

**SAFETY CONSIDERATIONS FOR HIGH SCHOOL SCIENCE LABORATORIES
WITH SPECIAL EMPHASIS ON, CHEMICAL HAZARDS**

by

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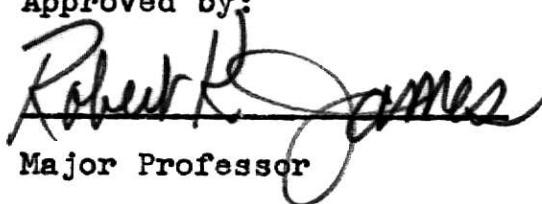
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PREFACE

Portions of the information selected for inclusion in this report were promulgated through industrial concern. It is recognized that the hazards of the industrial laboratory do not always coincide with the hazards that exist in the high school laboratory. As a general rule the quantities and the concentration of hazardous material in school laboratories are less than those used in their industrial counterpart, however, the same precautions are often necessary. Any precaution which serves to make the high school laboratory a safer place to learn merits consideration, regardless of its origin.

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CHAPTER ONE

THE SAFETY PROBLEM

According to a study conducted by Young (24), one major accident occurs per every forty students per year (1972) in Illinois high school chemistry laboratories. Assuming such findings can be extrapolated to the national high school science population the resultant accident toll would be prodigious. If science instructors are to provide safe laboratory experiences for students many precautions and control procedures must be considered.

The purpose of this report is to review the literature and cite information which elucidates laboratory safety hazards, precautions, and recommendations; and consolidate this information such that it may serve as a resource for improving the safety related competencies of science instructors.

CHAPTER TWO

PART 1: SAFETY IN LABORATORY DESIGN AND FURNISHINGS

If the laboratory is to be made safe, primary consideration must be given to the basic design and facilities of the room. The following list is representative of the types of items that should be considered:

1. Laboratory floors, walls, ceilings, and furniture should be constructed of noncombustible materials. (1)
2. Chemical storage rooms should be contained by fire walls and fire doors. (1)
3. Flooring should be smooth and impervious, but not slippery when wet. (2)
4. Furniture should have rounded corners and edges, and be resistant to splintering. (2)
5. Aisles and passages should be wide enough to allow quick evacuation, as well as uncongested normal traffic. (2)
6. Exit doors should swing outward from the laboratory. (1)
7. Adequate exits should be provided such that no area in the laboratory would be isolated from an escape route in the case of fire, explosion, or release of dangerous gas. (1)
8. Laboratory benches or tables should be arranged such that free escape is possible in two directions. (1)
9. Ventilation should be positive, (fresh air forced in), so that it will not compete with the operation of exhaust fume hoods. (3)
10. Ventilation should be continuous and provide approximately six complete air changes per day. (3)

11. Fume or exhaust hood considerations:

- a. Face velocities should be kept within the range of fifty to one hundred fifty linear feet per minute over the entire hood face. (4)
- b. Face doors should not be allowed to close completely. (At least a one inch opening must be left to ensure proper draw.) (1)
- c. Glass face doors should be wire reinforced and shatter-proof. (1)
- d. If several hoods are needed by the laboratory, select different sizes so that the correct size can be used for different experimental conditions. (4)
- e. Exhaust fans should be spark-proof and corrosion resistant. (1)
- f. Controls should be located outside the face door. (1)(4)
- g. Although wood and plastic hoods are much more inexpensive than soapstone or stainless steel hoods, one should consider what emergencies the apparatus will be put to and what hazards will be involved. (4)
- h. Generally, a deeper hood will have a more uniform suction across the face. (4)
- i. Generally, the lower the height and the clear opening the more satisfactory the air flow. (4)
- j. The face sill should be sloped or elevated to prevent experimental apparatus from being used too far out from the air flow. (4)
- k. Locate the hood away from doors, windows, heavily traffic-

ed pathways, or other possible negative pressure draft sources which might interfere with the suction of the hood. (4)

1. Although there are no standards for testing hoods for satisfactory operation, simple tests can be run on the hood exhaust action with smoke bombs, hot-wire anemometers, or release of odoriferous materials. (4)
- m. Discharge outlets should be carefully situated to prevent the exhaust from re-entering buildings via inlet vents or windows. (1)(3)(4)
12. Electrical outlets should be located on pedestals or splash boards to prevent entrance of water by flooding. (2)
13. All electrical equipment should be properly grounded using three wire cables and plugs. (1)(2)
14. Master shut-off switches and valves should be easily accessible to the instructor, especially gas and electricity. (2)
15. Fire extinguishers should be provided for combating class A, B, C, and D fires. (2)(5)
16. Install fire blankets, fire showers, and eye wash baths in accordance with the specifications of the State Fire Marshal. (5)
17. One or more first aid kits should be provided. (2)
18. Adequate protective outerwear should be provided for students and teachers in the form of gloves, aprons, goggles, visors, and safety shields. (2)
19. Carefully planned storage space should include: (2)
 - a. Special storage for chemicals that are toxic, flammable,

or that must be stored under protective liquid layers.

- b. Ringaured shelves.
 - c. Ready access to shelves so that apparatus and containers can be quickly and safely removed and replaced.
 - d. Racks or drawers with partitions for sharp tools.
20. Drains must be trapped and vented to avoid build up of hazardous fumes or the return of these fumes to the laboratory. (1)
21. Automatic fire detection and/or protection devices should be installed in areas of continual fire hazard. (5)
22. Areas should be provided for students and visitors to hang coats and shelve books, purses, etc. (5)

PART 2: LABORATORY EYE SAFETY

The extreme vulnerability of the eyes to the hazards which exist in the laboratory and the history of eye accidents in laboratories warrants special consideration of eye safety.

Kansas Senate Bill 152, signed in 1967, provides that all educational institutions in Kansas will assure that all students, teachers, and visitors in or proximal to activities in vocational-technical shops, industrial arts shops, and science laboratories shall wear eye protective devices which comply with the United States Standards Institute Safety Code Z2.1-1959.* (8)

In addition, the following considerations involving eye protective devices are suggested:

1. Ordinary corrective lens glasses are not sufficient. A safety monogoggle should be worn over corrective glasses. (8)
2. If goggles are used on a community basis the school should provide equipment and material needed to clean and sterilize these devices after each use. (8)
3. Ordinary safety goggles should be used against mechanical and corrosive hazards only, and not relied upon for shielding of electromagnetic radiation. (1)(9)

A device that is becoming quite popular in high school laboratories is the laser. (9) Laser light must be handled with extreme care due to its potential danger to the eye. Eye injuries

*The U.S. Standards Institute shall supercede references to the American Standards Association effective August 1968. (8)

can result from laser light in two distinct ways:

1. Intense visible light which damages the retina (9)
2. Ultra violet and infra red light which tend to be absorbed by the cornea, lens, and vitreous humor and heating the tissues beyond the danger point (9)

It is recommended that all persons involved in laser work follow these rules: (9)

1. Never look directly into a laser beam.
2. Never use the eye to detect a laser beam.
3. Do not rely on any protective device (goggles) for viewing the laser beam directly.
4. Prevent reflections from jewelry, hardware, tools, etc.
5. Use a shield as a laser setup to avoid accidental exposure.
6. Post warning signs at entrances to laser labs.
7. Employ some audible or visible signal to indicate that the laser is or is about to be operating.
8. Operate the laser in well lighted labs.
9. In demonstrations use screens with diffusely reflecting surfaces.

PART 3: ELECTRICAL HAZARDS

In addition to providing the sparks which ignite fires or explosions in the laboratory, (see PART 7), the use of electricity in the laboratory presents the hazard of electric shock. Pieters (10) discusses electrical hazards with enlightening clarity.

The human body can be thought of as a sensitive ammeter, of which the resistance to electric current varies widely with the circumstances surrounding the contact. It responds to very small electric currents, the effects of alternating current being the more severe.

The threshold of human perception of one hundred ten volt alternating current at a frequency of sixty cycles per second is 1 milliamper (ma). The let-go limits are from 6 to 9 ma, above which such a violent muscle contraction is caused that the victim is unable to release his grip. At 25 ma breathing becomes difficult or impossible, leading to asphyxiation which can result in respiratory paralysis. In such cases the victim can be saved only by immediate and continued artificial respiration. At 100 ma (one tenth of an ampere) the heart may become affected by ventricular fibrillation, which is nearly always fatal. Currents of 1000 ma (one ampere) or more usually cause severe tissue burns.

As stated above, the human body has variable resistance to electric current. This resistance variation ranges from 100 ohms to 500,000 ohms approximately. By employing these limits for resistance and the relationship between current, resistance,

and voltage defined by Ohm's Law (where current is equal to the product of the voltage and the reciprocal of the resistance) it can be demonstrated that a faulty 110 volt electric appliance can pass a current through the human body which ranges from an imperceptible 0.2 ma to a fatal 1,100 ma.

$$110 \text{ volts} \times \frac{1}{500,000 \text{ ohms}} = .0002 \text{ amps} = 0.2 \text{ ma}$$

$$110 \text{ volts} \times \frac{1}{100 \text{ ohms}} = 1.1 \text{ amps} = 1,100 \text{ ma}$$

Since the variability of the human body's resistance to electric current is so unpredictable, any electrical apparatus which produces even the slightest shock should be disconnected and repaired immediately. An important point to consider is that moisture generally decreases the body's resistance to electric current, thereby increasing the possible current amperage. For this reason electrical equipment should never be operated with wet hands or while standing in water. An essential precaution in using electricity is to ensure that the equipment is properly grounded. This simply means that the device should be equipped with a conducting pathway to the ground that offers less resistance to electric current than the human body, since the electric flow will follow the path that offers the least resistance.

