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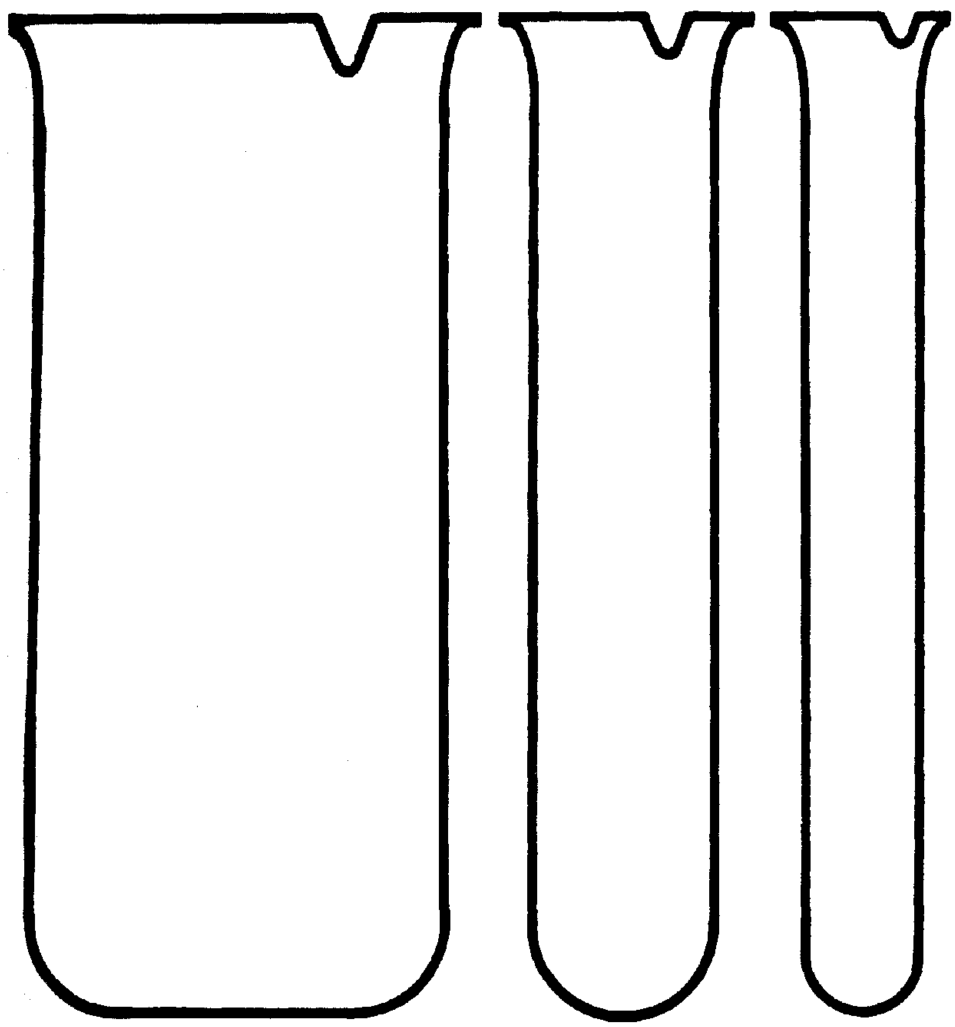
Manual of Safety and Health Hazards in the School Science Laboratory

Division of Training and Manpower Development



U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control
National Institute for Occupational Safety and Health

MANUAL OF
SAFETY AND HEALTH HAZARDS
IN THE SCHOOL SCIENCE LABORATORY

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DISCLAIMER

The material in this publication was collected from various sources in order to present as wide a range of information on the subject as possible; thus, the opinions and conclusions expressed are not necessarily those of the National Institute for Occupational Safety and Health.

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PREFACE

HOW TO USE THIS MANUAL

The purpose of this manual is to provide high school science teachers with a compact reference to hazards encountered while performing experiments in the areas of chemistry, the earth sciences, biology, and physics. These topics are located in Chapters 4 through 7. A health and safety hazard code is used so that the teacher can, at a glance, determine the relative danger of an experiment. Chapter 1 should be read first to understand the code and how it was developed.

Chapters 2 and 3 provide an abbreviated course in toxicology and selected safety topics that will be of immense value to teachers who do not have a background in those areas. Thorough reading of the chapters is strongly advised, as many topics covered are beyond the curriculum of the average teacher-education course. Additionally, Chapters 2 and 3 are a valuable source of hard-to-find health and safety information.

When preparing experiments, teachers are urged to locate the relevant experimental class using the table of contents, which is on pages v and vi. By turning to the appropriate sections, teachers can identify the sources of hazards in their experiments. Appropriate corrective and protective action should be incorporated in the work plan. Prior to the laboratory session, the potential hazards should be discussed with the students and a professional atmosphere established for conduct of the experiments.

CONTENTS

CHAPTER 1

INTRODUCTION AND OVERVIEW

Chapter 1

INTRODUCTION AND OVERVIEW

INTRODUCTION

This resource guide has been written for science teachers concerned about the safety of their students and themselves in the school science laboratory. Current publications on laboratory safety selected from the many texts written in this area are given in Table 1-1. This manual is an attempt to bridge the gap between the safety textbooks and actual experiments carried out in the high school laboratory. Based on experiments published in a wide spectrum of texts, this manual assigns experiments to classes and then discusses the hazards within those classes.

Modern laboratory courses and programs increasingly emphasize "hands-on" experiments; this emphasis necessitates an increased awareness by students and faculty alike of the inherent dangers involved with performing laboratory work. Tables 1-2 to 1-5 list classes of experiments in each science and their health and safety ratings. Of particular concern are the areas of chemicals and materials, procedures, equipment, glassware, and small laboratory tools used in experiments.

Safety planning should be integrated directly into the experimental procedure, and the reasons for actions taken should be understood. To conduct experimental work in the laboratory without consideration of the hazards involved and the potential environmental impact of the work is tantamount to science in the dark ages. NIOSH, OSHA, TSCA, and EPA are facts of life, and students deserve to be exposed to these government agencies as part of their academic scientific training. The regulatory aspects of these agencies are binding on us all and will influence our way of life for years to come.

Health And Safety Rating Scale

The health and safety hazard system used here is similar to and compatible with the hazard identification system of the National Fire Prevention Association (NFPA) in its *Hazardous Chemical Data Manual*. The system is also described in the NIOSH manual *Safety in the School Science Laboratory*.

The rating scale for both health and safety hazards uses numerals from zero to four. A rating of zero (0) for an experiment indicates relatively little hazard involved, while a rating of four (4) indicates a serious hazard that is potentially lethal.

Health ratings are based on the toxicity or pathogenicity of materials, chemicals, and organisms; safety ratings are based on flammability and reactivity of chemicals and materials, the nature of procedures, and the kind and nature of glassware, equipment, instruments, and small tools involved. Experiments received overall ratings after consideration of the quantity of materials used, their mode of dispensing, and the matrix (conditions and methods of use) in which the hazardous material exists.

Health Ratings

Where possible, a quantitative basis for the index ratings is used. Tables are presented that give the toxicity of chemicals and health and safety rating of each chemical used in the representative experiments. Occupational Safety and Health Administration (OSHA) time-weighted average exposure data and, when available, rat oral LD_{50} data are used in compiling the ratings. Where this information is not available, judgment is based on other pertinent toxicological information. The bases of the health ratings follow:

Health Rating Scale

Health Rating	**LD_{50}**
4	<50 mg/kg or Carcinogen
3	50 – 500 mg/kg
2	500 mg – 5 g/kg
1	5 g – 15 g/kg
0	>15 g/kg

In all microbiology experiments the presence of pathogens is assumed. The hazard level is assigned based on the nature of the pathogenic effects of the organism.

Safety Ratings

For safety ratings a quantitative basis is more difficult to use. If the experiment uses materials rated by NFPA, then that code is used as a basis. Again, the quantity, conditions, and sample matrix are considered in arriving at a rating number, and a zero (0) to four (4) scale is used for materials, procedures, equipment, and experiments.

A rating of 4 is assigned if very dangerous materials are used such as those rated NFPA Code 4. Effectively this includes: substances with flashpoints below 23°C (73°F) and boiling points under 38°C (100°F); materials that form explosive mixtures with air; materials readily capable of a fatal electrical shock; equipment with exposed high-voltage circuits; and cutting tools that are unguarded and powered.

A rating of 3 is assigned to experiments involving: materials with flashpoints below 23°C (73°F) and boiling points below 38°C (100°F); materials capable of explosion but requiring a strong initiating source or needing to be heated; and equipment capable of shock, burning, and cutting with severe results.

A rating of 2 is assigned to experiments using: materials that must be heated above ambient temperature before they can ignite (for example, liquids with a flashpoint of 38°C (100°F) or over, but not exceeding 93°C (200°F); reagents that can react violently but not detonate; and power tools that are insulated and cannot cut.

A rating of 1 is assigned when experiments involve: materials that must be preheated before ignition can occur (for example, materials that must be heated to 816°C (1,500°F) for 5 minutes before ignition can occur and liquids with flashpoints above 93°C (200°F) materials that, although usually stable, can become unstable at elevated temperatures; and hand tools capable of puncturing or cutting.

A rating of 0 is assigned when there is little possibility of injury from the equipment or the procedures involved. Materials used in these experiments will not burn and are not violently reactive with water or fire exposure.

A summary of the scale is given in Table 1-6.

TABLE 1-1

SAFETY MANUALS AND TEXTS

Bretherick, L. Reactive Chemical Hazards. CRC Press Inc., 2255 Palm Beach Lakes Blvd., West Palm Beach, Florida (1977).

Casarett, L.I.; Doull, L. Toxicology, The Basic Science of Poisons. Macmillan Co., Inc., 866 Third Avenue, New York, New York (1975).

Dean, R.A.; Dean, M.M.; Matz, L.L. Safety in the Elementary Science Classroom. The National Science Teachers Association, 1742 Connecticut Avenue, N.W., Washington, D.C. (1978).

Dean, R.A.; Dean, M.M.; Matz, L.L.; Virkus, R.N. Safety in the Secondary Science Classroom. The National Science Teachers Association, 1742 Connecticut Avenue, N.W., Washington, D.C. (1978).

Fairchild, E.J. (ed.) Registry of Toxic Effects of Chemical Substances (two volumes). U.S. DHEW, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, Cincinnati, Ohio (1977).

Fire Protection Guide on Hazardous Materials. National Fire Protection Association, 470 Atlantic Avenue, Boston, Mass. (1975).

Guide for Safety in the Chemical Laboratory. Manufacturing Chemists Association, 2nd Edition, 1825 Connecticut Avenue, N.W., Washington, D.C. (1972).

Pecsok, R.L.; Chapman, K. Modern Chemical Technology Guidebook for Chemical Technicians. American Chemical Society, 1155 Sixteenth Street, N.W., Washington, D.C. (1970).

Safety in the School Science Laboratory, Instructor's Resource Guide. National Institute for Occupational Safety and Health, Division of Training and Manpower Development, U. S. DHEW, Public Health Service, Center for Disease Control, Cincinnati, Ohio (1978).

Steere, N.V. Handbook of Laboratory Safety, 2nd ed. CRC Press Inc., 2255 Palm Beach Lakes Blvd., West Palm Beach, Florida (1976).

The Industrial Environment–Its Evaluation and Control. U.S. DHEW, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, Cincinnati, Ohio (1973).

TABLE 1-2

HAZARDS INDEX FOR CHEMISTRY EXPERIMENT CLASSES

Class of Experiments	Health/ Safety
Acids and Bases	2/1
Chemical Families	3/2
Chemical and Physical Change	2/2
Conductivity and Ionization	2/1
Crystals	0/0
Density Measurements	0/0
Equilibrium	1/1
Gas Laws	4/1
Heat of Reaction	2/3
Measurement	1/0
Organic Chemistry	2/3
Oxidation and Reduction	2/1
Qualitative Analysis	0/1
Radiation Chemistry	0/0
Scientific Processes and Procedures	0/1
Stoichiometry	2/2
Reaction Rates	0/0
Solubility	2/1
Thermal Chemical Measurements	2/2

TABLE 1-3

HAZARDS INDEX FOR EARTH SCIENCES EXPERIMENT CLASSES

Class of Experiments	Health/ Safety
Astronomy	0/1
Mapping	0/0
Oceanography	0/1
Paleontology	0/0
Physical Geology	0/1
Rocks and Minerals	1/1
Weather and Climate	0/1

TABLE 1-4

HAZARDS INDEX FOR BIOLOGY EXPERIMENT CLASSES

Class of Experiments	Health/ Safety
Animal Physiology/Anatomy/ Embryology	1/1
Animal Taxonomy	0/0
Bacteriology and Microbiology	0/1
Behavioral Studies	0/0
Biochemistry	1/1
Cellular Biology	0/0
Ecology	0/0
Evolution	0/0
Experimental Procedures	0/0
Genetics	0/0
Plant Anatomy and Physiology	0/1
Plant Taxonomy	0/0
Reproduction	0/0

TABLE 1-5

HAZARDS INDEX FOR PHYSICS EXPERIMENT CLASSES

Class of Experiments	Health/ Safety
Data Analysis and Measurement	0/0
Electricity and Magnetism	0/3
Heat	0/1
Light (Optics)	0/1
Mechanics	0/1
Nuclear Experiments	0/0
Sound	0/0

TABLE 1-6

HAZARDS RATING SCALE

SCALE	HEALTH	SAFETY
4	Brief exposure could result in death.	Serious accident 80 – 100% probable. Death or serious injury very likely to result from the accident.
3	Prolonged exposure could result in death. Brief exposure could result in serious injury.	Accident 60 – 80% probable. Death or serious injury likely to result from the accident.
2	Prolonged exposure could result in serious injury. Brief exposure could result in mild injury.	Accident 40 – 60% probable. Injury may result from accident.
1	Prolonged exposure could result in irritation or a mild injury.	Accident 20 – 40% probable. Slight injury may result from accident.
0	Prolonged exposure should not result in irritation or injury.	Accident 0 – 20% probable. No injury should result from accident.

To establish the ratings for the experimental classes, a series of typical experiments were reviewed for the potential hazards in procedures and materials. The following criteria were used to determine the ratings:

Toxicity of Chemicals
NFPA Health Hazard Criteria
Flammability of Materials Used in the Experiments
NFPA Reactivity of Materials
Pathogenicity of Biological Organisms
Electrical Hazard Potential
Hazards from Small Tools and Cutting Instruments
Procedures Involved in the Experiments
Hazards in Manipulating Laboratory Instruments and Glassware

CHAPTER 2

TOXICOLOGY — AN INTRODUCTION AND GLOSSARY

Chapter 2

TOXICOLOGY — AN INTRODUCTION AND GLOSSARY

INTRODUCTION

Man is continually exposed to toxic agents at work, in school and at play, in the food he eats, the water he drinks, the air he breathes, and the things he touches. There are multiple routes of entry into the body for toxic materials. Fortunately, the great majority of these substances are metabolized and cleared from the body without any significant or adverse effect. If the rate of absorption of a toxic substance exceeds its rate of elimination, the accumulation of the substance or its altered form becomes critical, resulting in effects recognized as abnormal or toxic. Reversible and irreversible injury or illness may result. The accumulation may be rapid, in which the toxic effect is called acute. If the accumulation of a toxic material occurs over a long term, the effect is classed as chronic toxicity.

Students are usually subjected to the potential for acute toxicity. Faculty, however, are more likely to experience chronic toxic effects. Persons in a typical workplace could experience either.

Toxicology can be simply defined as the study of poisons. This overly simple definition can be misleading because most everything can, in some situations, be a poison, particularly if given to a biological organism in a large enough quantity or when it is administered under abnormal circumstances such as during a disease. This concept was recognized by Paracelsus who, in 1537, wrote "All things are poisons and nothing is without poison; only the dose makes a thing a poison."

Accordingly, even salt and water can be poisons if an organism ingests too much. Likewise there are safe limits to carcinogens and poisons. For the maintenance of normal biological function it is essential that a well defined amount of substances be received, an amount called an optimal dose. The concept of optimal dosage applies to vitamins, minerals, and nutrients. In the case of vitamins and minerals, if the dose is too small, malnutrition results, if too large, toxic manifestations result.

A modern and explicit definition of toxicology may be stated as follows: *Toxicology is an interdisciplinary science predominantly dealing with chemical insults to man and his dependent environment.*

The science of toxicology has evolved into several subdisciplines based on emphasis. These include:

- Clinical Toxicology
- Forensic Toxicology
- Environmental Toxicology
- Occupational Toxicology
- Veterinary Toxicology
- Analytical Toxicology

Of primary interest in this manual is occupational toxicology, which is defined as the branch of toxicology that defines the limits of safety or chemical agents in the laboratory and workplace.

Routes Of Entry

From the occupational viewpoint there are two major routes of entry to the body by toxic agents: entry through skin with subsequent absorption and entry through inhalation with subsequent absorption. The first route is called the dermal route; the second is the respiratory route. Oral ingestion could occur but is more properly the field of clinical and forensic toxicology. The primary dermal and respiratory routes are illustrated in Figures 2-1 and 2-2.

The oral route is significant if people are permitted to eat, drink or smoke in working areas subject to contamination. This is particularly important in the case of laboratories. Laboratory personnel, students and teachers should never eat, drink, or smoke in the laboratory.

Expressions of Toxicity and Dose-Response

Toxicity of chemical agents is often expressed in terms of the effect of the dosage on an animal species. The most significant of these expressions is the LD_{50} value, which is the administered dose at which 50% of all

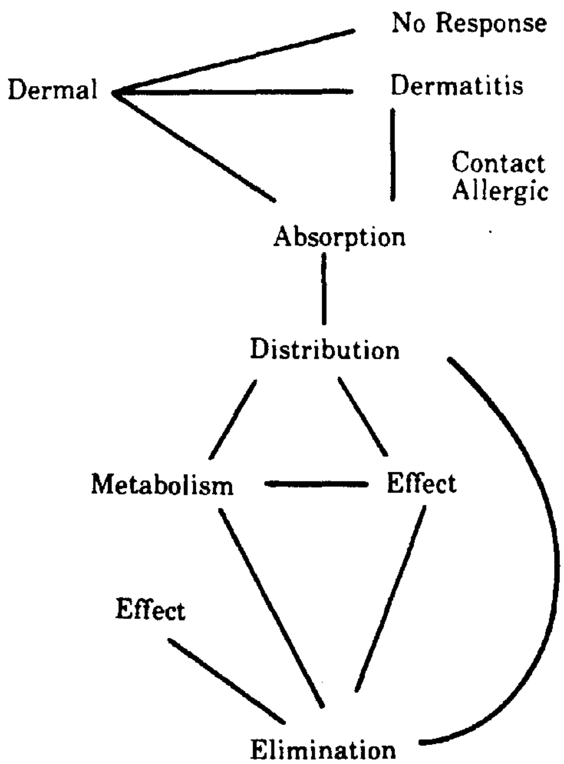

FIGURE 2-1

THE DERMAL ROUTE

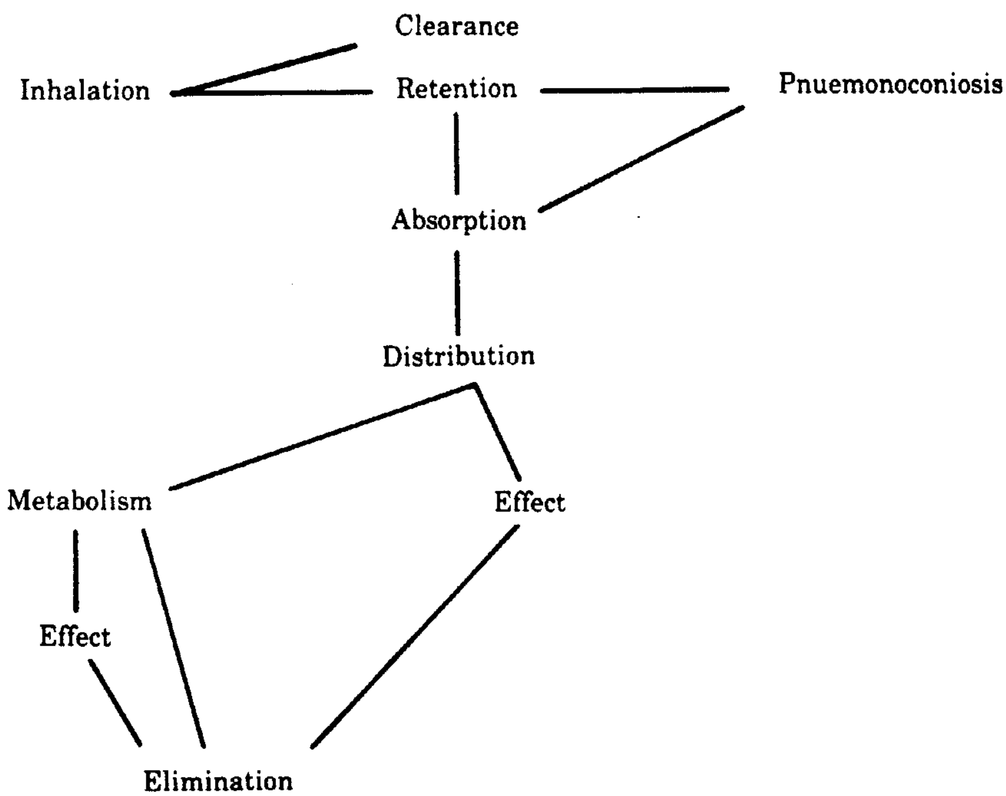

FIGURE 2-2

THE INHALATION ROUTE

tested animals die. The LD_{50} is usually expressed in terms of milligrams of the chemical per kilogram of body weight.

