must not be used for fires involving alkali metals or where live electric circuits are exposed.

Carbon tetrachloride type. These are for use on small fires but if they have to be used in confined spaces remember that carbon tetrachloride vapour is a narcotic, and that in addition it may, if heated, give rise to the dangerous gas phosgene. After the fire is extinguished the room should be thoroughly ventilated. Carbon tetrachloride should not be used where alkali metals are concerned but may be used where live electric circuits are exposed.

Carbon dioxide extinguishers have some advantages for small laboratory fires. No mess is made when they are used, they are quite easy to handle and there is little danger of nearby apparatus being knocked over or damaged. They can also be used where electric circuits are exposed. On the other hand, it must be possible for the operator to get very close to the fire and, as they have little cooling action, care must be taken until the extinguished material has cooled below the ignition temperature that the fire does not start up again.

Asbestos blankets will often smother a fire effectively
They should not be used where glass apparatus is concerned or vessels may be tipped over or broken with consequent spreading of the fire.

Dry powder extinguishers are now being used widely for most types of fire. They are particularly valuable for special risks such as magnesium swarf fires and those caused by metal hydrides where most other types either have little effect or are even dangerous to use.

Fire extinguishers must be readily available at all times; equipment should not be allowed to stand in front of them for even short periods.

BURNS

Apart from the actual burn injury itself it should be remembered that serious dangers can follow from shock or by infection of the burnt areas. Where skin burns are other than very minor ones one of the first-aiders must be called in at once. Arrangements should be made whereby sterile dry dressings are always available for first-aid covering of any extensive burns.

Treatment for shock is important for all accident casualties but in burn cases it cannot be over-emphasized. General shock treatment is to reassure the patient, apply warmth by blankets, keep the head low by raising the foot of the stretcher or bed and loosen clothing at neck, chest and waist. Sips of water can be given to the patient.

Electrical Hazards and Shock

There is risk of electric shock in handling any electrical wiring, connections or equipment. The majority of items of electric apparatus are carefully designed by the makers to eliminate such risks but nevertheless should always be handled with caution. No apparatus should be touched with wet or damp hands or when standing on a wet surface. The danger threshold is only some 20 milliamperes a.c. and the current produced by only 60 volts has proved fatal.

Most common causes of accident are careless or hurried assemblies, makeshift connections and high voltages. Connections between apparatus and 3-pin plugs should be made with 3-core flexible cable of suitable current rating.

It cannot be too strongly emphasized that all electrical connections, including re-wiring work, should be carried out by electricians. Connection to instruments should be made by a member of the Instruments Section if there is such a section in the laboratory or by some other person who is recognized as competent. Startling examples of carelessness are sometimes seen in connection of apparatus to plugs, often only after an accident has occurred.

The colour coding of the conductors in the mains connecting cable fitted to electrical equipment of foreign manufacture does not always conform to British convention. It is particularly dangerous when the earthing wire (green by British convention), is coloured red and so may be mistakenly connected to the live main, if not initially, then at some future date. There have been cases where accompanying instructions have drawn attention to the continental code but where the ends of the leads had been re-sleeved according to the British code. The only permanent safe solution is to change the whole connecting cable for one with conventional British colours.

For loose or temporary connections in wiring, porcelain or plastic connectors should be used. Do not use old or threadbare wire in any assembly and when insulation shows signs of thinning or cracking it should be replaced. Keep any wiring from lying on the bench tops as far as possible and away from any metal fixtures. Avoid using open knife type switches and always switch off any electrical apparatus before attempting to move, adjust or inspect it. If any liquid is spilled on to an electric motor, switch off and dry thoroughly before starting up again. If you have doubts at all about electrical apparatus or wiring, do not take a chance but consult the senior chemist in your laboratory or the Chief Engineer.

Treatment of Electric Shock

Turn off the current at the switch before attempting to rescue any person in contact with a live circuit. If this is not possible, use rubber gloves if they are quickly available, a dry mackintosh coat or dry woollen material to protect the hands. Before touching the person stand on a dry mat or take off your coat and stand on that. If the person can drink give him stimulants but above all obtain quickly one of the people qualified to render first-aid as artificial respiration and treatment of shock or burns may be necessary.

