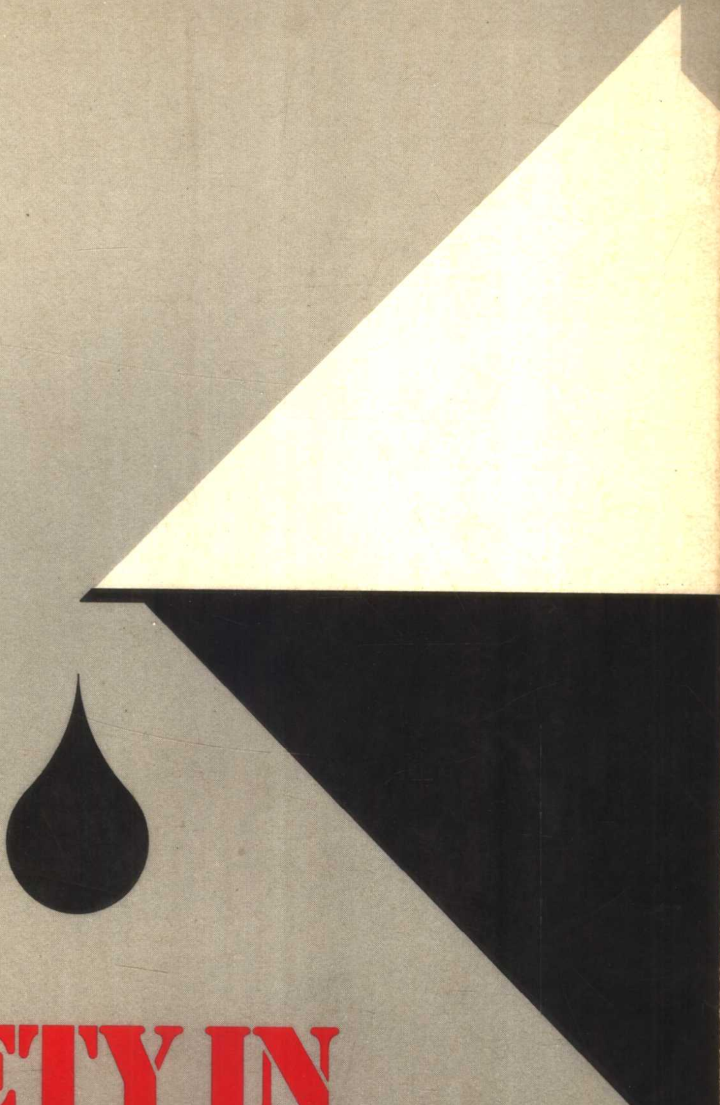

SAFETY IN WORKING WITH CHEMICALS

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Preface

In spite of the gathering evidence everywhere that chemical laboratory workers, including students, are subjected to greater environmental risks than the general population, safety instruction continues to be a haphazard activity. Often it is limited to the first "indoctrination" hour of the first laboratory period, when the student is only dimly aware of what will be going on during the remainder of the course. Furthermore, the usual emphasis is on immediate dangers, such as that of fire, while the hazards of chronic exposures are relegated, at least implicitly, to a secondary role.

It is tempting to recommend that separate courses in laboratory safety be instituted, but we are aware that such a proposal is unrealistic for an already crowded curriculum. Besides, we do not believe that "safety" should be separated from "chemistry," either in instruction or in concept. Accordingly, it is our recommendation (elaborated in appropriate chapters of the book) that existing laboratory courses accommodate safety instruction as an integral part of *all* the prescribed experiments.

We have tried to do more than write a set of rules or a safety "outline." However, this book is not an encyclopedia. Instead, it aims to *teach* the subject of chemical safety in a way that will provide understanding of the fundamental concept of safe practice. Its ultimate object is to contribute to the reduction of injuries and illness.