The LD_{50} is useful for comparing the toxicity of chemicals with each other. The LD_{50} differs with the route of administration and the species of animal used. In this manual, the rat oral LD_{50} is used. The rat was chosen because of its great metabolic similarity to man. Caution must be used in attempting to extrapolate the data to humans; it can be only a guideline.

The most important dose-response relationship for occupational toxicology is the "Threshold Limit Value" or TLV. The TLV is the concentration of chemical agent in the air to which it is believed that nearly all workers may be repeatedly exposed, 7–8 hours a day, 40 hours a week without adverse effect.

In some cases, OSHA has used the TLV to establish occupational limits. For an OSHA occupational exposure, a time-weighted average (TWA) is determined. The TWA is the sum of the products of the toxicant concentration and the duration of exposure taken over the total exposure time and is represented by the following mathematical expression.

$$TWA = \sum_{i=1}^{i=n} \frac{t_i C_i}{t_{total}}$$

Where: t = exposure time (minutes)
C = concentration (ppm or mg/m³)
n = total number of exposures
i = exposure number

$$= \frac{t_1 C_1 + t_2 C_2 + --- + t_n C_n}{t_1 + t_2 + --- + t_n}$$

Variables to the Dose/Response Relationship

Table 2-1 lists some factors that influence the significance of the exposure and resulting response. These variables affect all areas of toxicology.

Practicality of Using Available Information

Data from human exposure are often not in the literature; judgment must often be based on information derived from laboratory animal evaluation. To extrapolate to human situations is extremely difficult and subject to human judgment.

Experimental data can be obtained from the following types of tests to determine the general range of toxicity:

- Acute & Chronic Oral
- Acute & Chronic Dermal
- Acute & Chronic Inhalation
- Hypersensitivity
- Eye Irritation

Judgments of hazard are then based on:

- Human Exposure Information,
- Basic Toxicologic Tests,
- General Toxicologic Guidelines,
- Carcinogenicity, Mutagenicity, Tetragenicity, and Reproduction Information, and
- Basic Physiochemical Information.

A semiquantitative basis for toxicity ratings can be summarized by assigning a scale rating to toxicity. Hodge and Sterner proposed the scale in Table 2.2.

TABLE 2-1

FACTORS INFLUENCING TOXICOLOGY

Composition of the Sample
Manufacturing or Formulation Process
Vehicle, Adjuvants, Binding Agents, Coatings
Concentration and Volume
Site, Rate of Administration
Diurnal and Seasonal Effects
Species and Genetic Studies
Immunological Status
Sex and Hormone Status
Nutritional and Dietary Factors
Age, Maturity, Weight
Emotion, Stress, and Behavior
Pre-existant Factors
Unusual Temperature, Pressure
Radiation Effects
Environmental Factors
Size and Solubility
Previous Exposure to Chemical Agents
Synergistic and Antagonistic Effects
Metabolic Pathway Effects

TABLE 2-2

RATING SCALE BASED ON TOXICITY

Rating	Description	Rat Oral LD_{50} (mg/kg)	Rat 4 Hour LC_{50} (ppm)*	Probable Lethal Dose for Adult
1	Extremely Toxic	<1	<10	Taste (1 grain)
2	Highly Toxic	1–50	10–100	4 cc (teaspoon)
3	Moderately Toxic	50–500	100–1000	30 g (ounce)
4	Slightly Toxic	500–5000	1000–10,000	250 g (1 pint)
5	Practically Non-Toxic	5000–15,000	10,000–100,000	1 kg (1 quart)
6	Relatively Harmless	>15000	>100,000	>1 kg (1 quart)

*Concentration in air that kills 50% of test animals in 4 hours.
Hodge, H.C., and Sterner, J.H.: American Industrial Hygiene Association Quarterly. *10* 93 (1943).

INDUSTRIAL TOXICOLOGY GLOSSARY

AAPCC	American Association of Poison Control Centers
ABIH	American Board of Industrial Hygiene
ACS	American Chemical Society
Acute	A short-time frame of action measurable in seconds, minutes, hours, days.
Aerosol	A suspension of fine liquid particles in the air.
AIHA	American Industrial Hygiene Association
Autoignition Temperature	Minimum temperature that a substance must be to ignite spontaneously in the air.
Caustic	A substance that attacks tissue by direct chemical reaction. Often Alkali.
Ceiling Concentration (CL)	Maximum concentration of a toxic substance at any one time.
Chronic	Long period of action, weeks, years.
Corrosive	A chemical that attacks metals and body tissue, usually an acid.
Danger	Highest degree of hazard.
Dust	Airborne fine solid material.
Flashpoint	Lowest temperature at which a flammable liquid will ignite when a source of ignition is applied.
Hazard	A condition of danger either potential or actual that will interrupt or interfere with a normal orderly process.
Hazardous Chemical	A chemical having one or more of the OSHA hazardous chemical properties.
Insidious Material	Materials possessing a great potential for harmful effects upon people.
Insidious Material/ Chemical	A chemical acting in imperceptible steps, having a cumulative chronic effect.
Irritant	A substance producing local inflammation on contact.
LC_{50}	The concentration in air of a toxicant that kills 50% of the test animals in a specific time.
LD_{50}	The dosage administered to test animals that kills 50% of the number of test animals.
mg/m^3	Milligrams per cubic meter. Usually used in describing the concentration of fumes, mists, and dusts in air; i.e., milligrams (dust)/cubic meter (air).

OSHA TWA	OSHA occupational standard for air concentration.
Poison	A substance with an LD_{50} rat oral dose of 50 mg/kg or less.
ppm	Parts per million. Usually used in describing the concentration of gases and vapors in air by volume; i.e., microliters/liter (air), cubic meters/10^6 cubic meters (air).
Registry	Registry of Toxic Effects of Chemical Substances published by NIOSH.
TLV	Threshold Limit Value. An estimate of the average safe concentration of a substance tolerable over an 8-hour period.
Toxicant	A substance capable of producing injury, illness, or death to humans as a result of dermal absorption, ingestion, or inhalation.
TWA	Time-Weighted Average.

$$TWA = \sum_{i=1}^{i=n} \frac{t_i C_i}{t_{total}}$$

Where: t = exposure time (minutes)
C = Concentration of contaminant
n = total number of exposures
i = exposure number

CHAPTER 3

ADDITIONAL SAFETY CONCEPTS

Chapter 3

ADDITIONAL SAFETY CONCEPTS

3.1 INTRODUCTION

Many texts deal with safety concepts for the laboratory; a representative selection of texts is listed in Table 1-1. It is beyond the scope of this chapter to review the basic principles found in such texts, but the reader is referred to the NIOSH publication *Safety in the School Science Laboratory*. That manual covers potential hazards including personal protective devices, labeling, glassware, reagents, biological hazards, ventilation, and fire control. An outline of *Safety in the School Science Laboratory* appears in Table 3-1.

This chapter is intended to supplement information found in the NIOSH manual and in standard safety texts with guidelines and references that will be of special value to school science teachers.

TABLE 3-1

OUTLINE OF *SAFETY IN THE SCHOOL SCIENCE LABORATORY***

LESSON	CONTENT	TIME
	LECTURE LESSONS	
1.	SCOPE OF THE PROBLEM	30 Minutes
2.	NEEDS ASSESSMENT	30 Minutes
3.	LEGAL ASPECTS OF CLASSROOM SAFETY	15 Minutes
4.	STUDENT INVOLVEMENT IN SAFETY PROGRAMS	30 Minutes
5.	EYE AND FACE PROTECTION	45 Minutes
6.	PROCEDURES FOR HANDLING CHEMICAL REAGENTS	45 Minutes
7.	STORAGE AND DISPOSAL OF CHEMICAL REAGENTS	30 Minutes
8.	LABELING	20 Minutes
9.	HANDLING GLASSWARE	30 Minutes
10.	BIOLOGICAL AND ANIMAL HAZARDS	30 Minutes
11.	VENTILATION	30 Minutes
12.	FIRE CONTROL	30 Minutes
13.	LABORATORY HARDWARE	30 Minutes
14.	RECORDKEEPING	20 Minutes
	WORKSHOP LESSONS	
W-1	SAFETY PROGRAM PLANNING	50 Minutes
W-5	EYE AND FACE PROTECTION	50 Minutes
W-8	LABELING CHEMICALS	50 Minutes
W-13	SAFETY EQUIPMENT	2 Hours
	APPENDICES	
A.	AUDIO-VISUALS	
B.	LIBRARY RESOURCES	
C.	DIRECTORY OF RESOURCES	
D.	PROGRAM EVALUATION	
E.	WALK-THROUGH SURVEY	
F.	TRAINEE EVALUATION (reserved)	

* *Safety in the School Science Laboratory, Instructor's Resource Guide.* U.S. DHEW, PHS, CDC, NIOSH, 1978.

3.2 ELECTRICAL HAZARDS

Typical laboratories have a substantial number of electrical instruments; common items in well-equipped laboratories range from hot plates to spectrophotometers.

Some general rules for the safe operation of electrical equipment in the lab can be summarized as follows:

- Only use equipment in good working condition and of adequate and proper design.
- Inspect the equipment for frayed insulation and loose or broken wires.
- Make sure that the bench area under the equipment is dry.
- Make sure that the area around the equipment is free from flammables.
- Be certain that all power switches are in the OFF position before plugging the appliance into an outlet. This prevents sparking at the plug.
- Make sure that both the equipment and the receptacle are grounded properly.
- Unplug any electrical equipment before servicing it.
- Do *not* touch electrical equipment with wet hands.
- Do *not* substitute a conductor, such as a penny, for a fuse.
- Do *not* jerk plugs from outlets.
- Do *not* store explosives or flammable liquids in refrigerators or near electrical motors.

One of the best ways to ensure safety is to use grounded equipment and outlets. Laboratory workers must also be careful to keep dry and to wear well-insulated shoes and other protective equipment.

Remember, it is the current that hurts. The current running through the body at a point of contact depends on the voltage of the electrical source and the point of contact. An actual current of 25 mA can cause respiratory failure in a short time; 100 mA is quickly fatal. A moistened finger in contact with 110 volts will allow approximately 7–10 mA current to flow through the body.

Data on electrical shock are shown in Table 3-2.

3.3 BURN HAZARDS

In the school science laboratory there are two major sources of burns:

(1) Contact with heated surfaces and liquids or with flames.
(2) Chemicals spilled on the body.

In addition to direct chemical burns, chemical spills can often result in heat burns due to reaction with the skin.

The seriousness of a burn is classified in three degrees:

First Degree Burns
Affect the outer layer of the epidermis and are characterized by redness and heat. Itching, burning, and pain are common. In bad cases, hospitalization may be required.

Second Degree Burns
Affect the deeper layers of the epidermis and are characterized by mottled red skin and blisters. Considerable pain is common and body fluid is lost through the blisters. Infection is possible and hospitalization will generally result.

Third Degree Burns
Affect the skin and deeper tissue. The burns are white or charred in appearance. There is little pain because the nerve ends are burned. Internal loss of body fluid can occur. The danger of infection is high and extensive hospitalization or death will result.

Burns can be followed by primary shock from the pain and secondary shock due to loss of fluid and plasma proteins.

TABLE 3-2

EFFECTS OF ELECTRIC SHOCK ON THE HUMAN BODY*

ELECTRICAL RESISTANCE OF THE HUMAN BODY

Mode of Contact	Resistance Value
One dry finger on each electrode	100,000 ohms
One wet finger on each electrode	40,000 ohms
One salt/wet finger on each electrode	16,000 ohms
Tight grip on each electrode	1,200 ohms

ELECTRICAL CURRENT THROUGH THE HUMAN BODY

For 110-volt equipment, application of Ohm's law, $V=IR$, gives the following results.

Mode of Contact	R (ohms)	I (amps)	I (mA)
Dry Finger	100,000	0.0011	1.1
Wet Finger	40,000	0.0028	2.8
Salty Finger	16,000	0.0068	6.8
Tight Grip	1,200	0.092	92.0

DEGREE OF SHOCK

CURRENT		
AC (60 Hz)	**DC**	**Effect**
1 mA	5 mA	Threshold of sensation
6–9 mA	70 mA	Let go current, muscular decontrol
25 mA	80 mA	Danger to life from heat/respiratory failure
100 mA	100 mA	Fibrillation, death

* Source: *Modern Chemical Technology, Guidebook for Chemical Technicians*. American Chemical Society, 1970.

Obviously the primary aim of safety in the laboratory is to avoid all burns. Because accidents will happen, minimizing the seriousness of the burn to a mild first-degree burn is a desirable secondary target in laboratory safety.

Factors influencing the seriousness of a burn are:

1. Temperature at the point of contact.
2. Duration of the contact.
3. Chemical burn potential.

Each of these factors may be minimized by simple organizational or substitutive techniques. The following guidelines identify the practical approaches that can be made to prevent and minimize burns in the school laboratory.

Prevention

Most burns result from accidental contact with heated objects and liquids. The best way of preventing such burns is to ensure that the heated object is constantly attended by the student conducting the experiment or that it is placed where it is shielded from accidental contact. If a piece of apparatus is hot and unattended, it should be labeled or confined to an area where it will not be inadvertently touched.

Hot plates are one of the more dangerous pieces of equipment because they retain heat for a long period after they have been switched off. A hot plate sitting on the edge of a bench looks innocent–until a student leans his elbow on it while conducting casual conversation. Obviously, hot plates should be placed out of reach to avoid such an accident.

Forethought in the positioning of the apparatus to be used is also significant in preventing burns. Students should never have to reach across hot apparatus to perform an experiment. Apparatus should be placed so that if hot fluid is spilled, it will fall on the bench, not on the student. Open ends of glassware used for heating should be pointed away from all other students. When evaporating liquids, it is preferable to complete the evaporation with a hot plate (rather than a Bunsen burner) because it can heat lower temperatures more uniformly, which prevents hot liquid from spattering out of the container.

Chemical burns can be prevented by treating hazardous chemicals with extreme care. Hold the chemical at arm length toward the back of the bench. Do not place hazardous chemicals in unstable vessels or in apparatus that is not properly secured.

Minimization

Minimization techniques can help reduce the severity of a burn if an accident does occur. These techniques require substantially more forethought in operation than the more obvious preventive techniques but are extremely effective in reducing the overall hazard to the student.

(A) Temperature

Operating at a reduced temperature is a significant way of reducing the seriousness of accidental burns. Several examples follow of how this may be achieved by organizational and substitutive techniques:

Hot plate thermostats should be set at the desired temperature, not the maximum.

Bunsen burners should be operated at a sensibly low level; this will also improve experimental technique.

Objects should not be held for an excessive period of time in a Bunsen burner flame. Guard against students heating beyond the experimental end point.

Hot water baths should not be boiled unless absolutely necessary.

Light bulbs used in experiments should be substituted by bulbs of lower wattage whenever possible.

Heat-generating chemicals should be mixed slowly.

Dilute chemicals should be used where possible.

Experiments requiring lower heat levels should be substituted if possible.

Poor conductors should be used for holding samples which are heated.

(B) Duration of Contact

The best way to reduce the duration of contact is to ensure that accidental contact can occur only as a momentary action. Placing all hot apparatus and processes toward the rear of the bench will prevent prolonged contact due to falling or leaning and will allow the student to withdraw his hand rapidly if he does touch a hot surface.

The duration of liquid or chemical burns may be significantly reduced by having safety equipment readily at hand. A deluge shower will quickly reduce the temperature of hot liquid in clothing and will wash away chemicals that are causing burns.

(C) Chemical Burn Potential

Chemical burn potential is most easily reduced by substituting dilute solutions wherever possible. When this is not possible, protective clothing may be necessary. Chemical burns may be minimized if a deluge shower is readily available for use as soon as an accident occurs.

3.4 RADIATION HAZARDS

Radiation is one of the health hazards least recognizable to the senses. Most hazards possess a physical characteristic such as smell or appearance that alerts investigators to its presence, but radioactive materials cannot be identified without the use of instruments or effective labeling.

For this reason and because of its severe potential health hazard, radioactive sources are controlled strictly by the Federal Nuclear Regulatory Commission or by state authorities in those states which are agreement states. The regulations promulgated by these authorities are the most useful method of practically determining the potential health hazard of a given radioactive source.

Radioactive sources determined as "exempt" by the regulations are generally regarded as posing no health hazard to the user and require no license for possession.

Table 3-3 details typical "exempt" quantities for a variety of isotopes. The permissible quantity for each isotope varies according to its radiotoxicity. You should check to determine whether these figures are applicable to your particular locality, as the regulations vary from state to state. However, as an indicator of relative health hazards, these figures are an effective guideline to use.

Since radiation health hazard depends on the quantity of radiation received by the human body, the regulations recognize that multiples of exempt sources that exceed the limits in Table 3-3 do pose a potential health hazard and require licensing by the appropriate authority.

That authority issues radioactive material licenses detailing the maximum radioactivity that may be possessed at one time and the largest single source permissible for each isotope. The individual responsible for control of the radioactive material within the licensed organization must be designated and qualified by training and experience to properly handle radioactive materials.

Within the school science laboratory, exempt quantities are nearly always used. The head of the department should determine if sufficient exempt quantities are possessed for a license to be required.

Even if no license is required, the students will benefit from partaking in a controlled program for the handling of radioactive materials. The training will prepare them for the many industrial and medical circumstances where strict controls over the storage, issuance, and use of the isotopes are required.

A pattern of operation for the control of radioisotopes is described below. A similar procedure is recommended whenever radioisotope sources are possessed. This pattern may also be used as a model for developing procedures to comply with State or Federal licensing requirements.

SAMPLE PROGRAM FOR CONTROL OF RADIOISOTOPES

1. A responsible member of the staff should be appointed as the Radiation Safety Officer (RSO) for the school. He will be responsible for all aspects of procuring, storing, handling, and disposing of radioactive materials and will ensure compliance with the terms of licensing or for maintaining the exempt quantity status.

2. A leaded safe should be provided for the permanent storage of all sources. The safe should be identified with a radiation label and should be locked at all times.

3. A log book should be maintained for signing isotopes in and out of the safe. A sample page is shown in Table 3-4.

4. A source record should be maintained on each isotope source possessed by the department. A typical form is shown in Table 3-5.