Radiation Hazards

All workers who handle radioactive substances are exposed to potential risk of an unusual character in that none of the senses can perceive or assess the radiant energy which is, at certain levels, extremely harmful.

It is of the utmost importance that radioactive substances, received from any source of supply, should be accepted by one person (or an appointed deputy) whose knowledge and experience of such material make him fully equipped to advise on such matters as storage, dispensing, measurement and instrumentation, safety in their manipulation, and disposal of radioactive wastes.

It will normally be the duty of a safety officer to organize a system which calls for health checks at suitable intervals and which ensures that the radiation dose received by a worker over a fixed period is known; all the data collected by such a system of health surveillance should be permanently recorded. The safety officer will submit such records to a medical adviser who will arrange that certain medical examinations are made at appropriate intervals, or when unusual or potentially dangerous conditions make a health check advisable. The examination of a blood sample by a pathologist is the most common method of checking the effect of exposure to radiation. Many organizations insist upon what is often termed a "pre-employment check" on workers who will be exposed to a radiation risk; this takes the form of a clinical examination to establish the fitness of a worker for duties of a particular type.

External Radiation Monitored by Dosimeters

The dosimeter, or film badge, is a simple and convenient device for the measurement of the accumulated external radiation exposure over a known period. It is usually attached to the wearer's overall, but may be attached to the hands or wrists. Dosimeters may also be placed in selected positions within the vicinity of a radiation source; the radiation dose per unit of time is thus measured without risk to personnel. The issue of film badges and subsequent reports on radiation doses are undertaken by the Radiological Protection Service (Ministry of Health and Medical Research Council) Clifton Avenue, Belmont, Sutton, Surrey. This organization will advise on various facets of radiological protection, including, of course, the maximum permissible doses for different types of radiation.

It is quite impossible to cover the very many aspects of the handling of radioactive substances within the limited compass of this publication; such a severe condensation could be misleading and even dangerous if regarded as a reasonable complete summary.

Useful sources of information on this subject are:

Safe Handling of Radioisotopes, *Safety Series* No. 1.
International Atomic Energy Agency, Vienna, 1962.
H.M.S.O., P.O. Box 567, London, S.E.1.
Recommendations of the International Commission on Radiological Protection (I.C.R.P.) Pergamon Press, 1959.
Safety Spotlight-Isotopes, British Safety Council, Safety House, 60 Westbourne Grove, London, W.2.
Code of Practice for the Protection of Persons Exposed to Ionizing Radiations, H.M.S.O., 1957.
The Control of Radioactive Wastes, H.M.S.O., London, 1959, *Cmd.* 884.
The Hazards to Man of Nuclear and Allied Radiations, H.M.S.O., London, *Cmd.* 9780.
The Ionizing Radiations (Sealed Sources) (Leakage Test) Order, 1961. No. 1710 1711, 1712, 1713, 1714, 1715 and 1470, H.M.S.O., London, 1961.

Cylinders of Compressed Gases

Cylinders should always be painted in the appropriate colours of the British Standards Specification and the supplying company's attention should be drawn to any which do not comply with this requirement.

They should never be stored close to any major fire risk, such as an inflammable solvent store or near to any great heat such as a boilerhouse. If stored in a room there should be good top and bottom ventilation in case of leakage and if stored outside a building they should not be left lying on wet ground. They should preferably be stored in some outhouse which provides protection from the heat of the sun in summer and from snow and ice in the winter. Lighting in the store should be of the approved flame-proof type and switches are better outside the structure. Full and empty cylinders should be kept in different sections of the store and neither should be allowed to fall violently to the floor. Grease or oil may ignite when oxygen is present so oxygen cylinders should be carefully kept away from such contaminants and not even handled with greasy hands or oily rags. For transport from store to the laboratories bar transporters or proper trolleys should be used and for movement between laboratories the regulators should be removed unless trolleys are used.

Where cylinders are used for blowpipe work only good quality hose and connections as approved by the supplying company should be used. The cylinder should be properly secured in place and so sited that the blowpipe flame cannot reach it. Portable blowpipes when lit, even with a byepass flame, must never be hung on to the cylinder regulator.