PART 4: SAFE HANDLING OF GLASSWARE

Many of the accidents that plague the science laboratory are caused by improper heating, cutting, or handling of glassware. Such hazards can be reduced if the guidelines listed below are followed:

A. Applying heat to glass containers

Glass vessels containing liquid to be heated by an open flame should rest on an iron mesh with an asbestos center to prevent the flame from reaching the glass above the level of the liquid being heated. This helps avoid cracking of the vessel due to differential heat stress. (1)

Test tubes, however, can be safely heated by an open flame if the following rules are observed: (10)

1. Move the tube through the flame continuously to avoid local overheating.
2. Only use approved test tube holders or tongs when heating a test tube over an open flame.
3. Keep the tube out of the inner blue or nonluminous flame which is much hotter than the outer yellow flame.
4. Position the mouth of the test tube so that it is not pointing at anyone. This precaution is taken in the event the "cannon effect" should occur. This is when the superheated liquid in the bottom of the tube rapidly "bumps" or violently vaporizes shooting the overlying hot liquid out much in the manner of a miniature cannon. This could cause a tragic accident if the liquid is a strong acid or base and is sprayed into a person's eyes.

B. Cutting glass tubing (1)

In order to cut glass tubing make a small clean etch at right angles to the tubing with a file or glass cutter at the exact point on the tube where the severance is desired. Hold the tube in front of the body with the etch pointing away. Using garden-type gloves or a towel for protection place the thumbs behind and slightly to either side of the etch and gently bend the tubing outward. The glass should snap cleanly at the point of the etch. Immediately fire polish both ends of the tube. This simply means to melt the fractured surfaces smooth and round with a flame.

C. Inserting glass tubing into a stopper

This procedure, a common source of laboratory accidents, can be safely accomplished if the following rules are followed: (1)

1. Ensure that the tube and stopper hole diameters are the correct size for an air tight fit, but not so tight that excess strain is needed for insertion.
2. Always lubricate the tubing and stopper with glycerine.
3. Use a towel or garden gloves to protect hands.
4. Apply a direct force with the hands close together and avoid bending the tube to the side as to make it break.
5. Short twisting movements are preferred to long thrusts.

PART 5: SAFE HANDLING OF LABORATORY ANIMALS

Animals can be a stimulating asset to the science laboratory, but awareness of their habits and behaviors is essential. Gordon (11) has presented an assemblage of common sense guidelines for the safe handling of laboratory animals.

I. HOW TO PREVENT INFECTIONS

A. Know which animals are infection carrier possibilities

1. Turtles, baby chicks, and ducklings are frequent salmonella carriers.
2. Rats, mice, hamsters, raccoons, opossums, reptiles, and frogs may be infected with leptospirosis or Weil's disease.
3. Ringworm is frequently spread by dogs and cats.
4. Few animals are immune to internal and external parasites such as tapeworms, roundworms, bacteria, viruses, etc.

B. Suggestions for infection-infestation prevention

1. Don't handle laboratory animals unnecessarily
2. Always wash hands after handling an animal.
3. Avoid handling animals if there are sores or cuts on one's hands or arms.
4. Be aware that some children are allergic to certain animals.
5. Keep the animals and their quarters as clean as possible.
6. Ensure that no wires or jagged edges protrude from the cages.

II. HOW TO PREVENT BITES

- A. Do not allow fingers to be pushed into cage openings.
- B. Do not handle a frightened or excited animal.

- C. Ensure that no natural enemies, especially dogs or cats, are present to frighten an animal into defensive behavior while being held.
- D. Never tease an animal or force it to protect itself.
- E. Keep your face away from animals and their cages.
- F. Do not allow animals to be handled when floors are slippery or strewn with objects that make footing precarious.
- G. Prohibit poisonous or venomous animals from the laboratory.
- H. Wear garden-type gloves when handling rodents or nonvenomous snakes.
- I. Animals likely to bite should be housed in cages that have wire mesh too small to allow fingers to pass through.
- J. Students should be instructed on methods of holding animals which are both safe and comfortable for the animal.
- K. No animal should be touched or disturbed while eating, since so many animals instinctively protect their food.
- L. Rats are more properly picked up by the scruff or nape of the neck.
- M. Always cradle a hand snugly under a rabbit's hind legs when holding them to avoid scratches and cuts from their powerful kicks.
- N. Avoid picking up pregnant hamsters, for they can be very vicious and unpredictable at these times.
- O. Be cautious when handling baby animals if the mother is present, for she may be viciously protective of them.
- P. Never make sudden or offensive moves when handling animals.
- Q. Be sure that the animals kept in the laboratory are of a

compatible nature to avoid unnecessary stress and anxiety.

III. WHAT TO DO IF A PERSON IS BITEN

- A. Clean the wound with soap and water.
- B. Notify the principal or school nurse immediately.
- C. Keep the animal alive and isolated until health officials have had an opportunity to inspect it. If the animal is dead and cannot be delivered to health officials immediately it should be placed in a plastic bag and frozen.

IV. GENERAL PRECAUTIONS

- A. Be sure that the animals are given the proper food and plenty of fresh water.
- B. Aquariums should be drained with a siphon before being moved.
- C. Do not use wooden cages for rodents.
- D. Cages with removable drop trays are preferable since they can be cleaned without disturbing the animal.
- E. Be sure that aquariums and other heavy objects can be safely supported by the bench, table, or stand they are on.
- F. Many animals which are docile in the wild may become moody and unpredictable in captivity.
- G. Refer to your State Fish and Game Commission for regulations concerning keeping wild animals in captivity, since some states require a permit.

PART 6: LABORATORY FIRST AID

First aid should not be confused with medical treatment. The school policy handbook should be consulted for specific limitations in this area. The first aid procedures listed below are intended as a guide to emergency action that will keep the victim alive or comfortable until treatment can be administered by authorized medical personnel.

A. Abrasions and cuts (12)

1. Superficial - Wash gently with water and wipe debris away from the cut outward with sterile cotton. Apply antiseptic and a bandage.
2. Deep irregular wounds - Cleanse around the wound, apply clean dressing, and refer for medical attention.
3. Puncture wounds - Cleanse and cover with a clean dressing. Parents should be notified that medical attention may be required for tetanus prophylaxis.

B. Animal bites (11)(12)

Cleanse the wound with water, apply antiseptic and clean dressing, and notify parents for medical attention. Obtain complete information about the animal for police or health department officials.

1. Bee stings or insect bites - Remove the stinger if it is present. Apply aromatic spirits of ammonia or baking soda solution to the area. A cold compress or ice pack will help to relieve the pain.
2. Snake bites - Have the victim lay down and remain quiet. If the bite is on an extremity apply a constricting triangular

bandage between the bite and the heart. Apply suction to the bite with snake bite kit equipment. Apply an ice pack to the bite if possible. Obtain medical attention immediately.

C. Bleeding (12)

1. From the nose - Place the student in a sitting position with the head tilted slightly forward. Apply pressure to both nostrils with a gentle pinching for as long as is necessary (about ten minutes).
2. From wounds - If it is necessary to stop the loss of blood attempt the following applications of pressure in the order they are listed:
 - a. With a dressing or bandage compress to the wound
 - b. To pressure points
 - c. By a constricting triangular bandage to an arm or leg, but only in the case of severe, uncontrollable, life threatening hemorrhage.

D. Blisters (12)

If the blister is open apply a clean dressing, but do not open a blister.

E. Burns (1)(12)

1. Thermal burns

- a. Minor burns - Soak the burned area in ice water or apply an ice pack for 15 minutes and apply dry dressing.
- b. Extensive burns - Do not attempt to cleanse the area and do not apply any type of ointment. Call for medical aid immediately. Make the victim as comfortable as possible and treat for shock.

2. Chemical burns - This is tissue damage due to the action of strong acids, strong bases, or strong oxidizing agents. Immediate removal of the contacted substance is essential. This may mean removal of clothing, shower, or both. Skin contacts must be promptly flushed with an excess of water. Act quickly, but not recklessly.

F. Eye injuries (1)(12)

1. Foreign objects - Remove only those objects that can be safely and easily dislodged, otherwise this should be left to an expert.
2. Chemical eye burns - First aid consists of immediate and thorough flushing with water. Do not hesitate to get the person's hair or clothes wet, since these will quickly dry. Wet clothes is a much better fate than permanently impaired vision. The eyelids should be forced open to expose the entire eye to the water. This may be difficult since pain reflexes tend to keep the eye tightly closed. Never use neutralizing solutions or ointments on the eyes. Refer the victim to a physician eventhough no lasting pain is felt, since some compounds cause delayed action injury. (Acid has relatively rapid action, but alkali tends to cause more slowly progressive injury) Other than flushing the eyes with water, leave eye treatment to qualified medical experts.

G. Drowning or stopped breathing (12)

Apply artificial respiration as long as needed and treat for shock. Secure medical aid immediately.

H. Ears (12)

1. Earache - refer to the school nurse or principal
2. Foreign objects - refer to parent for medical attention

I. Seizures (12)

Keep the person lying down and turn him on his side until the seizure is over to prevent self injury. Notify the parents of the incident.

J. Fainting (12)

1. Faint - Place the victim flat with the head lower than the feet.
2. Feeling faint - Have the person stoop over with the head between the knees.

In both instances check for improper room ventilation.

K. Fractures (12)

Treat for shock. Do not move the victim and be sure to keep the injured area immobile. Secure medical aid.

L. Poisons (1)(12)(3)

1. Inhaled poisons

- a. Carry the victim to fresh air, but be cautious not to succumb to the same poisonous gases.
- b. Open all windows and doors and increase the exhaust system to the maximum.
- c. Loosen tight clothing especially about the victim's neck and waist.
- d. Administer artificial respiration if breathing has stopped or is weak.
- e. Prevent chilling and keep the victim quiet.