The book can be useful in a variety of ways. It can serve as a text for a short course in laboratory safety. It can be used as an indoctrination to safe practice for newcomers to any chemical facility —teachers, technicians, researchers, and students. Certainly it should be in the hands of all members of chemical safety committees.

The authors will appreciate all comments and suggestions regarding the subject matter of the book. All communications will be answered.

Michael E. Green
Amos Turk

Contents

1 Introduction

1.1 CHEMICAL HAZARDS—ACUTE AND CHRONIC

Once, when one of us (M.G.) was travelling in another country, he tried to communicate with a student across a language barrier. There was only one way he was able to explain to the student that he was a chemist. After pointing to himself, he slowly mimed pouring one liquid into another, following this by shouting BOOOMM!! Instant comprehension resulted.

Chemists have become all too notorious for their association with unwanted and accidental explosions. It is also well known that many of the substances chemists work with are toxic, some very much so. Until recently, the chronic effects of most of these substances were not well recognized, although a few chronic toxins have been known for many years. As early as 1775, cancer of the scrotum of chimney sweeps was described by Dr. Percival Pott. Chimney sweeps removed their clothing so as not to spoil it when working. The polycyclic aromatic hydrocarbons present in soot were presumably responsible for the cancer, although Pott, writing before Dalton, had no way of knowing this. Mercury, too, has long been known to be a chronic poison.

It is now known that most cancers are environmental in origin, with estimates by recognized authorities running as high as 90 per cent. This of course includes occupationally caused cancers, which are believed to be quite numerous in this country. It is officially estimated that about 15,000 workers are killed by occupational accidents each year. However, national surveys indicate that if chronic diseases, including cancer, were included the annual occupational death toll would be closer to 100,000, and serious illnesses approach four times that number.

It was, in part, data like these that led to the passage of the Occupational Safety and Health Act in 1970. This Act, effective April 28, 1971, established the Occupational Safety and Health Administration (OSHA) and the National Institute of Occupational Safety and Health (NIOSH). OSHA is charged with enforcing the law, which states that every worker in the United States has the right to a safe workplace. (The actual effectiveness of the law in its first 6 years is open to question, principally because of inadequate enforcement, but that is another story.) OSHA has among its tasks the setting of standards for exposure to chemicals in the workplace, as well as the enforcement of these standards.

Workplaces include universities and laboratories, except for "governmental" institutions (meaning not only federal agencies and national laboratories, but state universities and state agencies, public high schools, local government facilities, and so on). However, in 1975, President Ford signed Executive Order 11807, extending inspections under the Act to federal employees, both civil and military. Some municipal and state workers are beginning to come under the effective protection of the same standards.

NIOSH is one of the National Institutes of Health (though based in Cincinnati, not Bethesda). It was established mainly to provide the research upon which standards could be based. Chemists should know that NIOSH has issued a list of 1500 suspected carcinogens, many of which are rather common substances (see Chapter 5). Chemists are therefore likely to be at risk from more different substances than any other group of workers (except, perhaps, for those who fill the bottles that will be labelled "*Dangerous–Potential Carcinogen,*" or equivalent). OSHA has only begun to inspect laboratories, and although few have yet been fined, its enforcement procedures could become more vigorous soon.

However, with or without inspections, it is worth noting that chemists apparently do get cancer at a rate approximately 25 per cent higher than that of the general population. According to a report to a Senate committee in 1971, it was predicted that about

50 million of the 200 million Americans then living would get cancer, and 34 million would die of it. Combining these figures suggests that exposure to carcinogens would cause about 21 per cent of chemists to die of cancer, compared with 17 per cent of the general population.

Even established standards are not necessarily sufficient to protect against cancer or other chronic injury; this is especially true of the older standards. New standards are being issued as new information becomes available, leading always in the direction of a tighter standard. For example, the benzene standard has dropped from 10 parts per million (ppm), averaged over 8 hr, and 50 ppm for 15 min, to one tenth these amounts. Vinyl chloride was found to be a carcinogen, and its allowable 8-hr average concentration dropped from 500 ppm to 1 ppm. Compliance with the new standards often requires considerable improvement in safe practice. Sometimes it is not easy to comply with even older standards. The permitted *ceiling* concentration for hydrogen sulfide, for example, is 20 ppm, with a 10-min excursion (once only, if no other exposure occurs) to 50 ppm.