When in use in the laboratories cylinders should be securely fastened so that they cannot roll or fall. Proper stands or trolley stands should be used and, if not, cylinders should be firmly held by chains or clips. Cylinders of chlorine, phosgene and other very poisonous gases should be obtained in small sizes and not left in the building overnight or when not in use.

The regulating valves on cylinders should not be relied on to isolate apparatus from the cylinder pressure and the main cylinder valve should be closed immediately after any period of use. This should not be closed with any excessive force such as blows from a hammer or the fitting of a piece of piping over the handle to obtain greater leverage.

Apparatus connected to gas cylinders should have some form of safety vent so that in the event of a blockage a dangerous rise in pressure in some part of the system cannot occur. Particular care is necessary with cylinders of hydrogen. The explosion of a air-hydrogen mixture is always violent. Hydrogen diffuses very quickly through the smallest of leaks and an explosive mixture is easily formed in lines or vessels. Do not leave hydrogen cylinders connected to idle plant.

Dermatitis

Skin diseases are responsible for the loss of many thousands of working days in Industry each year and in chemical laboratories there are many substances which can cause skin irritation and forms of dermatitis. Some people are more susceptible than others: the power of resistance to the same chemical varies considerably and a booklet such as this can deal only with a few generalities.

People who perspire readily are often easily affected because irritant powders tend to cling to a moist skin for some time and length of contact is obviously an important factor. On the other hand, people who have excessively dry skins are also easily affected because the skin is liable to crack or scale and afford particles easy entry.

It can be said definitely that personal cleanliness is essential and that soap and water are the best materials to promote it. Because organic solvents are so readily accessible, laboratory workers are often tempted to use them to remove stains from the hands but their use defats and dries the skin and renders it more vulnerable to dermatitic infection.

Absences from work caused by dermatitis are normally quite lengthy. Ten weeks has been reported as average. Cure is therefore very slow and often not complete because people who have once had dermatitis are always susceptible to re-infection. Prevention is not only better but in this case easier than cure. Avoid dabbling or dipping the hands in any chemical solutions, however weak the solutions may be. Use ladles or stirring rods long enough to keep the hands well away from risk. Similarly, do not handle powders or other solids with bare hands but use some form of scoop. If you are advised to wear any form of protection such as gloves or to apply barrier creams to the skin make sure you do so strictly in accordance with the instructions of your senior chemist.

Barrier creams have proved to be very effective aids against infection provided they are used properly. A water-repellent cream must be used where the hands are likely to be wetted and an oil-repellent cream where contact is to be made with oils or non-water soluble materials. These two types are of course only the main sub-division of barrier creams. Different firms manufacture many different formulations. Indeed some of them have consultation services and will formulate a special cream against a specific risk on request.

It must, however, be emphasized that personal cleanliness is the main line of prevention and still essential even when such creams are used. The skin must be clean before they are applied and re-application is necessary at varying intervals. They must be applied carefully and worked well into the finger nail crevices. After work the skin must be thoroughly cleaned again.

The Factory Department of the Ministry of Labour has produced several publications on dermatitis of which the following are of particular value:

1. Prevention of Dermatitis (Factory Form 1863).
2. Memorandum on the prevention of industrial dermatitis with special reference to the use of barrier creams (Factory Form 330).

Finally, have all cuts and other injuries treated by one of the first-aiders to avoid giving any irritant materials easy entry through the skin and report at once any faint rash or skin irritation you may notice. Do not wait until the skin is seriously affected.

Toxic Chemicals, Gases and Treatment of Affected Persons

In any case of poisoning it is necessary to call a doctor or send the casualty to hospital after having performed the first duty of calling one of the laboratory staff trained in first aid. The cause of poisoning will generally be known and notes on some of the more common chemical injuries and treatment are given in the following pages. Other aids to treatment are available and we utilize two of them. The first is a Laboratory First Aid Chart produced by British Drug Houses Ltd., which gives quick reference to treatment required for many toxic chemicals. The second is a series of sheets called "Labels for Gassing Casualties", available from the Association of British Chemical Manufacturers. Some twenty sheets give vital information in a very concise form on fifty toxic gases or vapours. One section of each label lists the effects and symptoms caused by a gas or group of gases, another the first aid treatment required and others indicate the subsequent measures to be taken by a doctor or hospital. The advantages of this scheme are obvious. Firstly, laboratory first-aiders have precise instructions as to what they should do in each case and secondly doctors or nursing staff have immediate reference regarding further treatment. Neither local doctors nor hospitals should be expected to know without some reference what should be done for casualties affected by many of the chemical gases or vapours. The use of the labels does, however, necessitate prior consultation with hospitals to avoid the impression being given that they are being told how to do their work. We have found in every case that a consultative and diplomatic approach has resulted in appreciation and welcome of the liaison.