- f. Do not give the victim alcohol in any form.
- g. Secure medical attention as soon as possible.

2. Absorbed poisons

- a. Wash the contact area with soap and water.
- b. Remove contaminated clothing if necessary.
- c. Refer the person to a physician for an examination.

3. Swallowed poisons

In all cases the aim is to prevent absorption of the poison into the blood stream. Speed is essential. In all cases except those listed below remove the poison by inducing vomiting.

- a. Victim is in a coma or unconscious
- b. Victim is in convulsions
- c. Victim has swallowed petroleum products
- d. Victim has swallowed corrosive chemicals

If the victim is already vomiting and none of the excepted situations apply assist vomiting by giving warm water.

After positive identification of the poison has been made seek advice from a physician or emergency hospital for an antidote while waiting for authorized medical attendants to arrive.

M. Shock (10)(12)

In case of shock the victim feels faint, complains of thirst, and may vomit. The face will be pale and the skin will feel cold. The pulse will be rapid and the breathing will be weak. The victim should be layed flat with the feet raised. Tight clothing should be loosened. Cover the patient to conserve

body heat, but avoid extreme warmth. If the patient is conscious give water as desired, but never alcohol.

Artificial respiration may be needed if breathing has stopped. Secure medical care immediately.

N. Splinters (12)

Remove splinters that are readily accessible and apply antiseptic. If deeply embedded refer to parents for medical care.

O. Sprains (12)

Consider as a fracture until proven otherwise.

P. Toothache (12)

Refer the student to parents for dental care.

PART 7: CHEMICAL HAZARDS IN THE LABORATORY

I. HAZARDS IN CHEMICAL REACTIONS (6)

A. Combustion

Although rarely so considered, fire is a chemical reaction. Normal combustion reactions are fast, but controllable by regulating the a) temperature, b) availability of the oxidizing substance (usually oxygen), and c) availability of the fuel. Most combustion reactions require ignition, or minimal energy input, but a few types of combustion reactions occur spontaneously.

B. Oxidation

Oxidation differs from combustion only in the fact that the decomposition reaction is stopped enroute to the normal combustion products of carbon dioxide and water. Oxidation reactions are all exothermic and equilibrium is almost always in favor of reaction completion. Vigorously strong oxidizing agents such as salts of permanganic acid, hypochlorous acid and its salts, sodium chloride, chlorine dioxide, all chlorates, all peroxides, nitric acid, nitrogen tetroxide, and ozone should be used with extreme caution. Safety in oxidation reactions is usually represented by low concentrations of oxidizing agents, low concentrations of fuel, or low temperature.

C. Neutralization

Aside from the thermal effects resulting from too rapid addition of reactants, these reactions are relatively free from hazard. Exception to this might be taken if the concentrations of the reactants are extremely high.

D. Electrolysis

Reaction hazards are almost non-existent. The usual hazards which accompany this reaction, however, are introduced by the use of large amperages, poison hazards from the use of cyanides, possible explosion hazard from the evolution of combustible gas, or products in high oxidation states.

E. Nitration

All nitration reactions are potentially hazardous, not only because of the frequently explosive nature of the reaction end products, but also because most nitrating agents are also very strong oxidizing agents. This dual nature of nitrating agents makes possible many by- and co-products and some of these reactions are rapid and uncontrollable. Both the nitration and the oxidation reactions are exothermic. Temperature control must be exceptionally good if runaway reactions or explosions are to be avoided. The temperature sensitivity is increased by the presence of impurities, particularly oxides of nitrogen in liquid phase nitrations, for these act as catalysts for further oxidation. Rapid autocatalytic decompositions sometimes occur sub-explosively. These are called "fume-offs" and can be quite violent.

F. Esterification

Both organic and inorganic esterification reactions are generally slow. Catalysts are usually necessary to force the reaction to completion. Hazards are usually small, except when the esterifying material is a powerfully reacting material, esters of nitric or perchloric acid for example, or when one of the reactants is unstable.

G. Reduction

The hazards of the reaction are negligible. The hazards that do exist are almost entirely associated with handling the strong or reactive reducing agents.

H. Amination by ammonolysis

The most common aminating agent is ammonia. The reactions, which are frequently second order, appear to be first order because of the necessity of using a large excess of ammonia. The most common of these reactions are exothermic, but not strongly so.

I. Halogenation

All heats of reaction are highly exothermic. Chain reactions occur in both liquid and gaseous addition and substitution reactions, making detonation possible over a wide range of concentrations. Corrosion effects in halogen systems are extraordinarily difficult to solve.

A. Chlorination - Extremely diverse paths which these reactions run make predictions without experimentation difficult, if not impossible. All reactions are potentially dangerous.

B. Fluorination - Fluorine, being the most reactive chemical element, has reactions which are the most difficult to control. Direct reactions with hydrocarbons are violent and frequently explosive. The new bonds formed between fluorine and other substances are so strong and the heats of reaction so great that extreme precautions are needed to keep the reaction under control.

C. Bromination and iodination - These are similar to the chlorination reactions in nature, but the reaction conditions are far less critical.

J. Sulfonation

Sulfuric acid is the most common sulfonating agent, and the reactions require it to be in strong concentrations. In addition high temperatures are required to give satisfactory driving forces for the reaction. The reactions are somewhat exothermic, but are in most cases relatively easy to control.

K. Hydrolysis

Hydrolysis means decomposition with water, but only a few reactions (mostly inorganic) use water alone and unaided to effect hydrolysis. The inorganic reactions, such as lime slaking, sulfuric and phosphoric acid formation, etc, have problems not common to the organic reactions. While these inorganic reactions have control problems, they are all concerned with heat removal and contacting. Organic hydrolyses are run in both liquid and vapor phases and utilize the following reagents: 1) water alone, 2) acidic solutions, 3) alkaline solutions, 4) alkali fusion, and 5) enzymes. Most such reactions are comparatively slow and only slightly exothermic.

L. Alkylation

Hazards that exist are in the use of powerful corrosives, such as hydrofluoric acid or dimethyl sulfate, as alkylating or catalytic agents, but the reactions themselves are relatively trouble free.

II. FIRE AND EXPLOSION HAZARDS IN THE LABORATORY

A. Classification of fires

Fire classification is most commonly based on the type of fuel involved. Underwriters Laboratories have devised a standard classification for grading the relative hazard of various flammable liquids. (1) This classification is based on the following scale:

Ether class	100
Gasoline class	90-100
Ethyl alcohol class	60-70
Kerosene class	30-40
Paraffin oil class	10-20

Another classification of fires, perhaps the most universally accepted classification is the A-B-C-D classification, which is based on the type of combustible material involved. (6)

Class A Fires (6)

Class A fires are defined as fires in ordinary combustible materials such as wood, cloth, paper, etc., all of which produce glowing embers as the result of the formation of carbonaceous material such as charcoal. Usually overlooked is the fact that charcoal is a class A material which requires special consideration, because under certain circumstances class A approved fire extinguishing equipment is ineffective on charcoal fires. Also meriting special consideration are rubber, rubber-like materials, and certain plastics, which burn as class B material in the early stages of combustion, but as their decomposition proceeds they tend to burn as definitely class A material.

Class B Fires (6)

Class B fires are normally defined as fires in flammable petroleum products, or other flammable liquids, greases, etc. However, there are certain solids, of which naphthalene is an excellent example, which melt while burning and exhibit the characteristics of a flammable liquid. In addition, they have no embers as the class A solids have. At the present time (1965) flammable gases do not fall into any category, but practically they should be treated as class B materials, since in the case of flammable liquids the combustion occurs in the vapor region above the liquid rather than in the liquid itself. For many years it has been common practice to recommend against extinguishing fires in escaping gas, because it was felt that if the flames were extinguished the gas would continue to flow to form a dangerously explosive mixture with oxygen that might, upon ignition, cause greater damage than the original fire in which the addition of fuel was at a moderated rate. Practical experience, however, has shown that in some cases it is necessary to extinguish the flames in order to stop the escape of the gas.

Class C Fires (6)

Class C fires are defined as fires involving energized electrical equipment where the nonconductivity of the extinguishing media is essential. Where the electrical equipment has been de-energized extinguishing equipment suitable for class A fires may be used, unless flammable liquids such as transil oil are involved. In the latter case extinguishers suitable for class B fires should be employed.

Class D Fires (6)

Class D fires are defined as fires in combustible metals. Low melting point metals, such as sodium or potassium, present problems in extinguishment because the fire soon involves only liquid metal which, being of low specific gravity, allows most of the extinguishing agent to sink to the bottom while liquid metal is constantly re-exposed to the air. These metals also pose the problem that they spontaneously and very violently react with water.

High melting metals are found in a variety of forms. (chips, powders, turnings, sheets, ingots, castings, and extrusions) An extinguishing agent that might be entirely suitable for fires in castings might be hazardous to use on powders, chips, or turnings.

A very common combustible metal, magnesium, is unusual in that it falls between the extreme low melting point metals and the high melting point metals, so that as often encountered it is in one of the forms listed above, but it melts upon burning to form liquid magnesium.

Although the fumes of burning metals should never be inhaled, the fumes of burning radioactive metals present a very serious health problem to fire fighters. When metal hydrides are burning they should be considered more combustible than normal class D fires since both metal and hydrogen are burning. It is desirable to utilize a dry powder extinguishing agent when combating metal fires.

B. Fire extinguishing agents

1. Water-based agents

a. Water (pumped) (1)(7)

Water, which is suggested mainly for class A fires, extinguishes by:

- 1) Cooling the material below the temperature at which it will give off sufficient flammable vapors to support combustion.
- 2) Smothering by displacing the air which supplies oxygen.
- 3) Emulsification with an immiscible flammable liquid making the liquid surface temporarily noncombustible.
- 4) Dilution of flammable water soluble liquids.