OSHA is unable to cover most chemistry laboratories, either because of lack of inspectors or other budgetary problems, or because many laboratories are "governmental." Therefore many chemists will spend much of their careers in situations in which they are called upon to be their own safety experts, even though not directly subject to legal checks. However, teachers may be subjected to lawsuits.*

1.2 RESPONSIBILITY

Exposure to toxic chemicals is not the only laboratory hazard. The unexpected thunderclap of an explosion can be anything from distressing to disastrous; if it happens in a laboratory under a teacher's supervision, it can also mean a lawsuit. It may in addition mean severe injury, such as loss of an eye.

Faculty are responsible for more than their students' immediate safety. Attitudes toward laboratory health and safety, which are likely to be carried on long past school years, are formed in student

*See "The Personal Liability of Chemical Educators," *J. Chem. Educ.*, **54**:134 (1977).

laboratory courses. Obviously, these attitudes are important for future chemists. They are probably at least as important for another large group of students in undergraduate chemistry laboratories, the premedical students. Physicians, faced with an undiagnosed disease, all too often fail to look into the possibility of an occupational cause, at least until quite late in the treatment. Given the prevalence of occupational disease, it would be well if future physicians were made aware of the possibilities when they are themselves first exposed to the risk. (Even medical schools have tended to give relatively little attention to this field.)

This book should be valuable for students in undergraduate chemistry laboratory courses. In addition, the book provides a convenient manual for chemists who work at the laboratory bench and must be aware of the range of hazards they face, as well as for those who find themselves with responsibility for students, technicians, other chemists, or other workers. This is not an exhaustive treatise, obviously. Some general industrial hazards, such as lifting heavy weights, are omitted entirely. Principles and methods are described, and enough practical information is included to make the book directly useful in many circumstances. There are many other works dealing with laboratory safety, occupational health and safety in general, hazardous chemicals, and so on, as well as sources for obtaining new information in this rapidly changing field. Some of these are listed in the bibliography section at the end of the book. Each has value, and may at one point or another prove useful.

Obviously, not everything can be discussed in a book of this length. Many substances are referred to as "carcinogenic" without a serious attempt to separate strong from weak carcinogens. Given the present state of our knowledge, this would have been a fairly hopeless task. Furthermore, cost estimates are not given for such modifications as ventilating a laboratory or for doing the clinical chemistry necessary to maintain proper health checks on those exposed to a variety of chemicals. There were various points at which we could only say that certain steps would have to be taken, and recommend that expert advice be sought for the particular situation. There are some problems for which solutions cannot be stated in a few universally applicable rules; we hope that we have at least been successful in pointing out the existence of these problems.

One serious impediment to an adequate safety program is cost.

Money used for safety is unavailable for teaching or research. The problem is made more serious by the competitiveness of research. It seems likely that if chemists *as a group* insist that safe procedure be considered normal procedure, then safety equipment, supplies, and training could be funded by federal grants and supported by university administrations. Individual initiative on safety is less likely to be effective in a very competitive atmosphere. (This should not be construed as an excuse for inaction on safety but rather a statement of the necessity for cooperative action.)

We believe that most chemists will agree that increased attention to laboratory health and safety is now required; it is our hope that this book will aid in the solution of some of the problems raised.

2 Basic Laboratory Precautions

There are certain basic rules of safe procedure that all laboratories, particularly student laboratories, should follow. Most of these procedures, or rules, are known to all chemists. Unlike some of the information in the later chapters, these rules have generally been accepted for some time as being fundamental to the safe operation of a laboratory. Most are in fact discussed early in freshman chemistry. We begin with these precautionary rules.