When the cause of poisoning is not known there are two general principles:

1. Give large quantities of water or milk to drink.
2. Where the poison is at least known to be non-corrosive an emetic can be given. A corrosive poison is often evidenced by burning or whitening of the lips and mouth and in such cases an emetic must not be given.

Where casualties are caused by gassing it is almost certain that the gas will be known and the appropriate treatment can be given. If it is not known, the affected person should be removed to fresh air and clothing loosened at waist and neck. He or she should be kept lying down and warm but do not give stimulants. If breathing is weak or shallow give oxygen and only employ artificial respiration if breathing actually stops. With regard to administration of oxygen it should be emphasized that this can only be carried out by trained people; for other people to do so could be very dangerous. Two cautions are also necessary with regard to any unconscious casualty. It should be ascertained quickly that the tongue has not fallen back to block the throat airway and he must be then placed in such a position that this cannot happen. No attempt must be made to make such a casualty drink anything. It must also be understood that skilled medical attention must be obtained as quickly as possible for all eye or lung casualties and for other injuries other than very minor ones. That is why the constant repetition "Obtain medical or hospital attention" has not been made in all the following notes on first aid treatment.

ACETONE

SYMPTOMS	FIRST AID TREATMENT
A narcotic. Effects from mental confusion to full anaesthesia. Slightly irritant to eyes, nose and throat. Lowered temperature, pulse and respiration.	*Remove contaminated clothes. Fresh air, warmth and rest. Mouthwash with dilute bicarbonate solution. Apply artificial respiration if breathing stops. Transport by stretcher, car or ambulance.*

ACETYLENE

A narcotic. There may be mental confusion or even anaesthesia. Headache, faintness and soreness of the eyes are usual.	*Fresh air. Keep lying down and warm. Give oxygen and, if breathing stops, artificial respiration. Transport only by car, stretcher or ambulance.*

ACETIC ANHYDRIDE

Irritant gas. Can cause lung congestion, bronchitis or asphyxia.	*Keep lying down and warm. Wash mouth out several times. Give sips of water and only transport by car, stretcher or ambulance.*

ACIDS

SYMPTOMS	FIRST AID TREATMENT
Acetic: Skin yellowing and burning pain. Ingested: Burns on lips and mouth. May be pain in throat and nausea or vomiting.	*Wash skin or eyes copiously with water for at least 10 minutes. Wash mouth with water and then dilute bicarbonate solution. If ingested give plenty of water to drink and then milk of magnesia. Keep warm and quiet.*
Hydrochloric: Burning pain of skin or eyes. Lungs: Gas is strongly irritant and can cause acute or chronic bronchitis and severe lung congestion.	*As for acetic acid. Remove contaminated clothes. Keep lying down and warm. Mouthwash with dilute bicarbonate solution. Tea or coffee may be given. Transport by car, stretcher or ambulance. Ingested: As for Acetic Acid.*
Hydrofluoric: *Skin:* Deep and dangerous burns which often become ulcerous and are very slow in healing. *Eyes:* Extremely dangerous to eyes as liquid or gas. *Lungs:* as for hydrochloric acid.	*Wash copiously with water then apply ointment made of one part of light magnesium oxide and two parts of glycerine. It is usually necessary for a doctor to inject into and under the burn a sterile 10 per cent solution of calcium gluconate. This solution and the ointment can be bought and arrangements made with a local hospital that they will be sent to them with a casualty. Eyes should be irrigated with flowing water for at least 15 minutes. Lungs: as for Hydrochloric Acid.*
Nitric: Symptoms as for acetic acid except that burns are usually white before turning yellow.	*As for Acetic Acid.*
Oxalic: Local caustic action on skin and mucous membranes. Often inhaled as a fine dust or as a mist from boiling solutions.	*Wash skin or eyes copiously with water. If ingested give a suspension in water of chalk or magnesium carbonate to form insoluble salts and then a solution of calcium lactate to continue this.*
Phosphoric: Irritating and burning of skin. Very dangerous to eyes.	*As for Acetic Acid.*