The use of water as a fire extinguishing agent is subject to the following limitations:

- 1) Surface tension - limits the ability of water to spread or penetrate. Wetting agents are available which lower the surface tension of water, so this limitation can be somewhat overcome.
- 2) Reactivity - with carbides, peroxides, metallic sodium, magnesium dust, etc which result in the release of flammable gases and the evolution of heat.
- 3) Conductivity - of water to electricity makes its use on class C fires extremely dangerous.
- 4) Viscosity - of water is so low that it has a great tendency to quickly run off a burning mass.
- 5) Opacity and reflectivity - of water dictate that water has little ability to prevent the passage of radiant heat.

6) Low flash point flammables - are not effectively extinguished by water since as water reaches the surface of burning low flash point liquids it will not burn. In fact, it will probably sink due to its greater specific gravity. If the burning liquid is in an open container the continued addition of water may cause the container to overflow, spreading the fire.

b. Water canisters (6)

Water cartridge operated extinguishers are pressurized by inverting and bumping on a firm surface in order to puncture the seal of a compressed carbon dioxide cartridge which supplies the expelling force. The extinguishing properties and limitations of these extinguishers are the same as for pumped water, except for the additional limitation that they must be protected from freezing.

c. Soda and acid canisters (6)

All soda and acid extinguishers are put into operation by inverting to allow the acid solution to mix and react with the sodium bicarbonate solution to yield carbon dioxide gas which serves as the expellent. Never apply this agent to a person whose clothing is afire, since the unreacted chemicals are quite corrosive. These extinguishers should be recharged annually since sodium bicarbonate slowly decomposes to form sodium carbonate. Being water-based, soda and acid canisters must be protected from freezing.

d. Antifreeze Canisters (6)

1) Calcium chloride

Calcium chloride antifreeze solution cartridge operated extinguishers are pressurized by puncturing a carbon dioxide cartridge as was described for water canisters. Since calcium chloride solutions are corrosive, the container must be constructed of corrosion resistant materials. (Stainless steel is not suitable.) These fire extinguishers are functional down to temperatures of forty fahrenheit degrees below zero.

2) Lithium chloride (6)

Developed by the Department of Defense, this antifreeze solution extinguisher has similar properties to calcium chloride solutions, except that it is functional down to temperatures of sixty five fahrenheit degrees below zero.

3) Ethylene glycol (6)

Some owners of water-based canister extinguishers choose to use this common automotive antifreeze rather than the more corrosive antifreeze solutions. This is not recommended. If complete control of the fire is not achieved prior to exhaustion of the extinguisher the water will be evaporated and the fire will rekindle to become more intense than before, because ethylene glycol is a flammable liquid.

e. Loaded stream (6)

The chemical solutions listed so far have not increased the fire extinguishing effectiveness of water, but rather have been added to protect from freezing or to provide the expellent force. If chemicals are added which increase the fire extinguishing efficiency of water the solution is

called a loaded stream, the most common of these being potassium carbonate. Being of a corrosive nature, potassium carbonate solution extinguishers must be constructed of corrosion resistant materials.

f. Wetting agents (6)

Wetting agents are compounds which decrease the surface tension of water, thereby increasing its penetrating and spreading ability. Water alone is recommended only for class A fires, but water treated with a wetting agent, commonly called "wet water", is also suitable for extinguishing class B fires.

g. Foam (6)

1) Chemical foam bubbles are formed by carbon dioxide gas which results from a chemical reaction, commonly sodium bicarbonate plus aluminum sulphate.

2) Mechanical foam bubbles are formed by forced mixture of air with a dilute solution of a liquid foaming agent in water.

2. Carbon Dioxide Extinguishers (1)(6)(7)

Carbon dioxide extinguishes by:

- a. Diluting the oxygen concentration to the point where it can no longer support combustion.
- b. Cooling the material below the temperature needed to support combustion. It does this by the action of a rapid expansion of liquid to gaseous carbon dioxide, producing a refrigerating effect that converts part of the gas to a solid carbon dioxide snow. This snow quickly sublimates back to

a gas, absorbing much heat from the burning material and surrounding air.

The effectiveness of carbon dioxide as an extinguishing agent is subject to the following limitations:

a. Hot surfaces and embers

Class A fires that have been apparently extinguished by carbon dioxide may re-ignite as soon as the oxygen atmosphere has been renewed if hot surfaces or embers remain. Long periods of continual application of carbon dioxide may be required to maintain a smothering atmosphere until the material has cooled below the ignition point. Since portable carbon dioxide extinguishers have a limited volume, they are effective mainly on small concentrated fires.

b. Oxygen containing combustibles

Carbon dioxide extinguishers are not effective in combating fires in materials which are able to produce their own oxygen supply.

c. Reactive chemicals

Carbon dioxide is ineffective in combating class D fires. Burning sodium, potassium, magnesium, titanium, and metal hydrides react to decompose carbon dioxide.

3. Dry chemical extinguishing agents (1)(6)(7)

a. Bicarbonate-based dry chemical

Bicarbonate-based dry chemical extinguishing agents are recommended for extinguishing class B and class C fires.

1) Sodium bicarbonate-based dry chemical extinguishing

agents contain finely divided sodium bicarbonate powder treated with magnesium stearate to produce water repellency and free flowing properties. Due to ineffective action of these agents on preventing reflash of embers they are not recommended for combating class A fires.

2) Potassium bicarbonate-based dry chemical agents are very similar to the sodium bicarbonate-based agents, except that they have been found to be twice as effective against class B gasoline fires.

b. Multipurpose dry chemical

These are ammonium phosphate-based agents suitable for extinguishing class A, B, or C fires. These agents are found to be twice as effective as water against class A fires and slightly more effective than sodium bicarbonate-based dry chemical against class B fires. Other advantages of multipurpose dry chemical agents include:

- 1) For equivalent protection it weighs less.
- 2) There's little chance of using the wrong type of agent.
- 3) It is functional down to temperatures as low as sixty five fahrenheit degrees below zero.
- 4) Extensive water or corrosion damage to property is avoided.

4. Vaporizing liquids (6)

The most common vaporizing liquid extinguishing agent is carbon tetrachloride. When applied to a fire as a liquid it readily vaporizes to form a heavy gas that assists in the extinguishing action by smothering the flames (denying

oxygen accessibility). This agent is only approved for class B and C fires. Toxic fumes are liberated as a result of decomposition of the halogenated compound. For this reason carbon tetrachloride extinguishing agents are prohibited in some states.

C. Flammability

In the discussion of fire and explosion hazards several terms are used that might require definition.

Flash Point (1)(10)

The flash point of a flammable liquid is the temperature at which it gives off sufficient vapor to form a combustible mixture with air at the liquid surface or within a vessel.

Ignition Temperature (1)(3)(10)

The ignition temperature of a substance is the minimum temperature at which self-sustained combustion may be initiated independantly of the heating element.

Explosion Limits (10)

If the concentration of a flammable vapor in the air is within certain limits the flame propagated by ignition is propagated throughout the entire volume of the air and vapor mixture. Combustion proceeds with such speed and violence that it causes an explosion. These limits are a relatively narrow band of low concentrations. For this reason an empty flask or drum which has contained a flammable liquid is more dangerous than if full, the emptied container being more apt to be filled with a air and flammable vapor mixture that lies with explosive

limits.

Spontaneous combustion (10)

Most oxidation reactions can proceed below the ignition temperature with a definite, though small, velocity. As long as the heat of reaction is dispersed so that it does not produce a rise in temperature the reaction will proceed slowly with no serious consequences. If, however, the heat is allowed to accumulate, (where there is sufficient air for the reaction, but not enough ventilation to carry the heat away as soon as it is generated), the temperature rises steadily. This causes the reaction to proceed faster, more heat is developed, and finally a fire is started when the ignition temperature is reached.

Detection of flammable vapor (6)

The "hot-wire meter" is a device that can be used for testing the air for the presence of flammable vapor. It involves a galvanometer, a reference coil, a test coil, and a battery. As the air sample passes over the heated test coil combustibles burn on the incandescent wire and raise its temperature, thereby lowering its resistance to electric current. The resulting imbalance of resistance between the test and reference coils will register as a deflection on the galvanometer. Other principles which have been successfully employed to detect combustible gas include: thermal conductivity, diffusion rate, specific gravity, and infra red spectroscopy.

D. Chemicals which pose fire or explosion hazards

1. Acids

a. Per-acids (13) can be thought of as acids that contain more than the usual number of oxygen atoms.

1) Perchloric acid (1)(10)(13) may react explosively with reducing agents and inorganic compounds, or may even explode spontaneously in the anhydrous form. Clothing, paper, wood, etc, if soaked in perchloric acid and dried, may ignite by impact, friction, or heat. The more dangerous anhydrous form of the acid is produced from the salts or from aqueous solutions by heating with high boiling acids. The explosions are extremely violent and destructive. Solutions of aqueous perchloric acid at concentrations below sixty to seventy percent are stable and can be stored safely, but at concentrations above eighty five percent the acid is apt to explode spontaneously. Discolored perchloric acid solutions should be diluted with water immediately. Magnesium perchlorate, which is a common drying agent, will form explosive anhydrous perchloric acid upon contact with any strong acid. Esters of perchloric acid are also violently explosive, therefore alcohol solutions of perchloric acid should never be evaporated. Perchloric acid fires are best controlled with large quantities of water directed in a solid stream.