5. A copy of the departmental radioisotope regulations should be posted at the safe along with the log and a copy of the li-

TABLE 3-3

TYPICAL EXEMPT QUANTITIES*

Radioactive Material	Microcuries	Radioactive Material	Microcuries
Antimony 122	100	Gadolinium 153	10
Antimony 124	10	Gadolinium 159	100
Antimony 125	10	Gallium 67	100
Arsenic 73	100	Gallium 72	10
Arsenic 74	10	Germanium 71	100
Arsenic 76	10	Gold 198	100
Arsenic 77	100	Gold 199	100
Barium 131	10	Hafnium 181	10
Barium 133	10	Holmium 166	100
Barium 140	10	Hydrogen 3	1000
Beryllium 7	100	Indium 111	100
Bismuth 210	1	Indium 113m	100
Bromine 82	10	Indium 114m	10
Cadmium 109	10	Indium 115m	100
Cadmium 115m	10	Indium 115	10
Cadmium 115	100	Iodine 123	100
Calcium 45	10	Iodine 125	1
Calcium 47	10	Iodine 126	1
Carbon 11	10	Iodine 129	0.1
Carbon 14	100	Iodine 131	1
Cerium 141	100	Iodine 132	10
Cerium 143	100	Iodine 133	1
Cerium 144	1	Iodine 134	10
Cesium 129	10	Iodine 135	10
Cesium 131	1000	Iridium 192	10
Cesium 134m	100	Iridium 194	100
Cesium 134	1	Iron 52	10
Cesium 135	10	Iron 55	100
Cesium 136	10	Iron 59	10
Cesium 137	10	Krypton 85	100
Chlorine 36	10	Krypton 87	10
Chlorine 38	10	Lanthanum 140	10
Chromium 51	1000	Lutetium 177	100
Cobalt 57	100	Manganese 52	10
Cobalt 58m	10	Manganese 54	10
Cobalt 58	10	Manganese 56	10
Cobalt 60	1	Mercury 197m	100
Copper 64	100	Mercury 197	100
Dysprosium 165	10	Mercury 203	10
Dysprosium 166	100	Molybdenum 99	100
Erbium 169	100	Neodymium 147	100
Erbium 171	100	Neodymium 149	100
Europium 152 (0.2 h)	100	Nickel 59	100
Europium 152 (13 years)	1	Nickel 63	10
Europium	1	Nickel 65	100
Europium 155	10	Niobium 95	10
Fluorine	1000	Niobium 97	10

Table 3-3 (Continued)

Radioactive Material	Microcuries
Osmium 185	10
Osmium 191m	100
Osmium 191	100
Osmium 193	100
Palladium 103	100
Palladium 109	100
Phosphorus 32	10
Platinum 191	100
Platinum 193m	100
Platinum 193	100
Platinum 197m	100
Platinum 197	100
Plutonium 239	.01
Polonium 210	0.1
Potassium 42	10
Praseodymium 142	100
Praseodymium 143	100
Promethium 147	10
Promethium 149	10
Radium 226	.01
Rhenium 186	100
Rhenium 188	100
Rhodium 103m	100
Rhodium 105	100
Rubidium 86	10
Rubidium 87	10
Ruthenium 97	100
Ruthenium 103	10
Ruthenium 105	10
Ruthenium 106	1
Samarium 151	10
Samarium 153	100
Scandium 46	10
Scandium 47	100
Scandium 48	10
Selenium 75	10
Silicon 31	100
Silver 105	10
Silver 110m	1
Silver 111	100
Sodium 24	10
Strontium 85	10
Strontium 89	1
Strontium 90	0.1
Strontium 91	10
Strontium 92	10

*Occupational and Environmental Affairs Consultants

Radioactive Material	Microcuries
Sulphur 35	100
Tantalum 182	10
Technetium 96	10
Technetium 97m	100
Technetium 97	100
Technetium 99m	100
Technetium 99	10
Tellurium 125m	10
Tellurium 127m	10
Tellurium 127	100
Tellurium 129m	10
Tellurium 129	100
Tellurium 131m	10
Tellurium 132	10
Terbium 160	10
Thallium 200	100
Thallium 201	100
Thallium 202	100
Thallium 204	10
Thorium (natural)	50
Thulium 170	10
Thulium 171	10
Tin 113	10
Tin 125	10
Tungsten 181	10
Tungsten 185	10
Tungsten 187	100
Uranium (natural)	50
Uranium 233	.01
Uranium 234 Uranium 235	.01
Vanadium 48	10
Xenon 131m	1,000
Xenon 133	100
Xenon 135	100
Ytterbium 175	100
Yttrium 90	10
Yttrium 91	10
Yttrium 92	100
Yttrium 93	100
Zinc 65	10
Zinc 69m	100
Zinc 69	1,000
Zirconium 93	10
Zirconium 95	10
Zirconium 97	10

UNITED STATES ATOMIC ENERGY COMMISSION

COMPLIANCE OFFICES

Region	Address	Telephone: Daytime	Telephone: Nights and holidays
I Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont.	Region I, Division of Compliance, USAEC, 970 Broad St., Newark, N.J. 07102.	201–645–3960	212–989–1000
II Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Panama Canal Zone, Puerto Rico, South Carolina, Tennessee, Virginia, Virgin Islands, and West Virginia.	Region II, Division of Compliance, USAEC, Suite 818, 230 Peachtree St. NW., Atlanta, Ga. 30303.	404–526–4537	404–526–4537
III Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.	Region III, Division of Compliance, USAEC, 799 Roosevelt Road, Glen Ellyn, Ill. 60137.	312–858-2660	312–739-7711
IV Colorado, Idaho, Kansas, Montana, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas, Utah, and Wyoming.	Region IV, Division of Compliance, USAEC, 10395 West Colfax Ave., Denver, Colo. 80215.	303–837–4211	303–237–5095
V Alaska, Arizona, California, Hawaii, Nevada, Oregon, Washington, and U.S. territories and possessions in the Pacific.	Region V, Division of Compliance, USAEC, 2111 Bancroft Way, Berkeley, Calif. 94704.	415–841–5121 Ext. 651	415–841–9244

33 FR 5212

NOTE: The record keeping and reporting requirements contained in this part have been approved by the Bureau of the Budget in accordance with the Federal Reports Act of 1942.

TABLE 3-4

SAMPLE RADIOISOTOPE SOURCE REMOVAL FORM

Date Removed	Time	Source Type	Serial Number	User	Date Returned	Time

TABLE 3-5

SAMPLE RADIOISOTOPE SOURCE RECORD

RADIOISOTOPE SOURCE RECORD

Source Type:	**Storage:**	**Date Ordered:**
Nominal Activity:	**Date Disposed Of:**	**Date Received:**
Manufacturer:	**Disposal Method:**	**Receiving Survey:**
Serial No.:	**Disposal Authorization**	**Measured Activity:** **Survey Instruments:** **Measured By:**
Received By:		

Date Leak Tested	Leak Tested By	Results

cense. A sample radioisotope regulations manual follows these procedures.

6. Isotopes should be transported from the safe in lead blocks. The isotopes should be returned at all intermediate stages of the experiment when they are not in use. The lead block and isotopes should carry the radiation sticker.
7. All sources with a half-life greater than 30 days should be leak-tested prior to initial use and every 6 months thereafter. Sources with a leakage greater than 0.005 μCi should be rejected. A sample leak test certificate as supplied by manufacturers of radioisotopes is shown in Table 3-6.

SAMPLE PROGRAM FOR CONTROL OF RADIOISOTOPES

1. Procurement of Radioactive Materials

(A) Before any staff member attempts to procure any radioactive material, he must notify the Radiation Safety Officer (RSO) of his intent. The RSO will determine the need for the material as well as any unusual radiation hazards it might present.

(B) All purchase orders for radioactive materials must be initialed by the RSO or the Deputy RSO before leaving the premises.

2. Radioisotope Receiving Procedures

(A) Upon receipt of any radioactive material, the Radioisotope Source Record Form for that material is to be filled out and the RSO or his Deputy is to be notified by the receiving person.

(B) The RSO shall wipe test the package for contamination. Packages shall be opened carefully by the RSO.

(C) As the package is opened, the condition of the packing material shall be observed and any discolorations noted. The packing material should be checked for radioactive contamination.

(D) If any contamination, leakage, or shortages are observed, notify the vendor immediately.

3. Usage of Radioactive Materials

(A) Before any radioactive material can be removed from the safe, the RSO must be notified.

(B) All radioactive material users must fill out the removal form prior to removing material from the radioactive material storage safe.

(C) All radioactive material removed from the storage safe must be returned to the safe at the end of the experiment or the end of the day.

(D) All radioactive sources removed from the safe must be transported and stored in the lead storage containers designed for that purpose.

4. Emergency Procedures

In the event of any accident involving a radioactive source, notify the RSO and your department head immediately.

(A) Minor Spills

1. Remove all unnecessary personnel from the immediate vicinity of the spill.
2. Attempt to contain the spill and absorb the liquid with the large sheets of filter paper stored for that purpose.
3. Turn off all air-moving equipment (e. g., fans and air conditioners).
4. Make sure that no one leaves the area with contaminated footwear or clothing.
5. Don the appropriate protective clothing designated for radiation control: rubber gloves, plastic boots, lab coat.
6. Decontaminate (See Section 5).
7. Monitor all persons involved in the spill and cleanup.
8. Permit no one to resume work in the area until a survey is made, and approval of the RSO is obtained.
9. Prepare a history of the accident and subsequent cleanup for permanent inclusion in the department records.

TABLE 3-6

LEAK TEST CERTIFICATE

CUSTOMER ______________________________ P.O. ______________________________

CATALOG ________________________ CAPSULE TYPE ________ S/N ________________

RADIONUCLIDE ________________________ NOMINAL ACTIVITY ____________________

THE LEAK TESTS INDICATED BY THE CHECKED BOXES WERE APPLIED TO DETERMINE THE INTEGRITY OF THE SOURCE(S) IN THIS SHIPMENT.

☐ 1. STANDARD WIPE TEST
The source is swabbed over its entire surface with a moistened paper or cotton swab. After being allowed to dry, the swab is counted using a windowless gas flow proportional counter. Activity levels exceeding 0.005 microcuries will be cause for rejection.

Measured Activity: μCi beta gamma

☐ 2. BUBBLE TEST
The source is immersed in ethylene glycol to a depth of 2" in a glass container and a vacuum of 10 cm or less applied. A steady stream of bubbles from the window or weld detail will be cause for rejection.

☐ 3. SOAK TEST
The source is immersed in distilled water and maintained at 50°C for a 4-hour period or overnight at room temperature. After removal of the source the liquid is evaporated in a planchet and the dry residue counted in a windowless proportional flow counter. Activity levels exceeding 0.005 μCi will be cause for rejection.

Measured Activity: μCi alpha beta gamma

☐ 4. GAS SOURCE TEST (RADIOACTIVE GASES)
The source is placed in a vacuum desiccator or similar chamber, evacuated to less then 1 mm and left for a period of approximately 14 hours. Air is introduced into the chamber and the air monitored with an end window G.M. tube. Readings exceeding 1000 CPM will be cause for rejection of the source.

☐ 5. LEAK TEST NOT APPLICABLE
The active area of this source is uncovered or protected by a very thin coating. Although the deposit is adherent, it is not designed or certified to pass a standard leak test. The inactive portions of the source have been checked using the standard wipe test and found not to exceed 0.005 μCi of removable activity at time of shipment.

Date ________________________ ________________________
Health Physicist

(B) Accidents Involving Personnel Injury and Radioactive Materials

1. Wash minor wounds immediately under running water, while spreading the edges of the wound.
2. Report all radiation accidents involving wounds, overexposure, ingestion, and inhalation to the RSO as soon as possible.
3. Call a physician at once who is qualified to treat radiation injuries (a list of suitable physicians is given in Appendix A).
4. Permit no person involved in a radiation injury to return to school without the approval of the Radiation Safety Officer and the attending physician.
5. Prepare a complete history of the accident and subsequent activity related thereto for the Radiation Safety Officer's records.

(C) Fires or Other Major Emergencies

1. Notify all other persons in the room and building at once.
2. Attempt to put out fires if radiation hazard is not immediately present.
3. Notify the Radiation Safety Officer.
4. Notify the fire department and other local plant safety personnel.
5. Govern firefighting or other emergency activities by the restrictions of the Radiation Safety Officer.
6. Following the emergency, monitor the area and determine the protective devices necessary for safe decontamination.
7. Decontaminate under supervision of the Radiation Safety Officer.
8. Permit no person to resume work without the approval of the Radiation Safety Officer.
9. Monitor all persons involved in combating the emergency.
10. Prepare a complete history of the emergency and subsequent activity related thereto for the Radiation Safety Officer's records.

5. Decontamination Procedures

(A) Skin and Hands

1. Wash with mild soap and water for 2–3 minutes.
2. If (1) does not thoroughly decontaminate, then wash for 2 minutes with a gentle brush. Do not erode or break skin.

(B) Clothing

1. If levels permit, wash clothing in normal fashion. Permissible level: 0.1 millirem/hour.
2. If clothing is too heavily contaminated, place in heavy-duty plastic bag and then in isolated steel drum as a prelude to disposal.

(C) Floors, Walls, Benches

1. Decontaminate first by scrubbing floor with detergent solution.
2. If (1) does not work, scrub with a 25% solution of Contrad 70. Rinse with 1% HCl.
3. If further decontamination is necessary, wash floor with 20% HCl.

(D) Metal and Plastic Tools

1. Wash with a dilute (1%) solution of nitric acid (HNO_3), or a 10% solution of sodium citrate,

   or

2. Wash with a 10% solution of Contrad 70 followed with a 1% HCl rinse.

(E) Porous Surfaces

Use radioactive materials on nonporous surfaces only; porous surfaces are extremely difficult to decontaminate

(F) Glassware

1. Soak glassware in 25% solution of Contrad 70 or its equivalent for 24 hours and rinse with water followed by 1% HCl.
2. Soak glassware in concentrated nitric acid (HNO_3) for 24 hours and rinse.
3. If (1) and (2) do not work, soak glassware in 50% HCL and rinse.

4. If (1), (2), and (3) fail, dispose of glassware in the proper manner.

6. Waste Disposal

(A) Storage and decay: If the radionuclide has a short half-life, it can be stored until the activity has decreased to the point where it can be safely handled by normal waste disposal techniques. A short half-life is anything less than 40 days.

(B) If the material to be disposed of is in a liquid form, it may be disposed of by pouring down the drain only if the applicable state and Federal regulations are adhered to.

(C) If disposal of any radioactive liquid material would result in a violation of state or Federal regulations, dispose of the material by pouring the liquid into a heavy-duty plastic bag partially filled with an absorbent material, seal the bag and place it in a sealable metal can. Store the can in the metal drum designated for that purpose.

(D) Dispose of solid radioactive sources in the manner described for liquid sources in item C above. Measure the level of radiation emitted by each source at a disposal time and record on source form.

(E) Dispose of the drum by a commercial radioactive waste disposal firm.

(F) NOTE: All stages of the disposal procedure shall be monitored by the RSO. If, at any time, detectable radiation at the outside surface of the storage drum reaches a level such that any person working near the surface of the drum for 8 hours a day, 5 days a week would receive a radiation dose in excess of 0.30 rems per calendar quarter, the drum shall be disposed of as soon as possible.

3.5 USE AND CARE OF COMPRESSED GAS TANKS

Gaseous reagents are usually stored in heavy metal cylinders of various sizes. The gas is released through a high pressure valve that is protected by a domed cover when the cylinder is not in use. All cylinders are color-coded and labeled. With very few exceptions, gases are supplied at very high pressures (1,000–2,000 psi). The typical weight of a size 2 cylinder of gas is 45.5 kg (100 pounds). The tank is about 122 cm high and 25.4 cm (48 × 10″) in diameter.

Cylinders should be strapped and transported on two-wheeled carts. At the destination, they should be securely attached to the wall with straps or chains. Devices are available for attaching tanks to lab benchtops.

High-pressure tanks should ordinarily be equipped with a two-stage regulator of appropriate pressure ranges. Attachment fittings on regulators must match the tank valve. Adapters are available but their use is discouraged. *Never* use a regulator on an oxygen cylinder that has been used for some other gas. High pressure oxygen can react explosively with oil residues from other gases that have been transferred to the regulator. Regulators are attached to the valve of the tank, using a thin piece of plumbers' Teflon tape as a lubricant and seal.

When the regulator is attached and before opening the tank valve, be sure the valve for regulating outlet pressure is turned counterclockwise until there is no resistance. Then open the tank valve by turning it counterclockwise. Do *not* stand directly in front of a regulator during this step. An explosion or fire will blow out the face of the regulator gauges. If anything is to go wrong, it will happen at this point. Give the tank valve a full counterclockwise turn and then reverse it one-half turn clockwise. When the tank regulator shows the tank pressure, check for leaks at the valves with a soap solution, and tighten if necessary. Open the valve to the low pressure stage of the regulator (clockwise) to deliver gas at the indicated pressure. Open the needle valve to deliver gas to the system as desired.

High pressure systems should be shut down when not in use. To properly shut down the system, perform the following in order:

(1) Close high pressure valve (clockwise to tightness). (2) Open needle valve on delivery side to bleed gas out of the regulator (both gauges to read zero). (3) Turn regulator valve counterclockwise until loose. (4) Close the delivery needle valve.

Compressed gas cylinders are designed to operate safely up to 51.7°C (125°F). When they get hot, the pressure rises and a safety valve releases the contents. Otherwise, the tank would explode like a bomb.

If a fire breaks out in a system connected to a tank, shut off the tank valve before attempting to extinguish the fire.

3.6 GLASSWARE HAZARDS

Glassware in modern laboratories is usually made of Pyrex or Kimax glass. This type of glass offers the best resistance to chemical, thermal, and mechanical schock. It is a "hard" glass formulation that softens at a higher temperature than soda or "soft" glass.

Most laboratory accidents with injuries involve glassware failure that is caused by improper use. Glassware is fragile. Rules for appropriate handling can be summarized as follows:

—Never use glassware that is scratched or chipped. These are signs of damage or stress, leading to possible failure and dangerous results.

—Always lubricate glass tubing when inserting in rubber stoppers. This rule applies to tubing, rod, thermometers, tubes, condenser and flash fittings, and all other glassware. Glycerol or water is an appropriate lubricant.

—Always protect hands with several layers of cloth when inserting glass.

—Do not try to cut through glass tubing with a file. It will break up at the point of pressure and may result in injuries. To cut glass tubing and rod, make a scratch on the tubing with a sharp triangular file and a quick motion. Then snap tubing at the scratch. Glass is not "cut," but crystallized by the file scratch. It can be cleaned at the crystallized zone.

—Strip glassware with tape if it is to be used under vacuum or pressure. This reduces the possibility of flying glass fragments in case of implosion or explosion.

—Never heat soft glass that is thickwalled (bottles, jars, etc.). The glass will break at the zone between the thick and thin walls.

—Never heat pipettes, volumetric flasks, or burettes; they can change volume as a result of expansion and contraction. They can also fail.

—Never mix solutions in a volumetric flask by shaking the flask by its neck. The flask should be supported by the neck *and* the bulb.

—Do not heat bottles, graduated cylinders, volumetric glassware, funnels, jars, droppers, watchglasses, desiccators, glass plates, and test tubes. They are often made of soft glass, particularly in older apparatus. If so, they have low resistance to thermal shock. Soft glass tubing is widely used because it can be bent in the heat of a laboratory burner.

—In bending glass tubing, care must be exercised *not* to crimp the bend. The tubing is particularly weak at the crimp and more subject to failure.

—Manipulate heated glass with caution to avoid burns. Glass cools slowly.

—Use a tubing cutter on tubing with an outside diameter larger than 10–15 cm. File scratches often do not give smooth breaks.

—Always firepolish cut glass before use.

When heating glassware, wire gauze should be used to eliminate hot spots. Tongs or clamps should be used to minimize the risk of burns when heating glassware or manipulating chemicals.