SYMPTOMS	FIRST AID TREATMENT

ACIDS (*cont*)

Sulphuric: Strong acid causes rapid destruction of skin and tissues, more dilute solutions burn. Repeated contact with very dilute solutions can cause dermatitis.	*As for Acetic Acid.*

ALCOHOLS

Symptoms vary. Some people become sentimental, others quarrelsome and some fall asleep. There is often nausea, vomiting or depression.	*Keep warm. Give large amounts of warm water followed by an emetic and then coffee.*

ALKALOIDS

	Give a spoonful of pure charcoal in water and then an emetic.

AMMONIA

Irritation of eyes, skin and mucous membranes. Violent coughing or arrest of breathing. Gas and liquid both very dangerous to eyes.	*Remove any contaminated clothes. Wash skin or eyes thoroughly with flowing water. Keep lying down and warm. Sips of water may be given. Transport by car, stretcher or ambulance.*

ANILINE

Poisonous when absorbed through skin, when breathed as vapour or mist and when ingested. Toxic quantities can cause cyanosis, a sense of well-being, developing into headache or sleepiness. Dangerous to eyes.	*Remove contaminated clothes as quickly as possible, wash skin thoroughly with soap and water. If ingested, give an emetic. Oxygen may be given and, if breathing stops, artificial respiration.* DO NOT *give alcohol or oils. Affected eyes should be washed with water for at least 10 minutes. Transport by car, stretcher or ambulance.*

ANTIMONY SALTS

Often irritate the skin. When ingested may cause stomach pains or spasms of the limbs.	*Remove contaminated clothes. Wash skin thoroughly. If ingested, give an emetic. Keep warm and quiet.*

SYMPTOMS	FIRST AID TREATMENT

ARSENICALS

Poisonous by skin absorption, as a mist or dust breathed in and by ingestion. In the latter case there are usually stomach pains, vomiting, pallor and thirst. Treatment must be speedy.

Early medical attention is essential. Give milk or white of egg and then an emetic. Keep warm.

ARSINE

Sickness and stomach pain, perhaps delirium and then coma.

Remove contaminated clothing. Give milk, tea or coffee and keep lying down and warm. Transport by stretcher or ambulance.

BARIUM SALTS

Give magnesium or sodium sulphate.

BENZENE

Inhalation of the vapour can give acute or chronic poisoning according to concentration and time of exposure.

Acute effects are dizziness, excitement, breathlessness and narcosis.

Remove contaminated clothes. Fresh air, warmth and rest. Artificial respiration if breathing stops. Move only by car, stretcher or ambulance.

BROMINE

Liquid and vapour both dangerous to eyes. Inhalation causes inflammation of respiratory system and congestion of lungs.

Remove contaminated clothes. Wash skin or eyes thoroughly with water. Fresh air, warmth and rest. Oxygen may be necessary. Artificial respiration if breathing stops. Move only by car, stretcher or ambulance.

CARBON DISULPHIDE

Irritation of eyes and mucous membranes, headache, nausea, diarrhea.

Move to fresh air. Give oxygen if breathing shallow and, if breathing stops, artificial respiration.

CARBON DIOXIDE

An asphyxiant gas.

Loosen clothing at neck and waist. Keep lying down and warm. Give oxygen if badly affected and, if breathing stops, artificial respiration. Move by car, stretcher or ambulance.

SYMPTOMS	FIRST AID TREATMENT

CARBON MONOXIDE

An asphyxiant.

Loosen clothing. Keep lying down and warm. Give oxygen and, if breathing stops, artificial respiration. Move only by car, stretcher or ambulance.

CARBON TETRACHLORIDE

A narcotic vapour. May be mental confusion to complete anaesthesia.

Remove splashed clothing. Keep lying down and warm. Give oxygen if breathing shallow and artificial respiration if it stops.

CHLORINE

A lung irritant gas which causes coughing, bronchitis and severe lung congestion.