2) Peracetic acid (1) is formed by the air-oxidation of acetaldehyde and, under proper conditions, it is contin-

uously decomposed to form acetic acid. However, if acetic acid is to be distilled an organic inhibitor, such as hydroquinone, should be added to prevent the formation of an intolerable excess of explosive peracetic acid.

- b. Nitric acid (10)(13)(14), when mixed with an organic compound, is easily detonated. Nitric acid and ethanol are both commonly used to clean glassware, but one should be aware that these two compounds are so violently reactive with each other that they are used as rocket fuel. Most commercially prepared explosives are made with nitric acid or closely related nitrogen compounds. Strong nitric acid not only may generate sufficient heat to cause ignition, but will also nitrate clothing, paper, wood, etc. to the point that these materials may become explosive.

2. Alcohols (13)

Alcohols are usually volatile and flammable. They should not be mixed with silver nitrate or mercury nitrate as explosive fulminates may be formed, or with strong oxidizing acids, (perchloric or permanganic acid), or concentrated hydrogen peroxide, as these mixtures may result in spontaneous explosions. Alcohol-water solutions containing as little as twenty percent alcohol are still flammable.

3. Aldehydes (13)

Aldehydes are usually volatile and flammable. They also possess a wide range of chemical activity, since they can be oxidized into acids or reduced into alcohols.

4. Alkali metals (1)(10)(13)(15)

The alkali metals include lithium, sodium, potassium, rubidium, and cesium. These metals react vigorously with water to form hydroxides, and must often be stored under hydrocarbons to avoid air-oxidation. Representing class D fires, never attempt to extinguish an alkali metal fire with water, foam, soda and acid, carbon dioxide, or carbon tetrachloride. An effective extinguishing agent for these fires is dry soda ash, partly because of the water absorbing properties.

5. Alkalies (13)

The alkalies are most commonly represented by sodium hydroxide (caustic soda or lye) and potassium hydroxide (potash). These compounds are not combustible, but do generate a considerable amount of heat when mixed with water.

6. Ammoniacal silver nitrate (10)(16)

Ammoniacal silver nitrate, or Tollen's reagent, is a commonly used silvering agent. When kept for more than a few hours the ammonia and the silver ions give rise to extremely sensitive and unstable compounds, which may explode violently. As a precaution these solutions should be prepared only in small quantities and immediately after using they should be decomposed with dilute hydrochloric acid and discarded. If a solution has inadvertently kept for more than a day and traces of crystals are present it should be removed from the laboratory with remote handling devices and personal shielding to be detonated in a safe area outside the building.

7. Ammonium compounds (13)

Many ammonium compounds are explosive, such as:

ammonium bromate, ammonium chlorate, ammonium chromate, ammonium dichromate, ammonium nitrate, ammonium nitrite, ammonium perchlorate, ammonium permanganate, ammonium persulphate, ammonium picrate, and ammonium sulfonitrate.

These compounds are susceptible to detonation by various degrees of shock and heat.

8. Anhydrides (13)

Acid anhydrides are organic acids with the water removed. There is normally a greater fire hazard with the acid anhydride than with the corresponding organic acid.

9. Antimony compounds (1)(13)

When highly heated antimony burns with a brilliant light to form antimony trioxide. It spontaneously ignites in the presence of chlorine. The flammability of antimony sulphide is demonstrated by its use on match heads, and antimony sulphate is used as a pyrotechnic explosive.

10. Chlorates (1)(13)

Chlorates tend to liberate oxygen explosively under the influence of friction, shock, concussion, or heat. When in contact with strong acids chlorates evolve poisonous chlorine peroxide or chlorine dioxide gas. Sodium chlorate can cause a fire or explosion when in contact with any of the following: sulfur, sulphides, phosphorous, sugars, alcohols, ammonium compounds, powdered metals, oils and greases, sawdust, lint, or vegetable dusts. If clothing has become contaminated with

a chlorate keep away from flames and guard against ignition by friction or percussion, and change clothing as soon as possible.

11. Chlorine dioxide (1)

Being a common bleaching agent, chlorine dioxide is also a strong oxidizing agent capable of forming explosive mixtures with air. Such explosive mixtures are readily detonated by exposure to heat, electrostatic discharges, or even direct sunlight. It also reacts with organic matter, sometimes violently.

12. Chromates (1)

Ammonium, sodium, and potassium chromates are relatively stable in and of themselves, but are violently reactive as aqueous acid solutions or when brought in contact with organic compounds. Chromic acid (chromium trioxide) may also be hazardous under certain conditions.

13. Cresols (13)

Cresols are poisonous combustible disinfectants and preservatives. Water spray or class B approved extinguishers are suitable for combating cresol fires.

14. Esters (13)

Esters are almost all flammable with varying degrees of flammability among the class. Carbon dioxide, dry chemicals, vaporizing liquid, water spray, or foam are all suitable for combating ester fires.

15. Ethers (13)

Ethers are both volatile and flammable. Heavy ether

vapors can travel along the floor or table top great distances to reach an ignition source. Ethers ignite spontaneously when in contact with per-acids. On contact with air some ethers form explosive peroxides. These ether-peroxides will be discussed with the peroxides. Dry chemical or carbon dioxide agents are suitable for extinguishing ether fires.

16. Fulminates (1)(13)

The explosive nature of fulminates is illustrated by their use in blasting cap detonators. Silver fulminate is formed of a mixture of silver nitrate, nitric acid, and alcohol. Mercury fulminate is formed of mercury oxide and ammonia. Fulminates are easily detonated by heat or shock.

17. Nitrates (1)(13)

Nitrates are both flammable and explosive, as is illustrated by their use in commercial explosives. Ventilation during fire fighting is essential due to toxic fumes which are given off during the burning of nitrates. The most suitable extinguishing agent is the cooling effect of water.

18. Oxalates (13)

Only one oxalate, silver oxalate, is considered dangerous. It will detonate and explode upon heating.

19. Peroxides and peroxidizable compounds

- a. Barium peroxide (1) is not explosive like the nonmetallic peroxides, but can easily be a source of fire if moistened or heated when in contact with combustible material.
- b. Hydrogen peroxide (1) is not explosive in the ordinary three percent pharmaceutical dilution which is further

stabilized with acetanilide. Hydrogen peroxide is rapidly decomposed by contact with copper or finely divided metal, and in its concentrated solutions is an explosion hazard due to violent decomposition.

c. Ether peroxides (1)(10)(15)

Peroxides are known to form in many kinds of ether by auto-oxidation with oxygen or ozone. Distillation of ethers that contain peroxide impurities will concentrate the higher boiling peroxides into a violently explosive residue. For this reason it is a wise precaution never to evaporate ethers beyond one tenth their volume.

d. Peroxidizable compounds (17)

Peroxides are known to form in all of the following compounds, and each one of them have been responsible for a fatal laboratory accident.

List A

These compounds become peroxide hazards upon storage, and have a three month safe shelf life.

isopropyl ether, divinyl acetylene, vinylidene chloride, potassium metal, and sodium amide

List B

These are peroxide hazard on concentration, and have a safe shelf life of twelve months.

dimethyl ether, tetrahydrofuran, dioxane, acetal, ethylene glycol dimethyl ether (glyme), vinyl ethers, dicyclopentadiene, diacetylene, methyl acetylene, decahydronaphthalene (decalin), tetrahydronaphthalene

(tetralin), cyclohexene, and diethylene glycol dimethyl ether (diglyme)

List C

These compounds are peroxide hazards due to the initiation of polymerization, and have a twelve month self life.

methyl methacrylate, styrene, acrylic acid, acrylonitrile, butadiene, vinylidene chloride, tetrafluoroethylene, chlorotrifluoroethylene, vinyl acetylene, vinyl acetate, vinyl chloride, vinyl pyridine, and chloroprene.

e. Testing for peroxide impurities

Compounds in the three preceeding lists should be considered dangerously contaminated with explosive peroxides until tested safe. Compounds in list A should be listed for testing every three months and those compounds in lists B and C should be examined every twelve months. After each testing the container should be labeled with the test date. A quick test for peroxides before each use may be a wise precaution, especially if the compound is not used regularly. Herewith are six simple qualitative tests for the presence of peroxides:

1) Iodide test (10)(17) This test is based on the oxidation of iodide to iodine by peroxides. Mix 1 ml of the test material, 1 ml glacial acetic acid, and 100 mg potassium iodide crystals and observe color. Another method is to dip potassium iodide treated starch paper into the test material. Yellow color indicates no oxidation, but brown color means peroxides are present.

2) Ferrous thiocyanate test (17) This is a very sensitive test based on the fact that colorless ferrothiocyanate is converted to red ferrithiocyanate by peroxides.

The reagent: Dissolve 9 grams ferrothiocyanate in 50 ml of 18% hydrochloric acid. Add a little granulated zinc followed by 5 grams sodium thiocyanate. When colorless add 12 grams more sodium thiocyanate and decant from the unused zinc.

The test: Add one drop of the reagent to one drop test material. The following color relations indicate peroxide:

Barely discernible pink	.001% peroxide	
Pink to cherry	.002% peroxide	
Red	.008% peroxide	HAZARD
Deep red	.04 % peroxide	

3) Benzidine Test (10) This is a good test for ether peroxides. Add 5 ml of a cold saturated solution of benzidine in water to 5 ml of a saturated solution of sodium chloride. To this add 5 drops of a dilute ferrous sulphate solution. Ether which contains peroxides will color this reagent blue in a few minutes. When peroxide content is high the blue color appears immediately.

4) Ferrous-Rhodanide Test (10) The reagent is prepared as follows: Boil 30 ml of 10% sulfuric acid while a stream of carbon dioxide is bubbled through. Dissolve 5 grams of crystallized ferrous sulphate in the boiling liquid. After cooling in the stream of carbon dioxide, add 30 ml of 10% potassium thiocyanate and reduce the solution with .03 N

titanous chloride at forty centigrade degrees until the solution is colorless.