Many laboratory injuries occur when cleaning glassware. In addition to the possibility of injury from broken glass, there is also the posibility of injury from so-called "cleaning solutions."

Most glassware can be effectively cleaned with modern detergents and brushing, but more stringent cleaning is sometimes required. All chemical cleaners other than detergents are hazardous. The chemicals commonly used are: dichromate-acid, Trisodium phosphate, and alcoholic potassium hydroxide.

Dichromate-acid cleaners are mixtures of potassium dichromate and concentrated sulfuric acid. This combination dissolves and oxidizes organic grease and scum. It also dehydrates burns and oxidizes skin, causing blisters or second-degree burns on contact.

Trisodium phosphate cleaners are strong alkalies. They may burn as well as irritate skin.

Alcoholic potassium hydroxide is prepared from a concentrated solution of potassium hydroxide that is diluted with alcohol. It causes burns and is also extremely flammable.

These "cleaning solutions" are dangerous and should be handled accordingly. A full disclosure of the hazards involved should be included on the label.

CHAPTER 4

CHEMISTRY EXPERIMENTS

Chapter 4

CHEMISTRY EXPERIMENTS

4.1 EXPERIMENT CLASS: ACIDS AND BASES

Overview

School science laboratory experiments with acids and bases are a very rewarding and sound approach to introductory chemistry. The experiments in this class are plentiful and usually well-written.

Experiments with acids and bases introduce students to a variety of concepts fundamental to understanding acid-base theory. Typically, these experiments fall into the following subgroups:

TABLE 4.1-1
TYPICAL EXPERIMENTS WITH ACIDS AND BASES

Health/Safety Hazard	Subgroup
3/3	Preparation of Anhydrides of Acids and Bases
2/0	Acid and Base Indicators
2/1	Acid and Base Strength
1/2	pH Measurement and Concept
2/1	Acid and Base Titrations
2/1	Hydrolysis
2/1	Acid-Base Therapy

Chemical Hazards

Hazards involved in these experiments run the spectrum from substantial to very little hazard. Assignment of health and safety ratings to the subgroups is based on the nature of the chemicals and procedures used and on assumption of use of diluted solutions. Concentrations of the solutions of substances involved usually are dilute, lessening the degree of hazard. However, if students prepare their own solutions to be used in this class of experiments, the degree of hazard is immediately intensified.

As is obvious from a review of chemicals used in these experiments, the health and safety hazards involved are substantial if students deal with the substances directly. Sodium and sulfuric acid can cause third-degree burns easily. Sodium hydroxide can cause painful alkali burns. The reagents are, for the most part, very corrosive. Hydrogen sulfide is a very poisonous gas, about 20 times as poisonous as hydrogen cyanide; it is also extremely flammable, a fact often overlooked in the laboratory. When used as dilute solutions, however, most of the reagents are relatively safe, and the experiments can lead to injury only through thoughtlessness and carelessness.

To rate experiments with acids and bases as hazardous would be an overstatement. However, precautions are necessary, particularly in handling reagents such as:

Acetic Acid	Oxalic Acid
Ammonium Hydroxide	Sodium Hydroxide
Hydrochloric Acid	Sodium Peroxide
Hydrogen Chloride	Sulfuric Acid
Hydrogen Sulfide	Zinc Sulfate
Nitric Acid	

Asbestos, ammonia as a gas, and metallic sodium will also be encountered and should be treated with equal care.

Teachers and students should use personal protective devices (for example, lab coats, aprons, safety shields, and safety goggles) when handling all of the above substances. Fume hoods should be used with gases such as hydrogen sulfide, hydrogen chloride, and ammonia.

When generating gases and anhydrides, care must be exercised that the gas lines have no blockages. Excessive gas pressures can cause the generators to explode. The key to safety when working with sulfur dioxide, phosphorus pentoxide, and nitrogen oxides (all poisonous substances) is the use of small quantities of reagents. Hydrogen sulfide anesthetizes the nose so that detection of the gas odor becomes more difficult with continued exposure. Toxic effects of the gas are found at levels lower than the flammability hazard. Metallic sodium larger that 2 or 3 mm on an edge can be dangerous when placed in water; explosions can and often do result as the heat of reaction ignites the hydrogen gas produced.

Procedural Hazards

Typical procedures for this class of experiments can include the following safety hazards.

TABLE 4.1-2

CHEMICALS TYPICALLY USED IN ACID-BASE EXPERIMENTS

Health/Safety Hazard	Chemical	Registry Number*	OSHA TWA	Rat Oral LD_{50} (mg/kg)	NFPA Code
2/3	Acetic Acid	AF12250	10 ppm	3310	
3/3	Ammonia (gas)	BO08750	50 ppm CL	350	310
2/2	Ammonium Chloride	BP45500	19 mg/L m^3	1650	
3/3	Ammonium Hydroxide	BQ96250	50 ppm CL	350	
2/2	Barium Hydroxide	NA	NA	NA	
2/2	Bismuth Chloride	NA	NA	NA	
2/1	Boric Acid	ED45500	NA	2660	
2/2	Calcium Chloride	EW29850	NA	NA	
2/3	Calcium Oxide	EW31000	5 mg/m^3	NA	
3/1	Copper Sulfate	GL89000	1 μg/m^3 as Cu	300	
1/3	Ethanol (Ethyl Alcohol)	KQ63000	1000 ppm	14000	030
3/3	Hydrogen Chloride (gas)	MW96250	5 ppm	NA	
3/3	Hydrochloric Acid	MW40250	5 ppm	900	
4/4	Hydrogen Sulfide	MX12250	20 ppm CL	NA	340
2/2	Iron (III) Chloride	NO54250	1 mg/m^3	NA	
2/2	Lead Nitrate	OG21000	200 μg/m^3	NA	
2/3	Magnesium Hydroxide	OM35800	NA	5000	
2/2	Magnesium Sulfate	OM45000	NA	NA	
3/3	Nitric Acid	QU57750	2 ppm	NA	
4/4	Oxalic Acid	RO24500	1 mg/m^3	NA	
2/3	Phosphoric Acid	TB63000	1 mg/m^3	1530	
2/2	(Red) Phosphorous	TH34950	NA	NA	011
3/2	Potassium Nitrate	TT37000	NA	500	
3/3	Sodium (Metal)	VY06880	NA	NA	310
2/3	Sodium Acetate	AJ45500	NA	3530	
2/2	Sodium Carbonate	VZ40500	NA	4000	
1/0	Sodium Chloride	VZ47250	NA	3000	
2/1	Sodium Hydrogen Carbonate	VZ17500	NA	4220	
3/3	Sodium Hydroxide	WB49000	2 mg/m^3	NA	301
3/4	Sodium Peroxide	WD34500	NA	NA	404
1/1	Sodium Phosphate	WD59500	NA	7400	
3/1	Sulfur	WS42500	NA	500	
2/4	Sulfuric Acid	WS56000	1 mg/m^3	2140	301
3/2	Zinc Chloride	ZH14000	1 mg/m^3	350	
4/2	Zinc Sulfate	ZH52600	NA	50	

* Registry number is from NIOSH's *Registry of Toxic Effects of Chemical Substances* (1977).

When using pipettes, the pump action bulbs should be used. Do not use the mouth on a pipette because the potential for aspirating the material is great. Also remember that pipette tips and mouthpieces can be easily broken, resulting in severe cuts of the hand and fingers. Students should be alerted to the hazards in manipulating glassware.

The main danger in the use of burettes comes in the filling operation. Severe burns can occur from reagents dribbling down the arm when burettes are filled at elevated heights. Safety glasses should always be worn. Remember that alkalies cause more serious burns than dilute acids.

Acids should be diluted with great care. Most dissolution reactions with acids and alkalies are exothermic. Sufficient heat can be generated to drive quantities of concentrated reagents into the laboratory worker's face. Remember, add the acid slowly and gently down the side of the container while stirring.

Equipment Hazards

Care in the use of pH meters must be taken. Electricity, which is used in pH meters, is easily conducted by solutions used in this class of experiments. Injury from shock can result from sloppy technique. The area around the meter should be kept clean and dry.

Overall Rating

Acid-base experiments have an overall health/safety hazard rating of 2/1.

4.2 EXPERIMENT CLASS: CHEMICAL FAMILIES

Overview

Experiments in this class generally deal with the preparation and properties of elements and their compounds, particularly those with oxygen. From typical laboratory manuals, these experiments have been grouped into the following subsets, with health and safety ratings assigned to each.

A significant hazard arises from the use of chemicals in concentrated form or in neat form. Most chemicals typically used are reactive and quite toxic. A great deal of care must be taken with the reagents used; particularly toxic and dangerous reagents and relevant hazard data are listed in Table 4.2-2.

TABLE 4.2-1

TYPICAL EXPERIMENTS WITH CHEMICAL FAMILIES

Subset	Health/Safety
Preparation and Properties of Oxygen	3/2
Preparation and Properties of Halogens	3/2
Preparation of Non-Metallic Oxides	3/2
Preparation of Metallic Oxides	3/2
Chemistry of Transition Metals	2/1
Chemistry of Group II Metals	2/1
Chemistry of Sulfur	3/2
Chemistry of Zinc and Related Materials	2/1
Comparison of Metals	2/1

Many experiments in this class are better done as demonstrations, since safety is a prime concern. Instructors should recall that the most important toxicity effect in students is acute, but for teachers, the toxicity is chronic.

Chemical and Material Hazards

Reagents that are particularly dangerous in this class of experiments include those in Table 4.2-2.

TABLE 4.2-2

PARTICULARLY TOXIC AND DANGEROUS REAGENTS

Barium Chloride
Barium Peroxide
Bromine (also corrosive)
Carbon Disulfide (also flammable)
Carbon Tetrachloride (also carcinogen)
Chlorine (also corrosive)
Hydrogen Peroxide (52%) (also corrosive, explosive)
Iodine
Iron Oxide (also potential carcinogen)
Manganese Dioxide
Mercury
Potassium Chlorate (also oxidant)
Potassium Dichromate (also carcinogen)
Potassium Fluoride
Potassium Permanganate (also oxidant)
Silver Nitrate
Sodium Fluoride
Sulfur Dioxide (also corrosive)

Many experiments call for tests of gases with flaming splints. Care must be exercised with these tests so that the contents do not flash back at the student. The flaming splint should be so held that neither the mouth nor the bottom of the test tube is pointed at the user.

Common procedures for the identification of halogens involve the dissolution of the halogen and its extraction into carbon tetrachloride. Halomethanes are potentially carcinogenic in chronic exposure, and acute carbon tetrachloride toxicity affects the liver and brain. Carbon tetrachloride can be replaced in most applications with perchloroethylene, a much less dangerous solvent.

TABLE 4.2-3

CHEMICALS TYPICALLY USED IN CHEMICAL FAMILIES EXPERIMENTS

Health/Safety Hazard	Chemical	Registry Number	OSHA TWA	Rat Oral LD_{50} (mg/kg)	NFPA Code
0/1	Aluminum	BD03300	NA	NA	011
3/0	Aluminum Sulfate	BD17000	NA	270	NA
4/1	Ammonium Polysulfide	BS40270	NA	NA	NA
4/0	Antimony	CC40250	500 $\mu g/m^3$	NA	NA
4/0	Barium Chloride	CQ87500	500 $\mu g/m^3$ as Ba	118	NA
4/3	Barium Peroxide	CR01750	NA	NA	100
4/4	Bromine	EF91000	0.1 ppm	NA	400
2/0	Calcium Carbonate	EV95800	10 mg/m^3	NA	NA
2/0	Calcium Chloride	EV98000	NA	1000	NA
2/0	Calcium Nitrate	EW30000	NA	3900	NA
0/0	Carbon Dioxide	FF64000	10000 ppm	*	NA
4/3	Carbon Disulfide	FF66500	3 mg/m^3	NA	230
4/0	Carbon Tetrachloride	FG49000	10 ppm (suspected carcinogen)	2800	300
4/1	Chlorine	FO21000	1 ppm	**	301
3/1	Cobalt Nitrate	GG11090	NA	NA	100
2/0	Copper (Metal)	GL53250	NA	NA	NA
2/3	Hydrogen Peroxide (52%)	MX09000	1 ppm	NA	203
4/1	Iodine	NN15750	.1 ppm CL	NA	NA
4/0	Iron (III) Oxide	NO74000	10 mg/m^3 (possible carcinogen)		NA
2/0	Iron (II) Sulfate	NO85100	NA	1520	NA
3/0	Lead (N) Oxide	OG07000	200 mg/m^3	NA	NA
1/2	Magnesium	OM21000	NA	NA	012
2/0	Magnesium Oxide	OM38500	15 mg/m^3	NA	NA
2/2	Manganese Dioxide	OP03500	NA	NA	NA
4/0	Mercury	OV45500	1 $mg/10m^3$ CL	NA	NA
3/0	Mercury (I) Nitrate	OW80000	NA	297	NA
4/0	Mercury (II) Oxide	OW87500	NA	18	NA
0/0	Oxygen	RS20600	NA	NA	000
2/2	Potassium Bromide	TS76500	NA	NA	NA
2/3	Potassium Chlorate	FO03500	NA	NA	200
4/3	Potassium Dichromate	HX76800	25 $\mu g/m^3$	NA	101
3/1	Potassium Fluoride	TT07000	2.5 mg/m^3 as F	245	NA
2/3	Potassium Permanganate	SD64750	NA	1090	100
3/2	Phosphorus Pentoxide	TH39450	NA	NA	NA
4/1	Silver Nitrate	VW47250	10 $\mu g/m^3$ as Ag	NA	101
2/1	Sodium Fluoride	WB03500	2.5 mg/m^3	180	200
2/2	Sodium Thiosulfate	WE66600	NA	NA	NA
3/2	Sulfur Dioxide (gas)	WS45500	5 ppm	***	300
2/1	Zinc (Metal)	ZG86000	NA	NA	011

*100,000 ppm LC
**
***

Ammonium sulfide is dangerous because it reacts with moisture in the air to release hydrogen sulfide, a very toxic and flammable gas. Often the flammability of hydrogen sulfide is overlooked because of concern for its toxicity.

Another dangerous sulfide is carbon disulfide, which offers a double-barrel hazard of toxicity plus flammability. Carbon disulfide has a flashpoint of -30°C and an ignition temperature of 100°C. A light bulb will ignite carbon disulfide.

Experiments with the halogens involve chemicals that are both corrosive and toxic. Chlorine, bromine, and iodine cause burns that are always serious and, because of their corrosive nature, can permanently damage lung tissue. Acute exposure can lead to death, and chronic exposure can also lead to severe lung and bronchial disorders.

This class of experiments also involves the use of strong oxidizers: hydrogen peroxide, barium peroxide, sodium peroxide, potassium chlorate, potassium permanganate, potassium dichromate, and silver nitrate. All of these can form explosive mixtures with substances that are easy to reduce, including paper and various plastics. Disposing of excess reagent by dumping it into a waste paper basket could result in a serious fire.

Oxygen generation from mercury oxide includes a small amount of mercury vapor, an insidious poison. This experiment must be conducted in a hood. A tray should be provided in case the test tube breaks and spills the mercury.

Procedural Hazards

Typical in this class of experiments is the preparation of gases, particularly oxygen, hydrogen, hydrogen sulfide, and chlorine. These gases are often produced by heating and/or the introduction of an acid to a reaction vessel. The gases are directed by glass and rubber tubing, and collected by displacement of air or water. It is necessary to check the delivery system for restrictions. Glassware can explode under the pressure of the gases generated if free delivery is restricted. When collecting gases over water, care must be taken not to let the water back up the delivery line into the gas generator. The highly explosive character of these gases must be considered. Students should work behind shields and, of course, always with safety glasses or goggles. They should also be cautioned to wear full body covering and loose-fitting clothes in these laboratory courses.

Care must be taken in inserting delivery tubes through rubber stoppers. Glycerine should not be used as a lubricant with strong oxidants; lubrication with water is recommended. Make sure no rubber particles obstruct the tubing. Be sure to fire-polish all tubing before attempting to insert tubing in rubber stoppers. The quantities of reagents used in experiments of this class should be monitored carefully by the instructor.

The tip of a thistle tube or addition funnel must be kept below the level of the reagent being added. Otherwise, the reagent could run out of the tube and into the face of the student.

When burning metals such as magnesium, students should not look into the flame; the fire emits large quantities of ultraviolet radiation.

Work with solids and concentrated reagents also requires care. Lab coats or aprons and safety glasses should be worn at all times.

Reactions of antimony and hydrogen with chlorine are often explosive. In preparing these types of products, it is probably better for the instructor to use the experiments as demonstrations rather than as student experiments.

In experiments in which metal salts are vaporized to allow observation of the colors produced by metals in flames, the flame tests should be conducted in a fume hood so that the metal vapors do not concentrate in the laboratory.

Some experiments with aluminum suggest the use of a thermite reaction. If thermite reactions are run, the following precautions should be followed.

The reaction should be conducted:
- Outside
- Using small quantities of reagents
- Out of direct view
- Away from observers

Be aware of:
- The fire danger
- The heat generated, which is strong enough to fuse metals
- The long time it takes to cool

Do not test for odors of the chemicals involved unless necessary and safely done.

Remember that the odors are caused by chemicals which are themselves toxic.

In reactions that require the heating of liquids, a "boiling stone" can be added to keep the liquids from "bumping."

Equipment Hazards

Some procedures call for blowpipe techniques. Several precautions are necessary. When working with a blowpipe, keep the cheeks puffed while blowing and learn to breathe through the nostrils without interrupting the steady pressure on the blowpipe. When working with the blowpipe the face is close to a Bunsen burner. Care must be exercised so as not to ignite clothing or hair. Do not inhale through the blowpipe or touch the heated area. Keep the burner stationary.

Overall Rating

Chemicals used in experiments typical of this class are quite dangerous from both health and safety considerations. The quantities involved can cause injury if accidents occur. An overall rating of 4 is assigned to the potential health hazard and 2 for safety hazard. If appropriate use of fume hoods is made and if perchloroethylene is substituted for carbon tetrachloride, the health hazard rating changes from 4 to 3. Assuming the substitution, the rating is 3 for health and 2 for safety hazards.

4.3 EXPERIMENT CLASS: CHEMICAL AND PHYSICAL CHANGE

Overview

These experiments illustrate the differences between chemical and physical changes, and chemical and physical properties. Typically such experiments allow students to explore the chemical reactivity of substances and to categorize chemical behavior based on those properties. The application of chemical and physical properties to the science of separation is also illustrated by several experiments.

In most experiments, the emphasis is on observation. Typically the characteristics of a system before and after a change are carefully determined. Experiments in chemical and physical change are critically important to the high school science program.

For the most part, the major source of hazards in this class of experiments is in the procedures rather than in the chemicals. If handled properly, the chemicals and reagents are quite safe in the quanitities involved.

Chemical and Material Hazards

Generally, chemicals used in these experiments are relatively safe, especially in the quantities and matrices (solutions) in which they are used. The few exceptions that should be noted are listed in Table 4.3-1. Chemicals typically required are given in Table 4.3-2, and each is assigned a toxicity value if it is available.

Table 4.3-1

PARTICULARLY TOXIC AND DANGEROUS CHEMICALS

Ammonium Dichromate (carcinogenic Cr)
Ammonium Hydroxide (caustic)
Barium Nitrate
Carbon Disulfide (extraordinarily flammable)
Ethanol (flammable)
Hydrochloric Acid (corrosive)
Mercury Oxide (mercury vapor is extremely toxic)
Nitric Acid (corrosive)
Silver Nitrate
Sodium Chromate (carcinogenic Cr)
Sodium Hydroxide (caustic)
Sulfuric Acid (corrosive)

With normal precautions, experiments involving these compounds can be conducted safely.

Do not allow any eating or drinking in the laboratory. Students should wash thoroughly after handling metals and other reagents.

Procedural and Equipment Hazards

The only asbestos material used should be hard asbestos, which should be handled carefully. Most needs for asbestos can be filled by substituting a Pyrex plate, a watchglass, or one of the new ceramic materials. Remember that asbestos *dust* can be carcinogenic.