Loosen clothing. Keep lying down and warm. Milky tea or coffee may be given. Administer oxygen and move only by car, stretcher or ambulance.

CHLOROFORM

As for Carbon Tetrachloride.

As for Carbon Tetrachloride.

CHLORSULPHONIC ACID

A strong acid causing severe skin burns. When exposed to air it fumes because of breaking down with atmospheric moisture to hydrochloric and sulphuric acids.

As for Hydrochloric Acid.

COAL GAS

As for Carbon Monoxide.

As for Carbon Monoxide.

COPPER SALTS

If a fairly large amount is ingested give an emetic and, after vomiting, give white of egg or a suspension of charcoal in water. Avoid milk and oils.

CRESOLS

Produces white burns on skin or on lips and mouth if swallowed.

Skin: wash for some time with soap and water, then with alcohol.
Eyes: irrigate with flowing water for at least 10 minutes.
Ingested: give large amounts of dilute bicarbonate solution to drink and then an emetic. Afterwards give a demulcent such as egg white or milk.

SYMPTOMS	FIRST AID TREATMENT

CYANIDES AND HYDROCYANIC ACID

Causes rapid paralysis of the respiratory centre so first aid must be given very quickly. There may be headache and vertigo or even convulsions.

Place semi-prone and keep warm. Break an ampoule of amyl nitrite in a handkerchief under patient's nose so that the vapour is inhaled. Repeat every 2 minutes until medical attention available. Give oxygen if the breathing is very shallow and artificial respiration if it stops. Sterile solutions, for injection, of sodium nitrite (0.3 g in 10 ml water) and sodium thiosulphate (25 g in 50 ml water) can be bought and should be kept available for the doctor or to be sent to hospital with the patient.

CYCLOPROPANE

A narcotic. There may be headache or faintness and mental confusion up to full anaesthesia. Often conjunctivitis.

Remove contaminated clothes. Keep lying down and warm. Give oxygen and, if breathing stops, artificial respiration.

DIMETHYL SULPHATE

An irritant and systematic poison. Vapour can cause eye injury, lung irritation and bronchitis. Corrosive to skin.

Eyes: wash for some time with water and then dilute bicarbonate solution. Skin: wash as for eyes.

ETHYL CHLORIDE

A narcotic. As for Cyclopropane.

As for Cyclopropane.

ETHYLENE

As for Cyclopropane.

As for Cyclopropane.

ETHYLENE DICHLORIDE

As for Cyclopropane.

As for Cyclopropane.

ETHYL ETHER

Vapour when inhaled causes mental confusion to full anaesthesia.

Remove to fresh air and keep warm. If conscious, coffee may be given. Artificial respiration if breathing stops.

SYMPTOMS	FIRST AID TREATMENT

FLUORINE

Gas may cause asphyxia or bronchitis and lung irritation. It also causes dangerous burns of the eyes or skin.

Remove contaminated clothing. Keep lying down and warm. Mouthwash with dilute bicarbonate solution. Milky tea or coffee may be given. Transport by car, stretcher or ambulance.

FORMALDEHYDE

Irritation of eyes, skin, nose and throat.

Eyes: wash for 15 minutes with flowing water.
Skin: wash thoroughly with soap and water.
Inhaled vapour: remove to fresh air, lie down without pillow. Give tea or coffee. Smelling salts may help.

HYDROGEN CYANIDE

See Cyanides.

See Cyanides.

HYDROGEN SULPHIDE

Is almost as deadly as hydrogen cyanide. First aid must be prompt.

Remove to fresh air and loosen clothing. Keep lying down and warm. Give oxygen and, if breathing stops, artificial respiration. Move only by car, stretcher or ambulance

METHYL CHLORIDE

As for Cyclopropane.

As for Cyclopropane.

METHYL DICHLORIDE

As for Cyclopropane.

As for Cyclopropane.

NICKEL CARBONYL

Irritant gas which can cause bronchitis, lung congestion or asphyxia.

As for Chlorine.

SYMPTOMS	FIRST AID TREATMENT

NICOTINE

Dangerous poison to nervous system. Poisonous by skin absorption or by inhalation of vapour.

Slight exposure to vapour: nausea, vomiting, shock, confusion or muscular weakness.