The test: Shake 30 ml of the test material and 5 ml of the reagent together in a 35 ml stoppered flask. The presence and intensity of red color is an indication of the presence and concentration of peroxides.

5) Phenolphthalein Test (10) The reagent is prepared as follows: Dissolve 10 grams sodium hydroxide in 20 ml water and boil with 1 gram phenolphthalein and 5 grams zinc dust until the solution is colorless. Filter out the zinc dust and dilute the solution with water to a final volume of 50 ml. (The reagent must be stored in total darkness.)

The test: Shake together a sample of the test material, 4 drops of the reagent, 3 ml water, and 5 drops of .05% copper sulphate solution. Alternatively 2 ml water and 1 ml test material should be added down the side of a test tube. If a pink color develops this indicates that peroxides are present.

6) Titrimetric Method (10) This method is based on the liberation of iodine from potassium iodide, followed by titration with thiosulphate solution. Add 10 ml of the test material to 150 ml sulfuric acid in a conical flask, a few drops of a 1% ammonium molybdate solution as a catalyst, followed by 1.5 ml of a 10% potassium iodide solution. After 15 minutes titrate the iodine with .05 N sodium thiosulphate to ascertain the exact concentration of peroxide present.

f. Storage of peroxidizable compounds (10)(17)

Store peroxidizable compounds away from heat and light. Protect the containers from physical damage and ignition sources. Small metal cans and air tight lids are recommended. Light is a strong promoter of peroxidization, especially the ultra violet wavelengths.

g. Removal of peroxide impurities (17)

Method 1: Pass the contaminated liquid through a column of ordinary activated alumina. Flush the alumina with dilute acid and dispose in an approved land fill.

Method 2: Peroxide impurities in water insoluble liquids (ethers, hydrocarbons, etc) are easily removed by shaking with a concentrated solution of a ferrous salt. This solution can be prepared by mixing 60 grams ferrous sulphate, 6 ml dilute sulfuric acid, and 110 ml water. In some ethers an aldehyde impurity is formed by this method, but can be removed by washing with .5% potassium permanganate, 5% sodium hydroxide, and finally with water.

20. Phosphorous (13)

- a. White phosphorous ignites spontaneously in air, and should for this reason be stored under water. White phosphorous fires are best extinguished with water.
- b. Red phosphorous is flammable and ignites by friction or heat, but not spontaneously as does white phosphorous.

21. Dangerous mixtures (10)

The following mixtures of chemicals common to the science laboratory present the hazard of explosion:

- a. perchloric acid and alcohol
- b. sodium or potassium with water
aluminum powder with ammonium persulphate and water
- c. a chlorate with antimony sulphide
- d. chromium trioxide (chromic acid) or potassium permanganate
with sulfuric acid, sulfur, glycerol, or organic material
- e. organic material with aluminum alloys in nitrate salt baths
- f. ammonium nitrate with zinc powder and as little as one drop
of water
- g. barium rhodanide with sodium nitrate
- h. potassium nitrate with sodium acetate
- i. nitric acid with thiopene, or with hydrogen iodide
- j. a nitrate with an ester
- k. peroxides with magnesium, zinc, or aluminum
- l. chlorates and perchlorates with sulfuric acid
- m. a nitrite with potassium cyanide
- n. nitric acid with zinc, magnesium, or other metals
- o. potassium ferricyanide, mercuric cyanide or halogens with
ammonia
- p. phosphorous with nitric acid, nitrates, or chlorates
- q. mercuric oxide with sulfur
- r. magnesium or aluminum with chlorates or nitrates
- s. nitrates with stannous chloride
- t. magnesium with phosphate, sulphate, carbonate, etc
- u. oxalates and heavy metals
- v. liquid oxygen with organic material

22. Explosive atom types (10)

In a very broad generality the following atom pairings in chemical compounds represent a high frequency of encountered explosion hazards:

- O - O (ozone, peroxides)
- O - Cl (chlorates, perchlorates)
- N - Cl (chlorides of nitrogen)
- N = O (nitrates, especially organic nitrates)
- N = N (diazo compounds, azides)
- C $\equiv$ C (acetylene)

23. Precautions with explosion hazards (10)

When working with explosion hazards it is advisable to follow the principles below:

- a. Use only small quantities (never more than 100 mg).
- b. Apply heat with a steam or water bath, never open flames.
- c. Use a full shield, especially when a glass apparatus is involved, in case of an explosion.
- d. If it is practicable substitute a less hazardous compound.

III. TOXIC CHEMICAL HAZARDS

Toxicity (1) hazards are caused by chemicals or their fumes coming in contact with the body, being ingested, or being inhaled. Toxicity involves injuries sustained in the laboratory other than those caused by physical or mechanical force, external radiation, or heat. It develops in two manners: (1) Acute toxicity is that which is manifest on short periods of exposure, commonly of eight hours or less. Chronic toxicity is that which is manifest when the toxicants act on the body over a long period of time, usually involving daily or regular exposures for weeks, months, or years.

The following list represents some of the toxic hazards common to the high school science laboratory:

1. Acetic acid (1)(15)

Acetic acid in laboratory concentrations is considerably more corrosive to the skin than is generally believed. Concentrated acetic acid vapor is very irritating to the eyes, nose, and throat. Glacial acetic acid freezes at sixty fahrenheit degrees and expands upon solidification. This presents a container breakage hazard at slightly below room temperature if the container is of a nonexpandable or inflexible nature. Acetic acid corrosion hazards are proportional to its temperature and concentration.

2. Ammonia (15)

Ammonia is a strong respiratory irritant which has been known to cause sudden death due to bronchial spasm when in large concentrations, but it is relatively safe when in its more dilute concentrations. Ammonia is particularly hazardous

if splashed in the eyes. Ammonia should be washed off the skin or out of the eyes immediately.

3. Aniline (1)(15)

Aniline causes no appreciable local irritating action. However, dangerous systemic poisoning may result from inhalation or absorption through the skin. An absorption of only a few milliliters is sufficient to produce serious poisoning due to the conversion of the blood hemoglobin to a darker colored derivative which does not function as an oxygen carrier. Symptoms of aniline poisoning are bluish coloration of the skin, lips, and whites of the eyes. The victim may act sluggish or feel faint. Utilization of the exhaust hood when working with aniline and immediate washing of accidental contacts is essential.

4. Benzol (6)

Benzol is a useful solvent and was formerly a common constituent of metal polishes, plastic woods, and rubber cements. High concentrations of benzol vapors are anesthetic, but a single heavy exposure, even if the result is loss of consciousness, will seldom cause lasting harm. Benzol is a good example of a chronic toxicant, since the real danger of benzol lies in the damage to bone marrow which follows frequent and prolonged exposure to and inhalation of low concentrations of the vapor. The chronic disease caused by benzol is similar to leukemia and, like leukemia, is seldom curable.

5. Calcium chloride (1)

Anhydrous calcium chloride is a strongly hygroscopic salt which is capable of causing local irritation to the skin and eyes.

6. Calcium hydroxide (1)

Calcium hydroxide, or lime, is irritating on prolonged contact with the skin and especially the eyes.

7. Carbon monoxide (15)

Carbon monoxide is a chemical asphyxiant. Hemoglobin's affinity for carbon monoxide is roughly three hundred times its affinity for oxygen, so preferential respiratory absorption always takes place when carbon monoxide is present.

8. Carbon tetrachloride (6)

Carbon tetrachloride is a very useful solvent, especially for removing grease from fine electrical equipment. It also has uses as a fire extinguishing agent. Carbon tetrachloride vapor, however, is very toxic and much illness and many deaths have resulted from its careless use.

9. Chlorosulfonic acid (1)(15)

Chlorosulfonic acid violently decomposes in water to form sulfuric acid and hydrochloric acid. The toxic hazards of chlorosulfonic acid are a combination of the hazards of sulfuric acid and hydrochloric acid.

10. Chromic acid (1)(15)

True chromic acid does not exist. The compound which is commonly termed chromic acid is actually chromium trioxide in a concentrated solution of sulfuric acid. It should be considered slightly more corrosive to the skin than the sulfuric acid alone due to its strong oxidizing properties. Since it ignites ethanol and other organic solvents it should never be poured down drains.

11. Cyanides (15)

Hydrocyanic acid is a highly toxic colorless gas with the odor of bitter almonds. It blocks the cellular respiration by poisoning the oxidation catalysis processes. It is not, though irritating or corrosive to tissue.

12. Dimethyl sulphate (15)

Dimethyl sulphate is an odorless powerful lung irritant, as well as a lachrymator and vesicant. It is also absorbed through the skin and affects the mucous membranes.

13. Formaldehyde (15)

Formaldehyde is poisonous, therefor it is recommended that it be avoided as a biological preservative by substituting a less toxic substance.

14. Formic acid (1)

Formic acid is corrosive to the skin. Its hazards are roughly proportional to its temperature and concentration.

15. Halogens (1)(15)

Chlorine is a dangerous and strong lung irritant. Bromine fumes are highly irritating to the eyes, throat, and lungs. Liquid bromine causes tissue burns, therefor any accidental contacts should be immediately washed off with water. The utilization of the exhaust hood is essential when working with chlorine and bromine.

16. Hydrochloric acid (1)(10)(15)

Hydrochloric acid vapor is a primary irritant with destructive action on mucous membranes. Skin contact with the acid may cause tissue damage. Utilization of an exhaust hood and immediate wash-

ing of accidental contacts is essential. Hydrochloric acid toxicity is proportional to its temperature and concentration.