If experiments are conducted in which hydrogen is liberated, prepare the students for the explosion potential of hydrogen. Some procedures call for introducing a flaming splint over the mouth of an acid-filled generator, a very dangerous procedure. Even if no explosion occurs, the student's reaction to the bark of the

TABLE 4.3-2

CHEMICALS TYPICALLY USED IN CHEMICAL AND PHYSICAL CHANGE EXPERIMENTS

Health/Safety Hazard	Chemical	Registry Number	Rat Oral LD_{50} (mg/kg)	OSHA TWA	NFPA Code
1/3	Alcohol	KQ63000	14000	1000 ppm	030
0/1	Aluminum	BD03300	NA	NA	011
0/1	Aluminum Chloride	BD05250	3700	NA	302
4/1	Ammonium Dichromate	HX76500	NA	25 $\mu g/m^3$ as Cr	111
3/3	Ammonium Hydroxide	BQ96250	350	50 ppm CL	210
4/1	Barium Nitrate	CQ96250	355	500 $\mu g/m^3$ as Ba	100
1/2	Calcium Carbide	EV94000	NA	NA	142
4/3	Carbon Disulfide	FF66500	NA	3 mg/m^3	230
2/0	Copper (Metal)	CL53250	NA	NA	NA
2/0	Copper (II) Nitrate	GL78750	940	1 mg/m^3 as Cu	100
2/0	Copper Sulfate $5H_2O$	GL89000	300	1 mg/m^3 as Cu	NA
3/3	Hydrochloric Acid	MW40250	900	5 ppm CL	300
0/0	Iron Filings	NO45670	NA	NA	NA
2/2	Iron III Chloride	NO54250	900	1 mg/m^3	NA
2/2	Lead Nitrate	OG21000	NA	200 $\mu g/m^3$	100
1/2	Magnesium	OM21000	NA	NA	012
4/0	Mercury Oxide	OW87500	18	NA	NA
3/3	Nitric Acid	QU57750	NA	2 ppm	300
2/3	Potassium Chlorate	FO03500	NA	NA	200
2/2	Potassium Thiocyanate	NA	NA	NA	NA
4/1	Silver Nitrate	VW47250	NA	10 $\mu g/m^3$ as Ag	100
2/0	Sodium Bromide	VZ31500	3500	NA	NA
1/0	Sodium Chloride	VZ47250	3000	NA	NA
4/3	Sodium Chromate	GB29550	NA	25 $\mu g/m^3$ as Cr	301
2/1	Sodium Hydrogen Carbonate	VZ17500	4220	NA	NA
3/3	Sodium Hydroxide	WB49000	NA	2 mg/m^3	301
2/1	Sodium Iodide	WB64750	4340	NA	NA
2/2	Sodium Sulfite	WE22000	NA	NA	NA
3/1	Sulfur	WS42500	500	NA	210
2/4	Sulfuric Acid	WS56000	2140	1 mg/m^3	302
2/1	Zinc	ZG86000	NA	NA	NA

hydrogen is to jump, which could easily spill the acid in the generator. It is better to collect the hydrogen before testing.

Care must be taken when burning magnesium and aluminum because a great deal of intense ultraviolet light is liberated. The students should wear safety glasses and never look directly into the flame. Severe burns can result from dripping hot magnesium.

Tasting chemicals can be a fatal habit. This aspect of chemical properties should not be investigated with students at this level. Attempting to identify substances by odor can be equally dangerous. The use of taste and smell properties is unsafe and should be discouraged.

Students should have the proper technique of glassware manipulation demonstrated to them in advance of these experiments. They should be shown the procedural nuances in handling hot crucibles, evaporating dishes, test tubes, and laboratory hardware. They should be shown the burner and its parts, and how to manipulate the burner when hot.

Some experiments make better demonstrations when chemicals like ammonium dichromate and calcium carbide are used.

Heating potassium chlorate is always dangerous. Be sure the crucible or test tube is clean and free from organic debris. Explosions have resulted when potassium chlorate contacted rubber and grease.

The fume hood should be used freely in procedures that produce toxic products or smokes. The hood is particularly needed when dealing with carbon disulfide, chromates, hydrogen sulfide, mercury, sulfur dioxide, and similar substances.

Careful control of the issue of solid chemicals or neat liquids must be maintained. While safe in the quantities specified for the experiment, chemicals can become dangerous in the hands of students who believe that if 0.5 g is good, 5 g must work better (or make a better explosion).

The care required when manipulating carbon disulfide cannot be overstated. An incandescent 40-watt light bulb can cause carbon disulfide to ignite and explode.

Teachers should instruct students in the proper manipulation of glassware to reduce hazards from cutting.

Overall Rating

The health hazard from the reagents and materials used in chemical and physical change experiments is relatively moderate if the quantities are controlled. Therefore a health rating of 2 is assigned. Procedures in this class can lead to minor explosions, but flying glass may severely injure unsuspecting students. Because of this the class has an overall safety rating of 2.

4.4 EXPERIMENT CLASS: CONDUCTIVITY AND IONIZATION

Overview

Conductivity and ionization experiments can generally be divided into three categories:

- Conductivity Measurements
- Electromotive Series
- Ion Exchange

The experiments in this class introduce students to the concept of ionization, the properties of ionic compounds, the ease with which metals form ions, and the relative rates of certain ionic reactions, particularly ion exchange.

Chemical hazards in conductivity and ionization experiments can generally be held to a very low level. Active metals used in electrochemical series experiments probably constitute the major chemical hazard, which can be minimized by use of small quantities of metal. These experiments can be better utilized as demonstrations.

Caution must be exercised in the use of electrical equipment.

Chemical and Material Hazards

Since most chemicals used in this experiment class are in solutions when given to students, their potential hazard is greatly reduced. Except for alkali metals, the material hazards are slight.

When dealing with the alkali metals sodium and potassium, the instructor should cut the metals into small portions. Potassium can explode on contact with the air, so the chips should be covered with kerosene until ready to use. Though sodium and calcium can be handled with less danger, it is prudent to use these metals only in demonstrations.

The safety and health hazards of chemicals used in these experiments are tabulated in Table 4.4-1.

Procedural and Equipment Hazards

Experiments measuring the conductivity of a solution use an electrical system. The intensity of the current-carrying ability of the solution is measured. Such measuring devices have two electrodes that must be exposed and dipped into the solution. These electrodes can be the source of a severe shock. Any water or solution near the equipment can be the source of electrical shock.

Safety glasses or goggles and a safety shield should be used in experiments dealing with alkali metals and the electromotive series.

Procedures dealing with conductivity generally involve only electrical hazards. Those procedures involving fused salts involve greater degrees of hazard and are not necessary to convey concepts.

Overall Rating

All aspects considered, an overall rating is assigned of 2 for health hazards and 1 for safety hazards in conductivity and ionization experiments.

TABLE 4.4-1

CHEMICALS TYPICALLY USED IN CONDUCTIVITY AND IONIZATION EXPERIMENTS

Health/Safety Hazard	Substance	Registry Number	Rat Oral LD_{50} (mg/kg)	OSHA TWA	NFPA Code
1/3	Acetone	AL31500	9750	1000 ppm	130
3/0	Ammonium Carbonate	BP19250	86	NA	NA
4/0	Ammonium Thiocyanate	XK78750	NA	NA	NA
4/0	Barium Chloride	CQ87500	118	500 μ/m^3 as Ba	NA
4/1	Barium Nitrate	CQ96250	355	500 μ/m^3 as Ba	100
3/2	Calcium	EV80400	NA	NA	112
3/0	Dimethylglyoxime	EK29750	250	NA	NA
4/0	Lead	OF75250	NA	200 μ/m^3 as Pb	NA
4/0	Mercury II Iodide	OW52500	40	50 μ/m^3 as Hg	NA
1/3	Methanol	PC14000	13000	200 ppm	130
4/1	Nickel Nitrate	QR72000	NA	15 μ/m^3 as N	NA
4/3	Potassium	TS64600	NA	NA	312
2/3	Potassium Chlorate	FO03500	NA	NA	200
2/0	Potassium Sulfate	TT59000	NA	NA	NA
2/2	Potassium Thiocyanate	XL19250	NA	NA	NA
3/2	Sodium	VY06990	NA	NA	312
2/1	Sodium Carbonate	VZ40500	NA	NA	NA
1/0	Sodium Chloride	VZ47250	3000	NA	NA
0/0	Sucrose	WN65000	29700	NA	NA

4.5 CRYSTALS

Overview

Experiments on solids and crystals can be thought of in three categories:

Crystal Models and Structure
Analytical Chemistry and Hydrates
Complexes

These experiments help the student understand micro- and macrocrystalline structure, interchanges of crystalline structure, and the role of complexing liquids in establishing crystallinity.

Chemical and Material Hazards

Common experiments with crystals involve very few hazardous materials. Probably the most dangerous chemical is carbon disulfide. Work with this chemical must be conducted away from sources of flame or spark; even a hot light bulb will ignite carbon disulfide.

When building crystals with styrofoam balls, care should be taken not to use the new, super-stick glues. Some of these cements can glue fingers together so well that they must be surgically separated.

Procedural Hazards

When working with iodine, carbon disulfide, and sulfur, use the fume hood. Vapors of carbon disulfide can be ignited by a light bulb. Vapors of iodine are toxic and iodine is corrosive. Evaporation of iodine should be carried out in a fume hood.

When making crystals of ammonium chloride, do not heat the test tube directly with a flame. Use a hot water bath or hot plate. Be sure to use Pyrex test tubes so that they can be cooled without breaking.

Copper tetramine sulfate is a good crystalline model. When preparing this substance, safety glasses and fume hoods are needed.

When heating crucibles in the analysis for water of hydration of barium chloride, care should be taken; the crucibles become very hot. They should be supported by a clay triangle when heated with a flame. Students should be cautioned about the intense heat.

Overall Rating

The overall rating of these experiments is 1 for health and 0 for safety hazards, assuming strict control of carbon disulfide.

TABLE 4.5-1

CHEMICALS USED IN CRYSTAL EXPERIMENTS

Health/Safety Hazard	Chemical	Registry Number	Rat Oral LD_{50} (mg/kg)	OSHA TWA	NFPA Code
2/2	Ammonium Chloride	BP45500	1650	NA	200
3/3	Ammonium Hydroxide	BQ96250	350 CL	50 ppm	210
4/0	Barium Chloride	CQ87500	118	500 μ/m^3 as Ba	NA
4/3	Carbon Disulfide	FF66500	NA	3 mg/m^3	230
2/0	Copper Sulfate	GL89000	300	IN/m^3 as Cu	NA
1/3	Ethanol (Ethyl Alcohol)	KQ63000	14000	1000 ppm	030
3/3	Iodine	NN15750	NA CL	.1 ppm	300
1/0	Sodium Chloride	VZ47250	3000	NA	NA
3/1	Sulfur	WS42500	500	NA	210

4.6 EXPERIMENT CLASS: DENSITY MEASUREMENTS

Overview

Density measurement experiments introduce the concepts of mass and volume, and offer students the opportunity for high precision measurements. Typical experiments involve solids, liquids, and gases.

Chemical and Material Hazards

No specific materials hazards are involved, as long as one is selective about the materials used for measurement. Water is necessary if specific gravity is to be measured. Good organic liquids include glycerol and glycerol-water solutions, aliphatic alcohols of larger molecular weights, and chlorinated hydrocarbons of longer chain lengths.

Procedural Hazards

The only procedural hazards are in the measurement of the density of air. All evacuated glassware must be protected so that the risk of injury from implosion is reduced. Safety glasses are absolutely necessary.

Overall Rating

The overall rating for this class is 0 for health hazards and 0 for safety hazards.

4.7 EXPERIMENT CLASS: EQUILIBRIUM

Overview

Experiments on equilibrium usually illustrate La Chatlier's principle. Generally these experiments are not quantitative but observational and deal with dilute solutions and procedures that entail little hazard.

Chemical and Material Hazard

Except for compounds of chromium and their chronic carcinogenic effects, few solutions in these experiments cause problems. However, if students prepare their own solutions, care must be used; corrosive acids and dangerous solids will be encountered. Table 4.7-1 illustrates the typical chemical hazards encountered.

Procedural Hazards

The ordinary precaution of wearing safety glasses is urged. Care in diluting any solutions must be exercised. Use pipette bulbs. Remember, acids must be poured into water slowly, with vigorous stirring.

Overall Rating

No real or great health/safety hazard exists in these experiments as long as dilute solutions are used. An overall rating of 1/1 is assigned, unless students prepare their own solutions in which case a 1/2 rating is appropriate.

4.8 EXPERIMENT CLASS: GAS LAWS

Overview

Experiments in this class expose students to experimental verification of the classical gas laws. Included are experiments involving:

TABLE 4.7-1

CHEMICALS TYPICALLY USED IN EQUILIBRIUM EXPERIMENTS

Health/Safety Hazard	Chemical	Registry Number	Rat Oral LD_{50} (mg/kg)	OSHA TWA	NFPA Code
2/2	Acetic Acid	AF12250	3310	10 ppm	221
3/3	Ammonium Hydroxide	BQ96250	350 CL	50 ppm	210
4/2	Barium Chromate	NA	NA	NA	NA
4/1	Barium Nitrate	CQ96250	355	500 μ/m^3 as Ba	100
1/1	Calcium Hydroxide	EQ28000	7340	NA	NA
1/3	Ethanol	KQ63000	14000	1000 ppm	330
2/1	Iron Nitrate	NO71750	3250	NA	NA
3/3	Nitric Acid	QU57750	NA	2 ppm	300
4/1	Potassium Chromate	GB29400	NA CL	100 μ/m^3 as CrO_3	NA
4/1	Potassium Dichromate	HX76800	NA	25 μ/m^3	101
3/3	Potassium Hydroxide	TT21000	365	2 mg/m^3	301
3/2	Potassium Thiocyanate	XL19250	NA	NA	NA
2/4	Sulfuric Acid	WS56000	2140	1 mg/m^3	302

V dependency on P	Boyle's law
V dependency on T	Charles's law
P dependency on T	Gay-Lussac's law
Molar volume concepts	
Mass relationships	
Rate of diffusion	Graham's law

Typically these experiments offer little hazard over that expected when working with glassware. Work with mercury in glass requires extra care; the weight of the mercury can often stress and break glass. The health hazard of mercury is significant, but can be avoided.

Chemical and Material Hazards

The chief chemical hazard in these experiments arises from the traditional use of mercury for pressure-measuring manometers. Mercury's TLV is .05 mg/m^3; air saturated with mercury vapor contains about 15 mg mercury/m^3. Most laboratory workers handle mercury all too casually, considering that mercury vapor is 100 times more toxic than hydrogen cyanide. Metallic mercury is much less a hazard.

The effects of mercury toxicity are cumulative. Chronic exposure to mercury vapor at low concentrations can lead to mercury intoxication because mercury is eliminated very slowly from the body.

Mercury spills must be avoided. If spills do occur, however, they must be cleaned up completely. All the mercury spilled should be collected and returned to a closed container. Spills can be swept with a brush into a plastic dustpan; cracks and the areas under furniture can be cleaned up with a pointed tube at the end of a vacuum pump or aspirator. A collection vessel must be placed in the vacuum line.

Care must be taken because of the rapidly shifting weight of mercury in a container.

A dusting with powder sulfur or wet sawdust followed by a thorough cleaning, when repeated two or three times, will generally remove the last traces of mercury. Such treatment is effective, however, only if preliminary cleaning and vacuuming has been performed.

Mercury can amalgamate other metals easily. Vapor can be also released from the amalgams. Metal structures can be weakened from mercury contact.

Because vaporization of mercury is a function of temperature, mercury should not be used near heaters.

Further information can be obtained from "Mercury Vapor Hazards and Control Measures" written by N. V. Steere and published in the *Journal of Chemical Education* 42(7): A529, July 1965.

The use of mercury in these experiments can be circumvented to a great degree by the use of plastic syringes or "pistons," an experimental setup illustrated in Figure 4.8-1. Many designs of this apparatus have appeared in the literature. Instructors are referred to the pub-

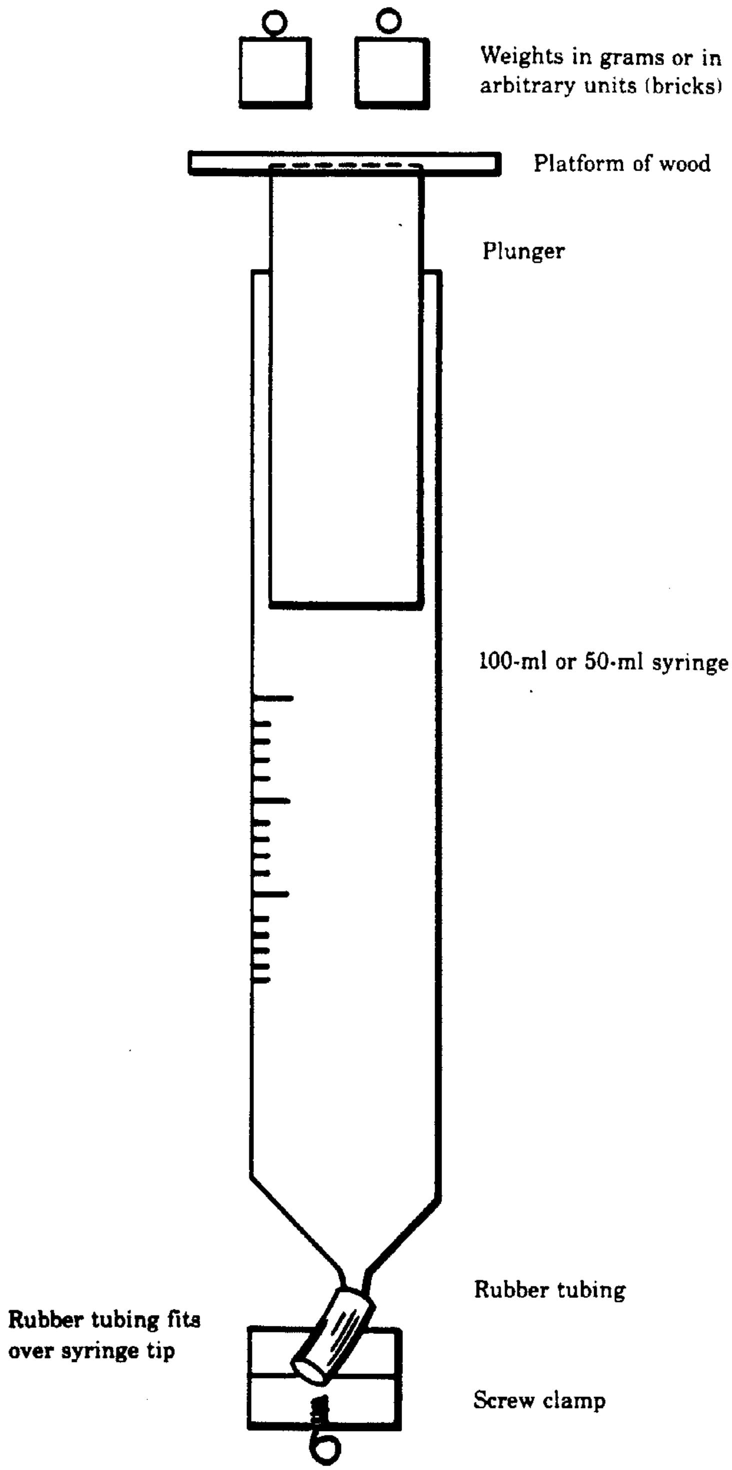
Weights in grams or in arbitrary units (bricks)
Platform of wood
Plunger
100-ml or 50-ml syringe
Rubber tubing
Rubber tubing fits over syringe tip
Screw clamp

FIGURE 4.8-1

lications *Science Teacher*, *Science and Children*, *Journal of Chemical Education*, and *Introductory Physical Science* for construction details. Commercial versions of the setup are available in most supply houses.