Severe exposure: similar but with numbness, cyanosis and collapse.

Heavy exposure: failure of respiration and circulation, then coma.

Remove contaminated clothes. Keep lying down and warm. Wash thoroughly if skin splashed. Give oxygen and, if breathing stops, artificial respiration. If conscious give tea or coffee to drink.

Move only by car, stretcher or ambulance.

NITROBENZENE

Toxic through the skin, when inhaled as vapour and when swallowed. There may be rapid intoxication or headache, vomiting, then coma. Low temperature and respiration. Other later effects make this material very dangerous.

Remove contaminated clothes.
Skin: wash thoroughly with soap and water.
Inhaled: keep patient at rest and warm. Oxygen may be given and, if breathing stops, artificial respiration. Tea or coffee but not alcohol. Move only by car, stretcher or ambulance.
Eyes: wash with flowing water for at least 10 minutes.

NITROGEN OXIDES (NITROUS FUMES)

A very toxic mixture of gases which may only have slight effects for some time after inhalation but extremely dangerous and even fatal ones several hours later.

Complete rest for several hours is essential. Tea or coffee may be given and transport must only be by stretcher or ambulance. Administration of oxygen and strict medical supervision is required for some time because of latent effects.

NITROUS OXIDE

A narcotic. There may be effects from mental dullness to complete anaesthesia.

Keep lying down and warm. Oxygen may be necessary and, if breathing stops, artificial respiration. Only move by stretcher or ambulance.

PHENOL

As for Cresols.

As for Cresols.

SYMPTOMS	FIRST AID TREATMENT

PARAFORMALDEHYDE

If swallowed and patient conscious give milk freely and then an emetic. Repeat this and then give more milk. If breathing becomes very shallow give oxygen and, if breathing stops, artificial respiration. If eyes affected wash for some time with flowing water.

PERCHLORETHYLENE

Vapour is a narcotic. A high concentration may produce tears and burning pain in eyes, nausea and from mental confusion to full anaesthesia.

Remove to fresh air and take off any contaminated clothes. Keep warm and quiet. Oxygen may be given and, if breathing stops, artificial respiration. Eyes: wash with flowing water for 10 minutes.
Ingested: give an emetic and, after vomiting, repeat.

PHOSGENE

As for Nitrogen Oxides.

As for Nitrogen Oxides.

PHOSPHORUS (YELLOW)

Fumes given off usually lead to chronic rather than acute poisoning. Skin contact produces dangerous burns which may be deep and very slow in healing.

Skin: the part should be plunged and kept in water if possible. If not, wash continuously with water until medical attention is available.

PHOSPHORUS OXYCHLORIDE

As for Oxides of Nitrogen.

As for Oxides of Nitrogen.

POTASSIUM HYDROXIDE

Caustic burns of the skin. Is extremely dangerous to eyes and immediate attention must be given.

Wash off thoroughly from skin. Eyes must be irrigated with flowing water for at least 15 minutes.

POTASSIUM PERMANGANATE

If swallowed may produce nausea and vomiting. Cold clammy skin.

Give an emetic. After vomiting, repeat and then give a suspension of pure charcoal in water. After that, milk may be given.

SYMPTOMS	FIRST AID TREATMENT
PYRIDINE	
Nauseating odour in low concentrations but sense of smell rapidly reduced in larger amounts. With heavy doses there may be shortness of breath and trembling of the extremities. Can cause dermatitis in contact with skin and serious injury to eyes.	*Eyes and skin: wash copiously with running water for some time. Inhaled: remove to fresh air. Take off contaminated clothes and if coughing is very persistent give oxygen.*
SILVER NITRATE	
Causes caustic burns of the skin or eyes. Poisonous if swallowed.	*Wash thoroughly from skin. Eyes should be irrigated with flowing water for at least 15 minutes. If swallowed, give salt water as an emetic twice, then milk.*
SODIUM HYDROXIDE	
As for Potassium Hydroxide.	*As for Potassium Hydroxide.*
SULPHUR DIOXIDE	
A suffocating odour and is corrosive as well as poisonous. Chiefly affects the respiratory tract.	*Remove to fresh air. Rest and quiet. If eyes affected, wash thoroughly with water.*
TETRACHLORETHANE	
As for Carbon Tetrachloride.	*As for Carbon Tetrachloride.*
TOLUENE	
As for Benzene although less toxic.	*As for Benzene.*
TOLUIDINES	
As for Aniline.	*As for Aniline.*
TRICHLORETHYLENE	
As for Cyclopropane.	*As for Cyclopropane.*
THALLIUM SALTS	
Soluble compounds can be absorbed through the skin. Poisonous if ingested – no food should be eaten where thallium compounds are used.	*Give an emetic, then tea or coffee. Keep warm and at rest.*
XYLENE	
As for Benzene although less toxic.	*As for Benzene.*