2.1 HANDLING GLASSWARE

The most common accidents in student laboratories are cuts and burns resulting from handling glassware. It seems inevitable that in the first laboratory period of a freshman class, someone will pick up a piece of hot glass. Fortunately, the results are usually more painful than serious, and the error is not usually repeated by the same individual. To minimize the number of students who make this mistake, it is helpful to *instruct* students to place a wire gauze near their burner before starting and put the freshly bent or fire-polished glass on it for several minutes after it is heated. If the air an inch above the glass feels warm to the palm of the hand, the glass is still too hot to touch.

More serious are the cuts resulting from broken glass. Students should be told to fire-polish freshly cut ends of pieces of glass. They should also be told how to insert glass tubing into rubber stoppers. The steps are

1. Lubricate the hole in the stopper with water or glycerine.
2. Hold the glass near the end to be inserted, thus minimizing the torque.
3. Hold the glass with a towel or rag to protect the hand in case the glass breaks.

To remove glass from a stopper, wet the handle of a file with glycerine, then work the lubricated file handle between the glass and rubber. As the file is twisted, it grips the rubber, but slips on the glass, thus working in the lubricant. After this, the glass can be removed.

2.2. AVOIDING POISONS

One of the main routes of entry for toxins is the mouth. This route is not common for laboratory workers; however, it is necessary to insure that no food is in the vicinity of an area where toxic substances, especially chronic poisons, may be found. It has been determined that even when a bottle from which a liquid has been poured is resealed, enough of the liquid remains on the threads of the cap, beyond the seal, to be a problem. If the food is fatty or oily, it will dissolve fatty or oily vapors. For similar reasons, food or beverages must not be left in laboratory refrigerators.

Likewise, smoking in laboratories should be ruled out because of the risk that the cigarette might become contaminated and carry toxic substances to the mouth, even if it were not ruled out for other reasons. Another related practice that has fortunately fallen into disuse is testing chemicals by taste or odor. Finally, no one with bare feet may be allowed in the laboratory. All of these practices are so grossly unsafe as to be flatly forbidden.

2.3 HOUSEKEEPING

Keeping the laboratory neat is a matter of survival. Loose electrical wires, spilled chemicals, water hoses running across aisles (other than properly installed plumbing), and similar avoidable hazards, are invitations to disaster.

a / Student Laboratories

In student laboratories, assuming the chemicals used are not of the order of toxicity that requires extraordinary precautions (for example, carcinogens—see Chapter 5), students should be instructed to clean up any spills they cause, whether at their own benches or in common areas such as near balances or in hoods. This practice is particularly necessary for volatile substances, especially if they are toxic or flammable. Volatile toxic substances should be used only in the hood; however, spills may occur outside the hood in any case. Disposable gloves should be available for use in cleaning up these substances. At the end of the lab period, it will generally be necessary to wipe off bench tops, make sure reagent bottles have been capped and returned to their appropriate location, and so on. Students should have specific assignments, each covering a section of the laboratory; it is the responsibility of the assigned student to leave his or her section in a clean, nonhazardous condition.

Other aspects of housekeeping, such as clear aisles and safe connections, are the responsibility, at least in part, of the person in charge of the laboratory. If a laboratory is being designed, a layout that places services close to where they will be used will reduce the amount of tubing, wiring, and other connections that must be run to distant locations.

b / Research Laboratories

Considerations similar to those described in part (a) apply to research laboratories, although more toxic chemicals may be in use. The researcher in these laboratories is responsible for maintaining a neat working area. Aisles must still be clear; access to safety showers, emergency exits, and other emergency apparatus must be unobstructed.

The general rules for housekeeping are well known, but it is necessary to apply them. Actual procedures for monitoring housekeeping will be discussed in detail in Chapter 7. Controls to insure that housekeeping requirements are met will be dealt with in Chapter 8. For handling carcinogens and other extremely toxic materials, procedures