17. Hydrofluoric acid (1)(10)(15)

Hydrofluoric acid is a colorless highly corrosive liquid or gas capable of causing severe deep tissue burns. Its action on the eyes is so rapid and severe that total blindness may ensue if immediate flushing with water does not occur. If not cleaned from under the fingernails hydrofluoric acid has been noted to cause painful and prolonged inflammation. The corrosive fumes of hydrofluoric acid dictate that it be used under the protection of an exhaust hood.

18. Hydrogen sulfide (6)(15)

Hydrogen sulfide is easily recognized by its distinctive odor which is produced in the deterioration process of rotting eggs. An essential consideration is that the unpleasant odor of hydrogen sulfide is only perceptible in its dilute and harmless concentrations. When dangerously high concentrations of this gas develop it causes paralysis of the olfactory centers of the brain, making the presence of this toxic gas unnoticeable. The result can often be fatal due to respiratory paralysis. One should immediately take warning and evacuate the area if working with hydrogen sulfide and the unpleasant odor seems to mysteriously disappear.

19. Lead (10)

Lead and most lead compounds are very toxic, and the absorption commonly takes place by:

a. Inhalation of vapors (often accompanying soldering, grinding,

or painting with paints that contain lead)

b. Ingestion (contaminated food or lead paints)

c. Skin absorption (such as by frequent contact with gasoline which contains tetraethyl lead additives)

20. Mercury (1)(2)(10)(15)

a. Toxic hazards

Mercury can be absorbed through the respiratory tract, the digestive tract, or the skin. Acute mercury poisoning results in damage to the kidneys, whereas chronic mercury poisoning damages the central nervous system. Inhalation of mercury vapors has a cumulative poisoning effect. Mercury poisoning is a very difficult affliction to overcome. Beginning at one hundred fahrenheit degrees sufficient mercury vapor is evolved to exceed safe limits in the surrounding air. The maximum allowable safe concentration of mercury vapor in the air is .1 mg per cubic meter.

b. Mercury storage

Mercury should be stored in tightly sealed polyethylene bottles to avoid much of the breakage-spillage hazard. If it is stored under a thin layer of water or light oil the chance of vapor escaping into the atmosphere is greatly reduced.

c. Controlling spilled mercury

Equipment or apparatus involving mercury should be assembled over a tray in the exhaust hood which will catch any spills that may occur. In the event of spillage if the temperature of the mercury is at one hundred fahrenheit degrees or more the room should be evacuated immediately until the mercury has cooled

to room temperature and the room air has been recycled. Never sweep or scoop mercury for this will merely spread and divide the droplets to a greater degree.

The proper method for collecting large mercury spills (any spill over a few drops) is by the use of a suction bottle. This is a relatively simple apparatus made from a glass tube six millimeters in diameter drawn out to a diameter of one millimeter at the distal end and connected by a rubber hose to a filter flask trap which is under the partial vacuum of an aspirator or suction pump. Ordinary vacuum sweepers should not be used for collecting spilled mercury since the mercury droplets will divide small enough to pass through the cloth trap and will be dispersed throughout the room as a dangerously concentrated mercury vapor. Another acceptable device for collecting spilled mercury is called the "mercury magnet". This is a spiral of copper wire treated with nitric acid and then amalgomated. This device will only pick up small amounts of mercury and is therefore not as useful as the suction bottle.

Since it is impractical to think that a mechanical device will be able to collect the minute amounts of mercury that can lodge in cracks and crevices it is advisable to cover the area of the spill with a chemical reagent that will tie up the mercury in a harmless state. Some of the most commonly suggested reagents are:

- 1) a little sodium hydroxide and sulfur in a gallon of water.

- (2)(15)

- 2) powdered zinc or sulfur (1)

3) flowers of sulfur or calcium polysulfide (10)

21. Nitric acid (1)(10)(15)

Concentrated nitric acid causes tissue damage accompanied by a yellow stain which develops due to a reaction between the acid and albumens in the tissue. Nitric acid vapor is a serious respiratory poison. Mixtures of nitric acid and sulfuric acid evolve extremely toxic fumes. Bottles of nitric acid should never be filled completely, exposed to heat, or stored in direct sunlight. Severe and permanent eye damage results if nitric acid splashes into the eyes and is not washed out immediately.

22. Nitrogen oxides (6)(15)

Nitrogen oxides are liberated whenever organic material is heated with nitric acid. Sometimes these are obvious brown fumes, but not always. The concentration of the brown fumes does not necessarily correlate to the toxic hazard upon inhalation. Nitrogen oxide vapors are extremely dangerous because of their delayed action. It is possible for a fatal quantity to be inhaled with no immediate noticeable effect. Pulmonary edema often results from prolonged inhalation.

23. Phenol (Carbolic acid) (1)

Phenol produces tissue damage to skin and eyes on contact. It poses no inhalation hazards at room temperature. It does, however, present a severe systemic poisoning hazard by absorption through the skin. Skin surface areas no larger than the palm of the hand are capable of absorbing fatal quantities in as little as fifteen minutes. Prompt removal of accidental

contacts is essential. An exhaust hood should be employed if phenol is to be heated.

24. Phosphoric acid (1)(15)

Dilute solutions of phosphoric acid are quite harmless and are often incorporated into soft drinks. Concentrations greater than fifty percent, however, cause serious tissue burns. As with most other acids, the hazard is proportional to the temperature and concentration of the solution.

25. Phosphorous halides (15)

Phosphorous halides are very irritating to the respiratory tract. Formation of strong acids on contact with water may result in tissue damage on contact.

26. Potassium hydroxide (1)(15)

Potassium hydroxide, commonly called potash, causes tissue damage on contact and evolves much heat upon rapid mixture with water.

27. Sodium hydroxide (1)(15)

Sodium hydroxide, commonly called caustic soda or lye, causes tissue damage on contact and evolves much heat upon rapid mixture with water.

28. Sulfuric acid (1)(10)(15)

Sulfuric acid chars and destroys plant or animal tissue due to its avidity for water, which it removes from organic matter. Fumes of sulfuric acid can cause respiratory irritation, loss of consciousness, and lung damage. Whenever diluting sulfuric acid with water the acid should be slowly added to the water, never the reverse. (This applies to all strong acids.)

IV. RADIOACTIVITY AND IONIZING RADIATION (18)(19)

In recent years radioisotopes have shown great educational application as biological tracers of molecular pathways, as well as in their traditional role in physical and chemical theory. Units of radioactivity in laboratory samples are measures in microcuries (μCi), a curie being equal to the decay rate of one gram of radium.

1 curie (Ci) = 3.7×10^{10} disintegrations per second

1 millicurie (mCi) = 3.7×10^7 disintegrations per second

1 microcurie (μCi) = 3.7×10^4 disintegrations per second

Microcurie quantities of radioactive material produce enough radiation to provide suitable counting rates, yet pose minimal radiation hazards. Radioactive materials in small specified quantities are approved for civilian possession, but a license with the Atomic Energy Commission is required. Copies of the Atomic Energy Commission's "Guide for Drafting Radiation Safety Instructions for Laboratory Use of Radioisotopes" are available upon request and should be posted in conspicuous areas in the laboratory.

Radiation poisoning can originate in two ways:

1. External radiation

External radiation is due to exposure to X-rays or radiation from sealed or unsealed radioactive sources external to the body. There are three methods of protection from external radiation:

a. Time

The radiation dosage is proportional to the time period of exposure. For this reason occasional medical X-ray photographs

are harmless to the patient, but X-ray technicians must be shielded to avoid prolonged chronic exposure.

b. Distance

The radiation intensity varies as the inverse square of the distance from the radiation source. In other words, if the distance is doubled the exposure to radiation will be one fourth, if the distance is tripled the exposure to radiation will be one ninth, etc.

c. Shielding

Shieldings attenuates the radiation by means of absorption in a dense solid mass.

2. Internal radiation

Internal radiation is the result of ingestion or inhalation of radioactive substances into the body with resultant exposure of the body as a whole and/or organs of the body into which these substances may be selectively absorbed.

The following rules should be obeyed when handling radioactive sources:

1. Handle radioactive sources only by tongs or forceps.
2. Radioactive sources should be held at a distance no closer than one foot from the body.
3. Sealed alpha emitting sources, because of the necessarily fragile nature of their construction, should be handled with extreme care.
4. Use liquid radioisotopes over a catch tray lined with paper.
5. Decontamination of equipment can be effected by scrubbing with soap and an excess of water.

V. SAFE DISPOSAL OF CHEMICAL WASTES

All too often laboratories are responsible for sewage microbe kills through the dumping of toxic or corrosive chemicals down sink drains. In order to avoid such incidents the following detoxification and neutralization procedures, which tend to reduce the chemical shock to the sewage system, are suggested:

1. Mercury compounds (22)

Mercury compounds that are water soluble should be dissolved, and those that are water insoluble should be treated with nitric acid to form water soluble nitrates and then dissolved. Adjust the pH of the solution to a green color with methyl violet pH indicator, thereby converting the mercury to the ion form. By passing hydrogen sulfide through the solution the mercury forms harmless sulfates which can be safely flushed down the drain with an excess of water.

2. Antimony, arsenic, barium, bismuth, cadmium, lead, silver, and strontium (22)

If only small amounts are involved follow the procedure for inorganic salts. If a larger amount or value is involved enlist the aid of a commercial agency specializing in this area.

3. Inorganic halides (22)

This procedure does not apply to fluorides, or halides of Hg, As, Sb, Bi, or Ag. Sift or pour the halide into a dry and well mixed layer of half kaolin and half soda ash in a large evaporating dish. After mixing thoroughly, spray with 6 M ammonium hydroxide while stirring. Cover the mixture with a layer of crushed ice, stir, and continue spraying with

ammonium hydroxide. When the fumes of the newly formed ammonium halide have partly subsided add iced water, stir, and dump the slurry into a large container. After all the material has been so treated neutralize the slurry with 6 M hydrochloric acid and slowly siphon the suspension into a drain with an excess of running water. If a fluoride is present use the procedure for inorganic salts.