Conclusions

The main rules and aids to accident prevention have been stated in various parts of this booklet. Every effort should be made to impress them on the staff and particularly newcomers, who should be made safety minded from the moment they start work and not left to learn precautions the hard way from accident experience.

Where personal injury does occur it is all important that prompt and expert first aid should be given to a casualty during the inevitable delay while professional medical attention is obtained. Such first aid care can be vital so it is important that a proportion of the staff should be trained not only in the usual first aid methods but also in ways of treating chemical injuries.

Staff should know at least their own sections of the laboratory thoroughly – the location of control valves and switches for the various services, location and use of fire extinguishing appliances, breathing appliances and where the nearest qualified first aiders are usually working. If there is an accident, obvious action to confine or extinguish fires and to deal with casualties should be taken but at the same time someone should be sent to obtain expert assistance. Afterwards, see that details of the accident are reported to the senior chemist in that section while they are still fresh in mind. Similarly, any accidents in which injury is narrowly averted should also be reported in order that precautions can be devised to avoid repetition. In this spirit all members of the staff are asked to assist by notifying any operation or equipment which they consider to be even potentially dangerous, so that personal injury or material damage is not the means of bringing the hazard to the notice of the Safety Committee.

The standard form used at the National Chemical Laboratory for reporting of accidents is reproduced in the Appendix. It is important that where there is any personal injury requiring first aid treatment the details should also be recorded in the local first aid book. In each of these books an extra column headed "Cause of Accident" should be ruled in. Accident prevention work requires that causes even more than results of accidents should be constantly made known so that attempts to eliminate them can be made. An accident is history as soon as it has happened but, like history, it can teach valuable lessons.

Appendix

To: 1. Assistant Director
2. Safety Officer
3. Office

REPORT OF ACCIDENT

1. What was the nature of the accident: where and when did it occur?	
2. Names of any injured persons:	
3. Nature of any personal injury or material damage:	
4. Measures taken to treat injury and by whom:	
5. Were fire extinguishers or other safety appliances used?	
6. Witnesses of accident:	
7. Was the injured person engaged on official duties and was he or she familiar with the operation in progress?	
8. Are you satisfied the accident happened as reported to you?	
9. Other comments:	
10. Can you suggest any precautions which will prevent a recurrence of this accident?	

11. Comments by Laboratory Safety Officer:

Signed..

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SOME PUBLICATIONS OF THE FORMER NATIONAL CHEMICAL LABORATORY

THE CHEMISTRY OF COMPLEX CYANIDES
M. H. Ford-Smith 1964 £1.37½

This is a comprehensive literature survey of an important but difficult field in inorganic chemistry. As well as containing 453 references and much explanatory matter, the author has made suggestions for research in this field. This book is based upon the work undertaken over a period of years at the National Chemical Laboratory, which was concerned with the solution chemistry of complex cyanides, with an interest arising out of investigations into the ion exchange processes for the recovery of gold. As a result its main concern was with the species present in solutions of the ions and cyanides.

THE DETERMINATION OF BERYLLIUM
1963 15p

An authoritative account of methods for the determination of beryllium in minerals and in general chemical applications. This work is based on extensive research undertaken at the former National Chemical Laboratory in the field of beryllium chemistry from 1958 to 1964.

THE DETERMINATION OF URANIUM AND THORIUM
1963 17½p

An authoritative account of chemical methods for the determination of uranium in minerals, ores and other chemical compounds. This account is based on the many years of experience in the extractive metallurgy of uranium and thorium in the former National Chemical Laboratory.

Obtainable from Her Majesty's Stationery Office at the addresses shown on cover p. iv or through booksellers.