Use of shallow cafeteria-type trays with slick, nonmetallic finishes under equipment that contains mercury or under experiments using mercury greatly reduces the hazards inherent in working with mercury. The trays are adequate to contain most spills.

Most experiments dealing with molar volumes involve magnesium, aluminum, lithium, calcium, and sodium. Science teachers are cautioned to the hazards inherent in these active metals when used with water and dilute acid. The hydrogen generated is explosive and the solutions are acidic.

Destroy excess sodium with isopropyl alcohol. Take care regarding the flammability of isopropanol and sodium isopropoxide.

Procedures and Equipment

If normal care is taken with the glassware and air lines, few procedural and equipment hazards exist. Be sure that glass tubing is lubricated before insertion into rubber stoppers.

Care must be taken if liquid nitrogen and dry ice/acetone baths are used. The hands and flesh must be protected from the extreme cold of these agents. Do not touch dry ice with bare hands; severe burns can result. Dry ice/acetone baths are also extremely flammable. Liquid nitrogen can so effectively freeze flesh (which becomes brittle) that fingers can be snapped right off.

When working with sodium, be sure that the working area is clean and dry.

Overall Rating

If mercury is extensively used by students in noncommercial mercury manometers or barometers, a health hazard rating of 4 is assigned. If alternatives to mercury are used, the health hazard is significantly reduced.

Because of the hazards involved with supercold systems and the flammable nature of some materials, a safety rating of 1 is assigned. Thus, the overall rating is of 4 for health and 1 for safety.

If the mercury, liquid nitrogen, and dry ice/acetone baths are not used, the health/safety rating for this class can be reduced to 0/0.

4.9 EXPERIMENT CLASS: HEAT OF REACTION

Overview

Experiments in this class usually involve neutralization reactions and illustrate concepts of heats of reactions. Typically these are all straightforward reactions involving common laboratory chemicals. The experiments are semiquantitative.

Chemical and Material Hazards

Chemicals usually used in experiments (dealing with heat of reaction) are listed in Table 4.9-1. Most offer serious threats to health and safety, and must be approached with much care. One factor that makes them dangerous is the heat released in reactions involving these substances.

Generally the chemicals will produce burns rather than result in toxic effects, although some students have attempted to ingest them. Dusts from the solids and mists from the acids must be avoided.

The nature of the hazards involved should be discussed with students before allowing them to experiment. The ability of NaOH to absorb both water and carbon dioxide should be discussed with students. This is a good way to reinforce the fact that students should not pick up NaOH or KOH pellets with the fingers.

Procedural Hazards

These experiments offer an excellent opportunity to reinforce the need for students to wear safety glasses and laboratory aprons or coats. Sodium and potassium hydroxides should be handled with extreme care. Use of tweezers or scoops is advised.

A solution of 0.1 m acetic acid and a quantity of sodium bicarbonate should be kept to neutralize acid spills.

The use of safety showers and eyewash stations should be demonstrated. It should be pointed out that the best first aid for burns is flooding with a copious amount of water. Do not attempt to neutralize acid or alkali spills on the skin.

When stirring solutions, use a stirring rod, not a thermometer. Care must be taken while stirring not to break the thermometer.

When using acids in gas burets, often the acid is added first to the buret, then the water. Because the acid is usually a diluted hydrochloric acid, the technique, although unusual,

TABLE 4.9-1

CHEMICALS TYPICALLY USED IN THERMOCHEMISTRY EXPERIMENTS

Health/Safety Hazard	Chemical	Registry Number	OSHA TWA	Rat Oral LD_{50} (mg/kg)	NFPA Code
2/2	Acetic Acid	AF12250	10 ppm	3310	221
3/3	Ammonium Hydroxide	BQ96250	50 ppm CL	350	210
3/3	Hydrochloric Acid	MW40250	5 ppm CL	NA	300
1/2	Magnesium	OM21000	NA	NA	012
1/1	Magnesium Oxide	OM38500	15 mg/m^3	NA	
3/3	Nitric Acid	QU57750	2 ppm	NA	300
3/3	Potassium Hydroxide	TT21000	2 mg/m^3	365	301
3/3	Sodium Hydroxide	WB49000	2 mg/m^3	NA	301

is safe if the water is poured slowly. It is *never* safe if the acid is sulfuric acid.

Sulfuric acid is particularly hard on clothing. Be sure that the acid is kept off clothing and does not contaminate workspaces.

Overall Rating

The health hazard in experiments on heat of reaction is comparatively low. Despite their toxicity, the materials have a health hazard rating of 2; perhaps a lower rating would be appropriate if most work were to be carried out in a hood. The safety hazard is 3. By their very nature, the greatest hazard in these procedures is in handling the reagents.

4.10 EXPERIMENT CLASS: MEASUREMENT

Overview

Most experiments in this class determine the density of a variety of substances, at which time students learn the proper techniques of measuring fundamental properties of length, mass, and volume.

Chemical and Material Hazards

Hazards involved in densimetric measurements depend on the chemicals selected for measurement. The traditional favorites, carbon tetrachloride, chloroform, and benzene, all are extremely toxic and are suspected carcinogens. Suitable replacements include perchloroethylene, toluene, and solutions of glycerol in water.

The use of metals in this context presents trivial hazards; care must be exercised, however, not to break glass tubes with the shot.

Overall Rating

An overall hazard rating of 1 for health and 0 for safety is assigned with the assumption that carbon tetrachloride, trihalomethanes, and benzene are not used.

4.11 EXPERIMENT CLASS: ORGANIC CHEMISTRY

Overview

These experiments introduce students to the nature, structure, and reactivity of organic compounds. Generally the experiments focus on the structure of organic compounds and the characteristic properties of hydorcarbons, alcohols, acids, and esters.

Organic synthesis experiments are, in general, greater health and safety hazards than typical high school inorganic and analytical experiments. These hazards are typified by the generally increased volatility and flammability of organic compounds.

High school instructors should take the time to review and demonstrate the proper use of firefighting equipment. Instructors should also design the experiments to be performed in fume hoods of proper design. The use of hoods usually reduces the hazards from fire and explosion as well as from toxic substances.

Chemical and Material Hazards

Experiments in this class and the health and safety hazards associated with them are reviewed in Table 4.11-1.

Most chemicals listed have health hazard ratings in the 1-2 category, which means they are relatively free of problems if used in very small quantities, in hoods, or in well-ventilated situations. These chemicals have flammability hazards in the 3 category, which means they can easily ignite and burn. Because of their volatility, they can explode if appropriate conditions exist.

Benzene is considered to be carcinogenic in humans. In most cases, toluene can be substituted for benzene without problems, and is much safer to handle.

Particular care must be taken with bromine, hydrochloric acid, soda lime, sodium hydroxide, and sulfuric acid; all are corrosive and can cause very serious burns. Sulfuric acid causes second-degree burns on contact, and liquid bromine as the pure element causes third-degree burns on contact.

Benzoyl peroxide is explosive. Only handle a little at a time. When dry, benzoyl peroxide is highly flammable, and at elevated temperatures it is spontaneously explosive. It is sensitive to shock, heat, and friction.

Calcium carbide is dangerous when wet. When dry it is relatively stable, but on contact with water, acetylene is produced. Acetylene is an explosive gas and can react with several metals to form spontaneously explosive products. Sufficient heat is generated on contact with water to cause acetylene to explode.

Procedural Hazards

The substitution of electrical hot plates with sealed elements for Bunsen burners is suggested. Because the surface temperature of a hot plate can be kept well under the temperature of a flame, there is less chance of exceeding the ignition temperature of the sample.

Students should be given appropriate instructions on labeling procedures.

Most of the experiments are safest if conducted in a fume hood. Students should be well-protected with aprons or lab coats and, above all, safety glasses or goggles.

Some highly dangerous experiments such as the production of acetylene, and procedures using benzene and carbon tetrachloride, can be best done as demonstrations.

Substitute perchlorethylene for carbon tetrachloride. Carbon tetrachloride is a carcinogen and acutely toxic.

All gas generators must be frequently checked for blockages.

In any polymerization process involving free radicals, there is a great possibility of explosion. Be sure benzoyl peroxide is used in small quantities only.

Metallic sodium should be destroyed with alcohol (ethanol or isopropanol).

Do not allow students to inhale the vapor and gases produced by this class of experiments and be certain that only small quanitites of materials are dispensed.

Equipment Hazards

Open flames are hazardous in many of these experiments. Students should be instructed in the safe use of hot plates and other electrical heating equipment.

Hazards arise from two sources. Hot plate surfaces often do not show signs of heating. The hands can be severely burned if a student places a hand on the surface.

The second source of hazard is electrical shock. The corrosive atmosphere of laboratories is hard on switches and cords. Hot plates should be inspected before use and not put into service with frayed cords or faulty switches. Hot plates must be used only on dry surfaces.

Overall Rating

A health hazard rating of 2 and a safety rating of 3 is assigned to this class of experiments. The quantities of chemicals are sufficient to warrant the high potential safety hazard.

4.12 EXPERIMENT CLASS: OXIDATION AND REDUCTION

Overview

These experiments introduce students to the concepts of oxidation number, cell EMF, redox reactions, and typical redox reagents. The experiments utilize typical redox reagents in solution form. Comparatively little hazard exists with these experiments because of the dilute solutions normally used. If students prepare their own solutions, the hazard risks increase dramatically.

Experiments involving chromium should be avoided. Chromium is a suspected carcinogen and its use is to be avoided in all but absolutely necessary situations. Oxidation and reduction reactions using cobalt available in sources such as Jolly's *Inorganic Synthesis* represent far safer systems.

TABLE 4.11-1

CHEMICAL AND MATERIAL HAZARDS FOR ORGANIC EXPERIMENTS

Health/Safety Hazard	Chemical	Registry Number	OSHA TWA	Rat Oral LD_{50} (mg/kg)	NFPA Code
2/2	Acetic Acid	AF12250	10 ppm	3310	221
1/4	Acetylene	AO96000	2500 ppm CL	NA	143
3/2	Aniline	BW66500	5 ppm	440	320
*4/3	Benzene	CY14000	10 ppm	3800	230
2/3	Benzoyl Peroxide	DM85750	5 mg/m^3	NA	144
3/3	Bromine	EF91000	0.1 ppm	NA	400
2/3	n-Butanol	EO14000	100 ppm	790	130
1/3	Sec-Butanol	EO17500	150 ppm	6480	130
2/3	t-Butanol	EO19250	100 ppm	3500	130
1/3	Calcium Carbide	EV94000	NA	NA	142
2/0	Calcium Chloride	EV98000	1000	NA	NA
2/1	Calcium Hydroxide	EW28000	2 mg/m^3	7340	NA
2/1	Calcium Oxide	EW31000	5 mg/m^3	NA	101
0/3	Cyclohexane	EU63000	300 ppm	29820	130
1/3	Cyclohexene	GW25000	300 ppm	NA	NA
1/3	Ethanol	KQ63000	1000 ppm	14000	030
1/3	Ethyl Acetate	AH54250	400 ppm	11000	130
2/1	Formaldehyde	LP89250	3 ppm	800	240
1/1	Glycerol	MA80500	NA	12600	110
3/3	Hydrochloric Acid	MW40250	5 ppm	NA	340
4/4	Hydrogen Sulfide	MX12250	10 ppm	NA	340
3/0	Lead Acetate	AI52500	200 $\mu g/m^3$	NA	NA
1/2	Magnesium	OM21000	NA	NA	012
0/4	Methane	PA14900	NA	NA	NA
1/3	Methanol	PC14000	200	13000	130
0/0	Methyl Methacrylate	PP73500	NA	NA	NA
2/3	n-Pentanol	SB98000	NA	3030	NA
2/0	Perchloroethylene	KX38500	100 ppm	NA	NA
2/2	Potassium Permanganate	SD64750	NA	1090	100
2/1	Salicyclic Acid	VO05250	NA	891	NA
4/1	Silver Nitrate	VW47250	10 μg as Ac	NA	100
2/3	Soda Lime	VX96500	NA	NA	NA
2/1	Sodium Acetate	AS43750	NA	3530	NA
2/1	Sodium Carbonate	VZ40500	NA	NA	NA
3/3	Sodium Hydroxide	WB49000	2 mg/m^3	NA	301
2/4	Sulfuric Acid	WS56000	1 mg/m^3	2140	302
1/3	Toluene	XS52500	200 ppm	5000	230

*Carcinogen

The use of personal protective devices is always encouraged. Safety glasses and goggles are suggested for all experiments. Aprons or lab coats should be worn also.

Chemical and Material Hazards

Typical chemicals used in oxidation and reduction experiments are listed in Table 4.12-1. In the standard form these reagents have typical health hazards rated at 3 and safety ratings of about 2. However, most reagents are used in dilute solution, which substantially lowers the actual hazard involved.

Appropriate use of fume hoods, which lessens the actual exposure substantially, is encouraged. Trichlorotrifluoroethane (TTE) and perchloroethylene should be substituted for the more traditional extraction solvents of chloroform and carbon tetrachloride.

Halogens show almost the same color in TTE as they do in carbon tetrachloride. Carbon tetrachloride has a TLV of 76 ppm and TTE has a TLV of 7,600 ppm. Carbon tetrachloride is a suspected carcinogen.

The widespread use of fairly concentrated acids is common to these experiments. Precautions must be taken with concentrated acids, and students must be trained to handle them safely. Sulfuric acid in particular is difficult to handle.

Sulfur dioxide and hydrogen sulfide gases are liberated in several experiments in this class. Care must be taken because both are quite toxic. Students should be cautioned against direct inhalation of these gases.

Students and faculty should not be casual in their work with these materials.

Take appropriate precautions with iodine and use only in a fume hood. Iodine stains can be removed with moistened sodium thiosulfate crystals followed by thorough washing.

Students should be cautioned about the use of flammable solvents near fire or flame, or near electrical equipment that can cause a spark.

Many salts of strong acids hydrolyze to some extent in water. Care should be exercised in dealing with these substances.

If chlorine or bromine generators are to be used, be sure that they are used in a hood. Glycerol, applied promptly to bromine contact, can reduce the burning.

Instructors should remember that bromine can cause third-degree burns almost on contact.

Safety precautions should be taken in storage and disposal of redox chemicals. Do not store oxidants near reducing agents. Do not throw waste chemicals down the drain or in waste cans made of plastics. Do not dispose of waste chemicals in cans that could be filled with paper, as paper is an excellent reducing agent. The Manufacturing Chemist Association's *Guide to Laboratory Safety* offers good information on reagent disposal.

Equipment hazards

Many experiments of this type involve the use of electrical source equipment rated at 0-12 volts and up to 2 amps. This equipment can, in the presence of very conductive electrolytes, cause a severe shock. The area near this equipment should be clean and dry, the equipment properly grounded, and the equipment in physically good condition. The power cord and the lead wires should be appropriately insulated. Remember that weaker currents of 80 mA are fatal.

Overall Rating

The overall hazard is rated at 2 for health and 1 for safety as long as students do not prepare their own solutions and if only small quantities of reagents are used.

4.13 EXPERIMENT CLASS: QUALITATIVE ANALYSIS

Overview

These experiments attempt to identify substances based on their chemical and physical properties. Various separation techniques are illustrated.

Included in this class are:

- Flame tests and spectra
- Precipitation separation of Pb, Ag, Hg
- Other analytical examples

Semi-micro procedures should be followed if possible.

The need for personal hygiene should be stressed.

Chemical Hazards

Little chemical hazard exists in this type of experiment, provided that reasonable controls are maintained. Reagents can be distributed in dropper bottles. If concentrated acids are used, however, care must be exercised. Very dilute solutions are used throughout.

Usually metal nitrates are used as samples in these experiments. Typical reagents used are given in Table 4.13-1.

Procedural Hazards

Glassware should be used with care. Hot water baths should be used to warm reactions, and students should be advised of the dangers in boiling water baths, especially if the baths are upset.

Safety goggles must be worn at all times and students should be directed to do flame tests in fume hoods.

Equipment Hazards

Centrifuges are used extensively in this work. Care must be taken to keep them bal-

TABLE 4.12-1

CHEMICAL HAZARDS IN OXIDATION AND REDUCTION EXPERIMENTS

Health/Safety Hazard	Chemical	Registry Number	OSHA TWA	Rat Oral LD_{50} (mg/kg)	NFPA Code
2/2	Acetic Acid	AF12250	10 ppm	3310	221
1/3	Acetone	AL31500	1000 ppm	9750	130
0/1	Aluminum	BD03300	NA	NA	011
3/3	Ammonium Hydroxide	BQ96250	50 ppm CL	350	210
3/0	Ammonium Carbonate	BP19250	NA	96	NA
4/1	Barium Oxide	CQ98000	500 $\mu g/m^3$ as Ba	NA	NA
*4/1	Chromium (111) Acetate	AG30500	NA	NA	NA
*4/1	Chromium (111) Sulfate	GB72000	NA	NA	NA
0/0	Copper (metal)	GL53250	NA	NA	NA
2/1	Copper Nitrate	GL78750	1 $\mu g/m^3$ as Cu	940	100
2/0	Copper Sulfate	GL89000	1 $\mu g/m^3$ as Cu	300	NA
1/3	Ethanol	KQ63000	1000 ppm	14000	030
3/3	Hydrogen Peroxide	MX09000	1 ppm	NA	203
3/3	Hydrochloric Acid	MW40250	5 ppm CL	NA	300
0/0	Iron	NO45670	NA	NA	NA
2/2	Iron (III) Chloride	NO54250	1 mg/m^3	NA	NA
2/1	Iron (II) Sulfate	NO85100	NA	1520	NA
3/3	Iodine	NN15750	.1 ppm CL	NA	NA
3/0	Lead	OF75250	200 $\mu g/m^3$	NA	NA
3/2	Lead Nitrate	OM21000	NA	NA	012
1/2	Magnesium	OM21000	NA	NA	012
1/1	Magnesium Nitrate	OM37500	NA	NA	NA
3/1	Manganese Dioxide	OP03500	NA	NA	NA
3/1	Manganese Sulfate	OP10500	NA	120	NA
3/3	Nitric Acid	QU57750	2 ppm	NA	300
2/1	Potassium Bromide	TS76500	NA	NA	NA
2/3	Potassium Chlorate	FO03500	NA	NA	200
4/0	Potassium Cyanide	TS87500	5 mg/m^3 as Cn	10	300
*4/2	Potassium Dichromate	HX76800	25 $\mu g/m^3$ as Cr	NA	101
3/3	Potassium Hydroxide	TT21000	2 mg/m^3	365	301
3/1	Potassium Iodate	NN13500	NA	NA	NA
3/0	Potassium Iodide	TT29750	NA	NA	NA
2/1	Potassium Nitrate	TT37000	NA	500	100
2/2	Potassium Permanganate	SD64750	NA	1090	100
4/1	Silver (Metal)	VW35000	10 $\mu g/m^3$	NA	NA
4/1	Silver Nitrate	VW47250	10 $\mu g/m^3$ as Ag	NA	100
2/1	Sodium Bisulfite	VZ20000	NA	NA	NA
2/0	Sodium Bromide	VZ31500	NA	3500	NA
2/1	Sodium Carbonate	VZ40500	NA	NA	NA
2/1	Sodium Carbonate	VZ40500	NA	NA	NA
1/0	Sodium Chloride	VZ47250	NA	3000	NA
*4/1	Sodium Dichomate	HZ77000	100 $\mu g/m^3$ as CrO_3	NA	101
3/3	Sodium Hydroxide	WB49000	2 mg/m^3	NA	301
2/3	Sodium Hypochlorite	NA	NA	NA	NA
2/1	Sodium Iodide	WB64750	NA	4340	NA
4/0	Sodium Oxalate	RO39000	NA	NA	NA
1/0	Sodium Phosphate	WD59500	NA	7400	NA
2/1	Sodium Sulfate	WE16500	NA	NA	NA

TABLE 4.12-1 (Continued)

Health/Safety Hazard	Chemical	Registry Number	Rat Oral LD_{50} (mg kg)	OSHA TWA	NFPA Code
3/2	Sodium Sulfide	WE19000	NA	NA	NA
2/2	Sodium Sulfite	WE22000	NA	NA	NA
2/0	Sodium Thiocyanate	XL22750	NA	764	NA
2/0	Sodium Thiosulfate	WE66600	NA	NA	NA
3/3	Sulfuric Acid	WS56000	1 mg/m^3	2140	302
3/0	Tin (II) Chloride	XP87000	2 mg/m^3 as Sn	700	NA
2/0	Trichlorotrifluoroethane	KJ40000	1000 ppm	45	NA
2/1	Zinc Metal	ZG86000	NA	NA	011
2/1	Zinc Nitrate	ZH47750	NA	1190	NA
3/1	Zinc Sulfate	ZH52600	NA	50	NA

*Carcinogen

anced or they will explode the tubes. Students should be cautioned to ensure that the centrifuges are kept dry. Centrifuges should be checked for electrical problems, particularly in the plug and power line.