4. Inorganic salts (22)

The inorganic salts include: alums, aluminum chloride, aluminum nitrate, aluminum sulfate, ammonium fluoride, ammonium nitrate, ammonium thiocyanate, borax, chromic salts, cobaltous nitrate, cupric nitrate, ferrous ammonium sulfate, ferrous chloride, ferrous sulfate, lithium carbonate, manganese sulfate, potassium acetate, potassium carbonate, potassium fluoride, potassium ferrocyanide, potassium hydrogen difluoride, potassium nitrate, sodium acetate, sodium benzoate, sodium bicarbonate, sodium carbonate, sodium chloride, sodium fluoride, sodium formate, sodium hydrogen difluoride, sodium iodide, sodium phosphates, sodium propionates, sodium silicate, sodium tetraborate, tin tetrachloride, zinc acetate, zinc chloride, magnesium chloride, and nickel nitrate. Add soda ash to the inorganic salt, moistening with water if needed. Neutralize the mixture with 6 M hydrochloric acid. If a fluoride is involved add slaked lime before neutralization. If the resulting material is a liquid it may be safely flushed down the drain with an excess of water. If the material is a solid it should be sent to an authorized landfill.

5. Acids (9)(22)

Neutralize all waste acids with 6 M ammonium hydroxide using an indicator such as litmus paper. Flush the neutralized liquid down the drain with excess amounts of water.

6. Bases (9)(22)

Neutralize all bases with 6 M hydrochloric acid using and indicator such as litmus paper. Flush the neutralized liquid down the drain with excess amounts of water.

7. Oxidizing agents (22)

Common oxidizing agents include: ammonium dichromate, ammonium persulfate, calcium chlorate, calcium hypochlorate, potassium perchlorate, potassium chlorate, potassium chlorite, potassium persulfate, potassium hypochlorite, sodium perchlorate, sodium chlorate, sodium chlorite, sodium persulfate, sodium hypochlorite, bromic acid, bromine, or iodine. Add to the waste oxidizing agent a large volume of a concentrated reducing agent solution (a bisulfite, a ferrous salt, but not carbon, sulfur, or other strong reducers). Acidify the reaction mixture with 3 M sulfuric acid to promote rapid reduction. When the reaction is complete neutralize the solution with soda ash and flush it down the drain with an excess of water.

8. Reduction agents (22)

Common reducing agents include: chromous salts, sodium sulfite, sodium thiosulfite, sodium bisulfite, sodium nitrite, and stannous chloride. Mix the water solution of the waste reducing agent with soda ash. If the slurry is effervescent wait for the reaction to subside. Cautiously add an equal

volume of calcium hypochlorite (the reaction may be vigorous) and allow the reaction mixture to stand for two hours. Neutralize the solution with 6 M hydrochloric acid and flush it down the drain with an excess amount of water.

9. Alkali and alkaline earth metals (22)

Have a fire extinguisher suitable for combating class D fires ready. Mix the waste material with an equal amount of soda ash and slowly add the mixture to butyl alcohol. Allow the reaction mixture to stand for twenty four hours, dilute the mixture with water, and neutralize with 6 M hydrochloric acid. Flush the liquid material down the drain with an excess amount of water.

10. Cyanides (22)

In case of cyanide spillage evacuate the laboratory immediately. Absorb liquid cyanide on paper towels or sweep solid cyanides onto paper. Place the paper and waste on an iron tray in an exhaust hood and incinerate. If there has been a skin contact it should be washed off with soap and water immediately. If larger amounts of waste cyanide are involved use one of the following methods:

- a. In a large beaker make the waste alkaline with a sodium hydroxide solution. Add to this slurry an excess of a ferrous sulfate solution and after one hour flush the resulting harmless cyanate solution down the drain with an excess amount of water.
- b. Add an excess of sulfur to an alkaline cyanide slurry and heat to convert the cyanide to thiocyanate. Flush the

product down the drain with an excess amount of water.

- c. Add the cyanide with stirring to a strong alkaline solution of calcium hypochlorite. Wait twenty four hours and then flush the resulting cyanate down the drain with an excess amount of water.

11. Inorganic peroxides (22)

These mainly include hydrogen peroxide, sodium peroxide, and potassium peroxide. Cover the peroxide waste with double volume of a nine-to-one sand and soda ash mixture and mix thoroughly. Slowly add from two to four liters of a sodium sulfite solution with stirring. Neutralize the slurry with dilute sulfuric acid, decant the sulfate solution down the drain accompanied with an excess amount of water, and send the sand to an authorized landfill.

12. Organic peroxides (20)

- a. Burning is probably the most suitable method of disposal. An isolated open ditch is an ideal location for the burning. Small quantities should be burned at a time to control the rate and hazard of combustion. Ignition is most safely effected by an electrical spark administered from a distance of not less than twenty five feet.
- b. Hydrolysis is accomplished most safely by using about ten times the weight of the peroxide of cold 10% caustic solution. Allow a minimum of twenty four hours for the reaction to reach completion. The decomposition products can safely be flushed down the drain with an excess amount of water.
- c. Dilution does not destroy peroxides, but it does make them

safer by lowering their concentration and therefor may be a wise precaution while preparing to dispose of the peroxide in another manner. As a general rule peroxide dilution by dumping directly into the sewage system is unsafe and is not recommended.

13. Inorganic sulfides (22)

Add to the sulfide waste a solution of ferrous chloride and stir until ferrous sulfate formation is complete. Neutralize the product solution with soda ash and flush it down the drain with an excess amount of water.

14. Carbides (22)

In an exhaust hood slowly add the carbide to a large container of water and burn off the hydrogen with a lighted burner as the pilot flame. Allow the precipitate to settle, decant the water, and send the solid to an authorized landfill.

15. Hydrocarbons, alcohols, ketones, and esters (9)(10)(22)

These substances should never be poured down the drainage system. Perhaps the most suitable disposal method for these compounds is burning in an open field or ditch as was proposed for organic peroxides.

16. Aldehydes (22)

Small amounts can be absorbed on paper toweling and incinerated on a metal tray in an exhaust hood. Large amounts should be covered with sodium bisulfite, diluted with water, allowed to stand for one hour, and flushed down the drain with an excess amount of water.

17. Carbon disulfide (10)(22)

Have a carbon dioxide fire extinguisher ready in case of an

emergency. It is probably most suitable to incinerate carbon disulfide in an open field or ditch. Carbon disulfide should never be poured down the drain, since it is poisonous, violently combustible, and can be detonated by shock or catalytic agents such as iron rust.

18. Carbon tetrachloride and carbon tetrabromide (22)

These compounds are water insoluble and highly toxic. Small amounts can be absorbed on paper toweling and incinerated on an iron tray in an exhaust hood. Larger amounts should be purified by distillation and reused. Wash any spill areas with soap and water. Never pour these compounds down the drain.

19. Radioactive wastes (19)

In accordance with Atomic Energy Commission regulations radioactive laboratory wastes may be disposed of as follows:

- a. By transfer of the waste to an authorized recipient, such as a licensed commercial radioactive waste collection service.
- b. By any method desired by the user provided special approval has been granted by the AEC.
- c. By diluted release into a sanitary sewage system.
- d. By burial in the soil.

CHAPTER THREE

CONCLUSIONS

It is obvious at this point that the literature is well represented by publications concerned with laboratory safety; this report certainly not exhausting the supply of information available to this concern. This compilation of safety hazards, precautions, and recommendations, and awareness of its implications, does not in and of itself provide the impetus for safety and accident prevention. It can be concluded that the significance of such information gains legitimacy when incorporated into formal safety policy. Such a policy must be able to implement and integrate the three following programs: (23)

A PROGRAM FOR PEOPLE

This program must be built around the concepts of training, knowledge, skill, attitude formation, firm supervision, administration, control of unsafe behavior, and counselling to overcome handicaps.

A PROGRAM FOR EQUIPMENT

This program must be able to effectively ensure safe design, proper maintenance, the right tools available and used for the job, the control of power is directed toward task performance rather than toward accidents, and the availability of personal protective equipment.

A PROGRAM FOR ENVIRONMENT

This program must wisely plan for laboratory layouts, building engineering, color combinations, lighting, ventilation, flooring, fire prevention, housekeeping, storage, and disposal.

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SAFETY CONSIDERATIONS FOR HIGH SCHOOL SCIENCE LABORATORIES
WITH SPECIAL EMPHASIS ON CHEMICAL HAZARDS

by

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Many of the procedures and manipulations common to the high school science laboratory inherently include certain elements of hazard. The purpose of this report is to consolidate information on these hazards so that a science instructor can deal knowledgeably and competently with them.

This information topically includes brief considerations of physical design and equipping of laboratory rooms; protecting the eyes from physical and chemical damage as well as laser exposure; theory and prevention of electric shock; guidelines for the safe manipulation of glass laboratory utensils; common sense suggestions for the safe handling of laboratory animals; and first aid procedures for many common laboratory injuries.

The major emphasis of this report, however, is placed on the safe storage, use, and disposal of chemicals. Selected information centers around topics which include the dangers involved in specific chemical reaction types; prevention, theory, and control of fires and explosions; toxic exposure to irritating, corrosive, destructive, poisonous, or radioactive chemicals; and detoxification and neutralization procedures that convert used chemicals into harmless wastes.

Awareness of safe environmental conditions, safe equipment and materials, and safe behavior is the essence of this report.