Overall Rating

An overall rating of 0/1 is assigned to the health/safety hazards of qualitative analysis experiments.

4.14 EXPERIMENT CLASS: RADIATION CHEMISTRY

Overview

Relatively few experiments on radioactivity are found in chemistry course curricula.

Chemical and Material Hazards

Little hazard exists in these experiments. Students should be cautioned on the chemical as well as radiation hazards of samples. Radioactive fluids should never be pipetted orally.

The reader is referred to Chapter 3 of this text for a discussion of sources, inspection, records, and license requirements and regulations.

Equipment Hazards

An electrical, high-voltage hazard exists in Geiger counters; care must be exercised.

Overall Rating

The health/safety hazard rating assigned to these experiments is 0/0.

4.15 EXPERIMENT CLASS: REACTIONS AND CALCULATIONS (STOICHIOMETRY)

Overview

Reactions and experiments ordinarily found in this class can vary widely in type, purpose, and concept. Quantitative experiments include work such as identifying the percent composition of a substance, the mole ratio of an equation, the composition of a hydrate, and molar volume of gases. The nonquantitative experiments are closely related to those in the Chemical Families class. A third group of experiments closely resembles procedures already discussed under Equilibrium.

The quantitative experiments focus on the basis of stoichiometry. The other experiment types are illustratory.

Chemical and Material Hazards

Chemical and material hazards in these experiments are highly dependent on the type of experiment performed and on the conditions employed. Much also depends on the approach of the instructor toward safe laboratory procedures. Chemical hazards for this class are listed in Table 4.15-1.

If students use pre-prepared solutions, the hazards are dramatically reduced. If students are exposed to dusts and mists, the hazards are increased.

Most experiments are fairly free of substantial chemical hazard. However, several items need to be underscored.

Many reactions call for the use of potassium chlorate, which is explosive if it encounters any reducing agents. Rubber in stoppers can provide that source of reducant. Never allow potassium chlorate to contact rubber. If sparking begins in an oxygen generator, remove the heat source immediately and withdraw any delivery tubes from any kind of water. Do not allow water to back up into the generator; an explosion will result.

Sodium thiosulfate will oxidize silver and remove silver or iodine stains.

When handling nitric acid, remember the likelihood of NO_2 fumes when the acid contacts

TABLE 4.13-1

CHEMICAL HAZARDS IN ELEMENTARY QUALITATIVE ANALYSIS

Health/Safety Hazard	Chemical	Registry Number	Rat Oral LD_{50} (mg/kg)	OSHA TWA	NFPA Code
2/2	Acetic Acid	AF12250	3310	10 ppm	221
2/2	Ammonium Chloride	BP45500	1650	10 mg/m^3	200
3/3	Ammonium Hydroxide	BQ96250	350	50 ppm CL	210
4/2	Barium Chromate	NA	NA	NA	NA
4/1	Barium Nitrate	CQ96250	355	0.5 mg/m^3 as Ba	100
2/0	Calcium Carbonate	EV95800	NA	10 mg/m^3	NA
2/1	Calcium Nitrate	EW30000	3900	NA	NA
2/1	Cobalt Nitrate	GG11090	NA	NA	100
0/0	Copper (Metal Wire)	GL53250	NA	1 mg/m^3 (Dust)	NA
2/0	Copper Nitrate	GL78750	940	1 mg/m^3 as Cu	100
3/3	Hydrochloric Acid	MW40250	NA	5 ppm CL	300
2/1	Iron (II) Sulfate	NO85100	1520	NA	NA
3/2	Lead Nitrate	OG21000	NA	0.2 mg/m^3 p6	100
3/1	Manganese Sulfate	OP10500	120	NA	NA
4/0	Mercury (I) Nitrate	OW80000	297	NA	NA
3/3	Nitric Acid	QU57750	NA	2 ppm	300
4/1	Nickel Chloride	QR64800	48	0.015 mg/m^3 as Ni	NA
4/1	Nickel Nitrate	QR72000	NA	0.015 mg/m^3 as Ni	NA
2/0	Potassium Chloride	TS80500	552	NA	NA
4/2	Potassium Chromate	GB29400	NA	0.1 mg/m^3 CrO_3	NA
2/1	Potassium Nitrate	TT37000	NA	NA	100
4/1	Silver Nitrate	VW47250	NA	.010 mg/m^3	100
1/0	Sodium Chloride	VA47250	3000	NA	NA
3/3	Sodium Hydroxide	WB49000	NA	2 mg/m^3	301
2/1	Sodium Iodide	WB64750	4340	NA	NA
3/1	Sodium Nitrate	WC56000	NA	NA	NA
2/4	Sulfuric Acid	WS56000	2140	1 mg/m^3	302
2/1	Zinc Nitrate	ZH47750	1190	NA	NA

a metal. Nitric acid dissolution and reactions should always be carried out in a fume hood.

Silver nitrate can cause serious burns. Treat with water and sodium thiosulfate.

Students should wash thoroughly when working in the laboratory. Remember safety glasses and aprons or coats.

Label accurately. Since many reagents have names that sound alike, be sure to label with name and formula.

Procedural Hazards

Reagents are heated in most of these experiments. Hot acids burn worse than cold acids. Use extra care.

Remember to check gas generators for freedom from obstructions; obstructions can cause explosions.

Remind students of the precautions necessary when dealing with hot equipment. Burns are very likely in this class of experiments. Likewise, accidents caused by students letting go of hot objects must be considered.

Overall Rating

An overall health/safety hazard rating of 2/2 is assigned to this class of experiments.

4.16 EXPERIMENT CLASS: REACTION RATES

Overview

This class of experiments illustrates the concept of reaction rates and explores the effects of temperature, concentration, and catalysis.

These experiments generally present little hazard but do, however, offer much scientific experience.

TABLE 4.15-1

CHEMICAL HAZARDS IN STOICHIOMETRY EXPERIMENTS

Health/Safety Hazard	Chemical	Registry Number	Rat Oral LD_{50} (mg/kg)	OSHA TWA	NFPA Code
2/2	Acetic Acid	AF12250	3310	10 ppm	221
1/3	Acetone	AL31500	9750	1000 ppm	130
2/2	Ammonium Chloride	BP45500	1650	10 mg/m^3	200
3/3	Ammonium Hydroxide	BQ76250	350	50 ppm CL	210
4/0	Barium Chloride	CQ87500	118	.5 mg/m^3	NA
2/0	Calcium Carbonate	EV95800	NA	10 mg/m^3	NA
2/0	Calcium Chloride	EV98000	1000	NA	NA
0/0	Copper (Metal Wire)	GL53250	NA	1 mg/m^3	NA
2/0	Copper Sulfate	GL89000	300	1 mg/m^3	NA
3/3	Hydrochloric Acid	MW40250	900	5 ppm CL	300
3/3	Hydrogen Peroxide	MX09000	NA	1 ppm	203
2/1	Iron Sulfate	NO85100	1520	NA	NA
3/2	Lead Nitrate	OG21000	432	0.2 mg/m^3	100
3/2	Lead Iodide	NA	NA	NA	NA
3/0	Lead Oxide	OG07000	NA	200 mg/m^3	NA
1/2	Magnesium	OM21000	NA	NA	012
2/0	Magnesium Chloride	OM28000	2800	NA	NA
1/1	Magnesium Sulfate	OM45000	5000	NA	NA
3/1	Manganese Sulfate	OP10500	120	NA	NA
3/3	Nitric Acid	QU57750	NA	2 ppm	300
2/1	Potassium Bromide	TS76500	NA	NA	NA
2/1	Potassium Carbonate	TS77500	1870	NA	NA
2/3	Potassium Chlorate	FU03500	NA	NA	200
2/0	Potassium Chloride	TS80500	NA	NA	NA
*4/2	Potassium Chromate	GB29400	50	1 mg/m^3	NA
2/1	Potassium Nitrate	TT37000	500	NA	100
2/2	Potassium Permanganate	SD64750	1090	NA	100
4/1	Silver Acetate	NA	NA	NA	NA
4/1	Silver Nitrate	VW47250	NA	0.01 mg/m^3	100
2/1	Sodium Acetate	AJ43750	3530	NA	NA
2/0	Sodium Bicarbonate	VZ17500	4220	NA	NA
1/0	Sodium Chloride	VZ47250	3000	NA	NA
3/3	Sodium Hydroxide	WB49000	NA	2 mg/m^3	301
2/1	Sodium Iodide	WB64750	4340	NA	NA
4/1	Sodium Oxalate	RO39000	NA	NA	NA
2/1	Sodium Sulfate	WE16500	NA	NA	NA
2/2	Sodium Sulfite	WE22000	NA	NA	NA
2/0	Sodium Thiosulfate	WE66600	NA	NA	NA
2/4	Sulfuric Acid	WS56000	2140	1 mg/m^3	302
2/1	Zinc	ZG86000	NA	NA	011

*Carcinogen

Chemical Hazards

Most of the reactions are solution reactions, involving the use of fairly dilute solutions. This alleviates most hazards. A list of reagents typically used in this work is given in Table 4.16-1.

Overall Rating

An overall hazard rating of 0 for health and 0 for safety is assigned to experiments dealing with reaction rates. This rating assumes that normal safety precautions are taken.

TABLE 4.16-1

CHEMICAL HAZARDS FOR REACTION RATE STUDIES

Health/Safety Hazard	Chemical	Registry Number	Rat Oral LD_{50} (mg/kg)	OSHA TWA	NFPA Code
2/1	Cobalt Nitrate	GG11090	NA	NA	100
2/0	Copper Sulfate	GL89000	300	1 mg/m^3 as Cu	NA
3/3	Hydrogen Peroxide	MX09000	NA	1 ppm	203
3/1	Manganese Dioxide	OP03500	NA	NA	NA
3/1	Potassium Iodate	NN13500	NA	NA	NA
3/0	Potassium Iodide	TT29750	NA	NA	NA
2/1	Sodium Bisulfite	VZ20000	NA	NA	NA
2/3	Sodium Hypochlorite	NA	NA	NA	NA
2/0	Sodium Thiosulfate	WE66600	NA	NA	NA
2/4	Sulfuric Acid	WS56000	2140	1 mg/m^3	302

4.17 EXPERIMENT CLASS: SCIENTIFIC PROCESSES AND PROCEDURES

Overview

This class of experiments offers the student a unique opportunity to learn the scientific method. Such open-ended experiments also offer the opportunity to learn many safety practices for the laboratory. Why not have the student identify as many sources of hazards in the experiments as he can?

Chemical and Material Hazards

Few chemicals are suggested in these experiments, and those that are suggested are relatively safe unless ingested. This gives occasion to teach more safety rules.

Procedural Hazards

Students should not return chemicals to reagent jars. The usual care must be taken with liquids.

Lubricate glass tubing before insertion. Watch for hot glass and keep flames away from reagents.

Hair, which is very flammable, must also be kept away from flames. Lighted candles are dangerous. Have students treat candles with great care.

Students should never taste laboratory chemicals. Students should be given the opportunity to learn about toxicology through these experiments.

Safety glasses and aprons or lab coats are necessary at all times in the laboratory.

Overall rating

These experiments, if properly managed, have a hazard rating of 0 for health and 1 for safety.

4.18 EXPERIMENT CLASS: SOLUBILITY

Overview

Solubility experiments illustrate the dynamic nature of solubility and the effects of temperature, common and diverse, on solubility. Quantitative experiments are also found in which the solubility product for a salt is determined. The rate and mechanism of solubility is also explored.

The nature of the experiments is quite varied, and a wide range of mostly minor hazards exists.

Chemical Hazards

Chemicals used in this class are listed in Table 4.18-1. These chemicals are fairly common and, while they represent hazards, are not extraordinarily dangerous.

Benzene and carbon tetrachloride should be replaced by toluene and trichlorotrifluoroethylene, respectively.

Procedural Hazards

Water baths are used to obtain a constant temperature. Care must be taken not to crash the samples into the walls of the water bath. Also, if the bath is hot, consideration must be given to problems of burns.

Safety glasses should be worn at all times.

Proper care should be given to the disposal of chemicals produced in these experiments.

TABLE 4.18-1

CHEMICAL HAZARDS IN SOLUBILITY EXPERIMENTS

Health/Safety Hazard	Chemical	Registry Number	Rat Oral LD_{50} (mg/kg)	OSHA TWA	NFPA Code
3/1	Ammonia (gas)	BO08750	350	50 ppm	301
3/0	Ammonium Carbonate	BP19250	96	NA	NA
2/2	Ammonium Chloride	BP45500	1650	NA	200
4/0	Ammonium Oxalate	NA	NA	NA	NA
2/0	Ammonium Sulfate	BS45000	3000	NA	NA
*4/3	Benzene	CY14000	3800	10 ppm	230
*4/0	Carbon Tetrachloride	FG49000	2800	10 ppm	300
2/0	Calcium Chloride	EV98000	1000	NA	NA
2/1	Calcium Nitrate	EW30000	3900	NA	NA
1/3	Ethanol	KQ63000	14000	NA	030
1/1	Glycerol	MA80500	12600	NA	110
3/3	Hydrochloric Acid	MW40250	900	5 ppm CL	300
3/3	Hydrogen Chloride	MW96250	NA	5 ppm CL	300
4/2	Iodine	NN15750	NA	0.1 ppm	NA
4/0	Lead Chloride	OF94500	NA	0.2 mg/m^3	NA
1/1	Magnesium Nitrate	OM37500	NA	NA	NA
2/0	Potassium Chloride	TS80500	552	NA	NA
4/2	Potassium Chromate	GB29400	NA	100 μ/m^{3}CL as CrO_3	NA
2/1	Potassium Nitrate	TT37000	NA	NA	100
1/0	Sodium Chloride	VZ47250	3000	NA	NA
3/3	Sodium Hydroxide	WB49000	NA	2 mg/m^3	301
3/1	Strontium Nitrate	WK98000	540	NA	NA
2/4	Sulfuric Acid	WS56000	2140	1 mg/m^3	302

*Carcinogen

Lead chromate is one such compound that is isolated and weighed. It is highly toxic and probably carcinogenic. The use of lead chromate can be obviated by alternative experiments. Copper carbonate and other chemicals produced have been described from time to time in the *Journal of Chemical Education.*

Some experiments use concentrated acids and bases, which must be handled with extreme care. Never pick up sodium hydroxide pellets with the fingers.

When heating test tubes directly with a flame, be sure they are pointed away from others and yourself.

Hair is flammable. Be careful when working around open flames, and keep hair contained at all times.

Iodine should be handled in the hood only.

When working with ammonia or hydrogen chloride, all work should be done in the fume hood.

When working with dropper bottles of solutions, students must be careful to return the proper dropper to the correct bottle. Cross contamination of solutions can have very dangerous repercussions.

Equipment Hazards

If electrically controlled water baths are used, care must be exercised to properly ground the instruments.

Overall Rating

This class of experiments has an overall rating of 2 for health hazards and 1 for safety hazards.

4.19 THERMAL CHEMICAL MEASUREMENTS

Overview

Thermal chemistry experiments illustrate the concepts of melting and melting points, heat of fusion, the relationship of phase and energy changes, heat of neutralization, heat of

TABLE 4.19-1

CHEMICAL HAZARDS IN THERMAL CHEMISTRY

Health/Safety Hazard	Chemical	Registry Number	Rat Oral LD_{50} (mg/kg)	OSHA TWA	NFPA Code
*1/1	Acetamide	AB40250	10300	NA	NA
2/2	Acetic Acid	AF12250	3310	10 ppm	221
2/1	1,4 Butanediol	EK05250	1525	NA	NA
3/1	Camphor	EX12250	NA	2 ppm	NA
*2/0	p-Dichlorobenzene	CZ45500	500	75 ppm	NA
2/1	Diphenylamine	JJ78000	NA	10 mg/m^3	NA
1/3	Ethanol	KQ63000	14 g/kg	1000 ppm	030
3/3	Hydrochloric Acid	MW40250	900	5 ppm CL	300
2/2	Napthalene	QJ05250	1780	10 ppm	220
2/2	Napthol	QL29750	2420	NA	NA
2/2	p-Nitrotoluene	XT33250	2144	5 ppm	310
2/0	Octadecanol	RG20100	NA	NA	NA
2/2	Paraffin	RV03500	NA	NA	NA
3/3	Potassium Hydroxide	TT21000	365	2 mg/m^3	301
3/0	Potassium Iodide	TT29750	NA	NA	NA
2/0	Salicyclic Acid Phenyl Ester (Salol)	VO62500	50	NA	NA
3/3	Sodium Hydroxide	WB49000	NA	2 mg/m^3	301
2/1	Sodium Iodide	WB64750	4340	NA	NA
2/0	Sodium Thiosulfate	WE66600	NA	NA	NA
2/2	Urea	YR62500	NA	NA	NA

*Suspected Carcinogens

combustion, and heat of reaction. The experiments in this class include:

Cooling curves and melting points
Heat of fusion, phase change
Heat of combustion
Heat of neutralization

Chemical Hazards

Low melting point organic compounds are employed in these experiments. Several of these substances are suspected to be carcinogens, several are flammable, and most are toxic. These explorations are best done in a properly vented fume hood.

Table 4.19-1 lists the substances used.

Napthalene and p-nitrotoluene are good substitutes for p-dichlorobenzene. Acetamide is not a good substitute because it is suspected to be carcinogenic.

Procedural Hazards

Thermometers, which can be easily broken, should not be used as stirring rods. If mercury is spilled from a broken thermometer it should be cleaned up properly, using an aspirator first, then powdered sulfur or wet sawdust. The spill should then be vacuumed with a special purpose apparatus and the sulfur treatment performed again.

For experiments using organic solids, a length of chromed steel wire or copper wire makes a good stirring rod.

Safety glasses should be worn at all times. Experiments using organic chemicals should be performed in the fume hood.

Students should be instructed in the use of tongs for handling hot beakers and test tubes.

The flammability of these organics is high in all cases. Avoid contact with open flames. Students should have proper instruction with a CO_2 extinguisher.

Care must be exercised in heating liquids in test tubes. Fumes can ignite and blow back into the tube. Liquids can be ejected from localized superheating.

Instructors are cautioned never to use "makeshift" alcohol burners. They are dangerous.

Potassium hydroxide and strong acids should be handled carefully.

Overall Rating

Thermal chemistry experiments have a health rating of 2 and a safety rating of 2.

CHAPTER 5

EARTH SCIENCES EXPERIMENTS

CHAPTER 5

EARTH SCIENCES EXPERIMENTS

5.1 EXPERIMENT CLASS: ASTRONOMY

Overview

Experiments in astronomy promote the students' understanding of the sun, moon, planets, and stars, and how the light emitted can be analyzed to learn more about these bodies. Using bench equipment students demonstrate how light can be analyzed by using lenses, spectroscopes, and other optical devices.

Generally little hazard exists in this class of experiments. The greatest danger comes from the potential for burns or damage to the eye from the sun and other light sources that are used.

Typical school laboratory experiments in astronomy can be grouped into the following subsets, each of which have health and safety ratings.

**TABLE 5.1-1
TYPICAL EXPERIMENTS
IN ASTRONOMY**

Subset	Health	Safety
Using sun as a light source	0	2
Using burner, moon or light bulb as a light source	0	1
Using chemical on wire as a source	1	1

Material and Chemical Hazards

Chemicals should only be encountered when performing nichrome wire flame tests. The most common chemicals used are recognized as toxic, and adequate precautions should be taken to ensure good ventilation of the experimental area. In poorly ventilated or confined laboratories, flame tests should be performed in a fume hood.

When large numbers of students are performing flame tests, the potential exists for individual acute toxicity exposure or instructor chronic toxicity exposure.

The general nature of an "unknown" compound should be ascertained before performing a flame test. Students should never ingest the chemicals.

The following list describes the toxicity of commonly used compounds:

**TABLE 5.1-2
CHEMICALS USED IN
ASTRONOMY EXPERIMENTS**

Health Safety	Compound	Rat Oral LD_{50}
1/0	Sodium Chloride ($NaCl$)	3000 mg/kg
2/1	Strontium Chloride ($SrCl_2$)	2250 mg/kg
3/1	Lithium Chloride ($LiCl$)	757 mg/kg
3/1	Copper Chloride ($CuCl_2$)	140 mg/kg

Procedural Hazards

The most hazardous light source used in these experiments is the sun. Students must be clearly instructed not to look at the sun directly or through lenses. Students should not sight objects close to the sun, which would increase risk of accidental viewing of the sun. Dark glasses are insufficient protection against the rays of light from the sun.

When the sun's rays are focused with a lens, a great deal of energy is concentrated causing rapid heating at the focal point. Objects placed at this point may become very hot and liable to burn the fingers if touched. Paper or other combustible materials placed at this point may ignite after a short time.

Other light sources used in these experiments are tungsten light bulbs, alcohol burners, and Bunsen burners. All sources require that care be taken to avoid burns. Special care should be taken to avoid spilling alcohol from the alcohol burner.

When performing flame tests, the nichrome wire or paper clip that is used should be held with a well-insulated holder or long-handled pliers. The wire and holding device should be placed on an insulated mat and allowed to cool thoroughly before handling.

The eyes should be either kept well away from the flame test or else goggles should be worn. Overloading the wire causes spattering, and material can fall into the burner jets causing blockage. Unknown chemicals should not be placed in the flame.

Many astronomy experiments call for the assembly of cardboard holders. Normal care should be taken in the use of sharp cutting tools. The use of high-strength, quick-bonding adhesives should be avoided as fingers can be easily bonded together and require surgical separation.

Equipment Hazards

Glassware is commonly used in these experiments. Care should be taken to avoid breakage by dropping or contact with hot surfaces.

Overall Rating

Astronomy experiments are relatively free from danger, and have an overall rating of 0 for health hazards and 1 for safety hazards.

5.2 EXPERIMENT CLASS: MAPPING

Overview

The purpose of experiments in mapping is to develop student understanding of the relationship between their geographical environment and the same represented on a map. Students build contour models, determine latitudes, and measure elevations using magnetic compass, protractor, sextant, and other devices.

Procedural Hazards

Students do not encounter any hazards not normally present in everyday life. However, a few important common sense precautions should be noted.

Care should be taken to avoid looking directly at the sun when making sightings. When constructing experimental instruments from cardboard, sharp cutting tools should be used with caution. The use of high-strength, quick-bonding adhesives should be avoided, because fingers can be easily bonded together and require surgical separation. Since staplers are commonly misused by students, stapler use should be controlled; staples can be embedded in the skin or shot into the eye.

Overall Rating

With normal, everyday care, no health or safety hazard exists while performing mapping experiments. Overall ratings of 0 for health and 0 for safety hazards are assigned.

5.3 EXPERIMENT CLASS: OCEANOGRAPHY

Overview

Oceanography experiments develop the students' understanding of the factors that determine the characteristics of the oceans. Using simple laboratory equipment, students perform tests and simulations with synthesized sea water to determine density, the movement of sediments, and the character of waves. Some mapping of the ocean floor is also performed.

Material and Chemical Hazards

Silver nitrate is the only chemical of appreciable toxicity that can be encountered when performing oceanography experiments. Skin contact should be avoided because of the toxicity and caustic nature of silver nitrate, which has a health hazard rating of 4 and a safety rating of 1. If powdered calcium carbonate is used, normal care should be taken to avoid inhalation of the dust.

Procedural Hazards

The most hazardous activity is the heating and evaporation of sea water in a container, usually effected by a Bunsen burner. Students should guard against burns from heated surfaces and ensure that the containers holding the heated water are stable and will not spill or turn over. There is also the possibility of extinguishing the burner flame and allowing gas to escape into the laboratory.

When evaporating water, the Bunsen burner's flame should be regulated to avoid violent spattering as the water evaporates. The students should keep their eyes away from the evaporation or should wear protective goggles. Electric hot plates are best for evaporation. Care should be taken to avoid water spillage on electrical parts or handling the equipment with wet hands. Students should be instructed to switch the hot plate off immediately at the end of the experiment and to guard it from accidental contact by another person until it has cooled. The large thermal capacity of hot plates causes them to retain high temperature for a long time compared with Bunsen burners and other such devices.

Equipment Hazards

For experiments involving the settling of sediment, plastic columns are recommended because they are less likely to break than glass columns.

Overall Rating

Assuming normal standards of care and attention, experiments in oceanography present a very low level of hazard and have a hazard rating of 0 for health and 1 for safety.

5.4 EXPERIMENT CLASS: PALEONTOLOGY

Overview

Experiments in paleontology acquaint students with the techniques used to develop an understanding of the prehistoric era. Using simulation techniques, students learn the concepts of radioactive decay and the formation of fossils.

Material and Chemical Hazards

The use of radioisotopes to make autoradiograms is a perfectly safe procedure provided that "exempt" reference sources are used. Most catalogs indicate which sources are exempt, and these are the only sources that should be used in the school laboratory. The Federal maximum exempt levels are listed in Table 3-3.

Although exempt sources are safe to handle, it is advisable to educate students in the precautions to be taken when handling radioactive materials. Sources should not be touched. Handle the sources with forceps and wash hands after the experiment is completed. Sources should be returned to an approved storage area and the return recorded on a log sheet.

Overall Rating

Experiments in this class present no procedural or equipment hazards, and have an overall rating of 0/0 for health/safety hazards.

5.5 EXPERIMENT CLASS: PHYSICAL GEOLOGY

Overview

Physical geology experiments promote student understanding of the factors that shape the continents of the earth. By simulation techniques students learn the effects of pressures within the earth, freezing, flowing water, winds, convection, conduction, and radiation. Techniques used to measure characteristics of the earth and the factors that shape it are investigated.

The different types of equipment used in these techniques present a number of hazards. However, with normal care the risk of accident remains low.

Experiments in this class can be grouped into the following subsets, each of which have health and safety ratings.

TABLE 5.5-1
TYPICAL EXPERIMENTS IN PHYSICAL GEOLOGY

Subset	Health	Safety
Physical Inspection and Observation	0	0
Model Construction	0	0
Water Movement	0	0
Water Analysis and Evaporations	0	1
Heat Transfer	0	1
Chemical Reactions	0	1

Material and Chemical Hazards

In general, the only chemical experiments to be attempted involve such substances as dilute hydrochloric acid with calcite. Little risk exists in this type of experiment although students should be instructed not to add water to the acid. The statement "acids go swimming" should be constantly repeated even if the mixing of acids with water does not form part of the experimental procedure.

Some texts suggest an experiment involving ammonium dichromate that dramatically simulates the effects of a volcano. The ammonium dichromate is ignited using burning magnesium, resulting in a volcano-like effect. This experiment should never be performed in the school laboratory for two reasons.

First, ammonium dichromate is highly toxic. The compound is acutely toxic and the chromium given off by the reaction is chronically toxic. Teachers who supervise those reactions expose themselves to a known carcinogen in the form of chromic oxide, which has a TWA of only 25 $\mu g/m^3$ and a hazard rating of 4 for health and 1 for safety.

Second, the demonstration does not accurately reflect the conditions of pressure and heat that produce volcanoes. Substitutions of less harmful demonstrations, while not so spectacular, would better simulate these effects. For example, the pressure exerted on a collapsible baby bottle to force food such as syrup through the orifice better simulates the effects of a volcano.

Procedural Hazards

A large number of relatively minor procedural hazards exists in this class of experiments.

When collecting water samples from natural water sources there should be close supervision. If it is necessary to enter the water, protective boots should be worn and the water should always remain below the ankles. If samples are collected from an elevated bank, a collecting device should be used that does not require stretching out over the water. Students should never work alone. Water that is stagnant or contains sewage effluent or industrial effluent should not be sampled.

When evaporating liquids, a low level of flame should be used. The evaporation should be completed with an electrical hot plate to avoid spattering of the residue. The students should be warned to keep their eyes and hair away from the heating operation and to avoid burns through contact with heated surfaces.

Heat is used in many of the experiments and may be generated by flame, light bulb, heated rocks, etc. Careful forethought in placing these heat sources so students do not have to reach across them during another part of the experiment greatly reduces the hazard of burns. If the experiment requires water to contact heated surfaces, the resulting steam and flying drops of boiling water should be avoided.

A typical wind experiment requires the blowing of fine sand into a dune. Students should be instructed not to blow too hard, which can cause sand to fly back and into the eyes. Continuous hard blowing may also induce dizziness and fainting. It may be preferable to blow through a straw.

Equipment Hazards

Glassware is used extensively in these experiments, and the teacher should be aware of the general precautions to be taken in its handling. Particular care should be taken to clamp glassware firmly to ring stands but to avoid overtightening. Glass tubing should be lubricated before inserting into stoppers.

The use of mercury thermometers is quite acceptable if students are alerted to the dangers of breakage: besides the broken glass, mercury is spilled and can run into cracks in the floors and woodwork. Mercury does not present an immediate acute hazard in such situations but will tend to build up a strong vapor pressure in the room that could lead to chronic effects, especially for the teacher.

To reduce the hazard of breakage, thermometers should not be used for stirring and should not be shaken in the air. When positioning the thermometer, care should be taken to ensure that movement of the apparatus will not stress the thermometer.

Other equipment such as steam tables can have electric motors attached; precautions should be taken to avoid spillage of water onto the electrical contacts. All electrical equipment should be regularly inspected for frayed power cords or damage to the casing.

These precautions also apply to fans. Long hair should be tied back to prevent its being pulled into the blades. Fans should have adequate guarding.

Experiments in physical geology require a good deal of modeling, and therefore the usual precautions in the use of sharp cutting instruments.

Metal spheres are often used to demonstrate characteristics of the earth and care should be taken to avoid these items' flying off apparatus at high speeds.

Although numerous other minor equipment hazards exist, normal operational care should prevent any major experimental hazards.

Overall Ratings

Assuming that the students do not perform the volcano experiment, the experiments in this class pose no significant hazard. The class is varied and the range of equipment encountered correspondingly large, but adequate care and preparation for dealing with new devices obviates any additional risk. Therefore, experiments in physical geology carry hazard ratings of 0 for health and 1 for safety.

5.6 EXPERIMENT CLASS: ROCKS AND MINERALS

Overview

Experiments with rocks and minerals promote student understanding of their composition, formation, and physical characteristics. Using field samples and chemical simulation, students observe and draw conclusions about these factors.

The use of chemicals is significant and therefore increases the hazard. Experimental procedures used are separated below into sub sets that indicate the varying health and safety hazards.

TABLE 5.6-1
TYPICAL EXPERIMENTS WITH ROCKS AND MINERALS

Subset	Health/Safety Hazard
Observation of physical characteristics	0/0
Effects of chemicals on minerals	1/1
Chemical simulations	2/1

Material and Chemical Hazards

Most chemical experimentation with naturally occurring minerals involves the application of dilute hydrochloric acid to the specimen. Dilute hydrochloric acid is not particularly dangerous, but students should learn to treat it with the respect deserved by all acids. Water should never be added to the acid; the saying "acids go swimming" should be repeated. Dilute hydrochloric acid is not very corrosive, though students should be warned to avoid contact with skin or clothing and to guard against splashes.

When dilute hydrochloric acid is applied to mineral specimens, gases often result. Due to the varied composition of the minerals, it is not always possible to predict which gases will be evolved. Therefore, such experiments should be performed in well-ventilated areas or in the fume hood. Gases should not be smelled directly.

Textbook experiments with rocks and minerals carry many chemical simulation experiments such as coloring brass beads by heating with various compounds, extracting lead and mercury, and reproducing lava flow effects. The health and safety rating for the more commonly used chemicals is listed in Table 5.6-2.

All experiments involving the heating of chemicals should be conducted in a fume hood or a well-ventilated area. Heating experiments involving chromium nitrate, nickel chloride, mercury, and other compounds with a high health hazard rating should only be performed in a fume hood. The chemicals should never be smelled.

Because chromium nitrate is a carcinogen, its use should be avoided where possible. When lead and mercury are extracted, the beads of metal produced should not be touched.

When many students perform tests involving the heating of chemicals, the potential exists for acute toxicity exposure of individual students or chronic toxicity exposure of instructors who supervise several classes.

Procedural Hazards

Insist on the wearing of safety goggles in many experiments in this class. This form of eye protection is essential when breaking rocks with a hammer and when heating chemicals that tend to spatter or eject from test tubes.

Students should understand the dangers from flying particles and substances originating from a work group other than their own. Before breaking rocks, care should be taken to ensure that other students are not within range of flying particles. Alternatively, guards should be positioned around the area where rocks are broken. Rocks should be held firmly with long-handled pliers to avoid injury to the fingers and to prevent movement.

Test tubes should always face away from the student and not point at other people in the room. Student should never attempt to look down into the tube.

Normal care should be taken to avoid burns when using Bunsen burners and holding devices. Equipment should be allowed to cool on insulated mats and must be completely cool before handling.

After handling rocks or chemicals, students should wash their hands. This sensible housekeeping procedure is a wise precaution after performing any experiment whether it involves hazardous substances or not.

Equipment Hazards

There is little need for glassware or specialized equipment in this experiment class. If alcohol burners are used, normal care should be taken to avoid spillage. Students should be acquainted with techniques required for fighting alcohol fires.

Overall Rating

The large number of chemicals encountered in this experiment class tends to increase the hazard potential. If adequate precautions are taken to avoid breathing emissions from those

TABLE 5.6-2

CHEMICAL HAZARDS IN ROCK AND MINERAL EXPERIMENTS

Health/Safety Hazard	Chemical	Registry Number	OSHA TWA	Rat Oral LD_{50} (mg/kg)	NFPA Code
1/3	Acetone	AL31500	1000 ppm	9750	130
2/0	Borax	ED45500	2660	NA	NA
2/0	Calcium Chloride	EV98000	NA	1000	NA
*4/1	Chromium Nitrate	GB63000	3250	NA	100
2/1	Cobalt Nitrate	GG11090	NA	NA	100
2/0	Copper Sulfate	GL89000	300	NA	NA
2/0	p-Dichlorobenzene	CZ45500	500	75 ppm	NA
2/1	Iron II Ammonium Sulfate	BR65000	NA	3250	NA
2/0	Iron Chloride	NO54250	900	1 mg/m^3	NA
2/1	Iron II Sulfate	NO85100	NA	1520	NA
3/0	Lead	OF75250	200 $\mu g/m^3$	NA	NA
3/1	Manganese Dioxide	OP03500	NA	NA	NA
2/2	Napthalene	OJ05250	10 ppm	1780	220
4/1	Nickel Chloride	QR64800	48	15 $\mu g/m^3$	NA
3/0	Salol	VO62500	NA	NA	NA
2/0	Salicyclic Acid	VO05250	NA	NA	NA
2/1	Sodium Carbonate	VZ40500	NA	NA	NA
2/0	Sodium Thiosulfate	WE66600	NA	NA	NA
3/1	Sulfur	WS42500	NA	NA	210

*Carcinogen

chemicals when heated, an overall hazard rating of 1/1 for health/safety is assigned.

5.7 EXPERIMENT CLASS: WEATHER AND CLIMATE

Overview

Experiments in weather and climate demonstrate to the students how weather patterns are shaped and the various methods used to measure them. Most experiments to be performed by students are laboratory simulations that often use artificially created temperature differentials to demonstrate the weather – and climate – shaping effects.

Material and Chemical Hazards

No hazardous chemicals or materials are generally used in these experiments. However, because so many of the techniques call for heating, attention should be paid to substituting less combustible materials when constructing apparatus.

Procedural Hazards

Several standard experiments call for air to be heated in paper or polyethylene bags by using flame burners. This is an extremely hazardous procedure, especially when several student groups work simultaneously in the laboratory. Wherever possible, hot air blowers or light bulbs should be substituted.

In certain cases it is impossible to obtain sufficient heat without the use of a flame. The students should be informed clearly of the fire hazard involved and, if not already acquainted with the use of fire-fighting equipment, should be instructed in its use. Combustible materials should be kept at least 10 cm away from a small flame source.

In all experiments involving heat, care should be taken to avoid burns. Forethought in the positioning of apparatus with respect to the student's seating position can minimize the risk. High-powered lamps become extremely hot and radiate heat to equipment not directly in contact.

Substitution of electrical heating sources for flame sources has already been discussed. This concept of substitution can be applied to several other experiments in this class. For example, an experiment that tests a wind velocity indicator by holding it out of a car window can be performed in the laboratory using a simple wind tunnel. Wet experiments can be performed by passing air over the thermometer instead of waving the thermometer in the air. Apparatus can often be constructed from plastic tubing instead of glass.

Equipment Hazards

Several glassware items are used in wind and climate experiments. Precautions should be taken to avoid breakage, especially if mercury thermometers are used.

Substituting electric blowers and light bulbs for flame sources introduces the hazard of electric shock. Equipment should be inspected regularly for worn cables or damage to the casing, and students should be instructed to avoid water spills near the equipment.

Overall Rating

If the concept of substitution is applied to the more hazardous techniques used in standard textbooks, this class of experiments has little hazard. On this assumption, a rating of 0 for health and 1 for safety is assigned.

CHAPTER 6

BIOLOGY EXPERIMENTS

Chapter 6

BIOLOGY EXPERIMENTS

6.1 EXPERIMENT CLASS: ANIMAL PHYSIOLOGY/ANATOMY/EMBRYOLOGY

Overview

Experiments in this class can be organized into the following subgroups:

Subset	Health/Safety
Respiration	1/1
Sensory Activities	1/1
Anatomy-Characteristic Structures	1/1
Heart and Blood	1/1
Embryology	1/1

The purpose of these experiments focuses on introducing students to fundamental biological concepts of respiration, metabolism, sensory function, blood, specific organs and structures, and embryology and development.

Typically, the experiments involve very little hazard to students and faculty if safe practices are followed. Students and teachers must be aware of the need for antiseptic conditions, use care in manipulating dissecting instruments, develop a professional attitude toward work, and treat microbiological materials as though they could be pathogens. Care must also be taken in manipulating glassware. Pipettes with bulbs should be used. Glass tubing, cover slips, and slides need to be handled with care. Thermometers are glass and need to be treated gently.

Chemical and Material Hazards

Typical chemicals used in experiments in this class are listed in Table 6.1-1. Attention should be given to formaldehyde, alcohol, and isopropyl alcohol. All three are very flammable and, in some cases, explosive. All represent some degree of toxicity, with formaldehyde being the most toxic.

Nicotine, iodine, and quinine sulfate are commonly used in a laboratory and are very dangerous. In these experiments, they are used in dilute solution, which significantly reduces the hazards involved.

Teachers are cautioned about the corrosive nature of hydrochloric acid and iodine, and the caustic nature of potassium and sodium hydroxides.

Acetic acid in concentrated form is a very strong skin poison and can cause very severe and painful burns.

Procedural Hazards

The procedural hazards involved are generally minimal, particularly if appropriate conditions have been met.

When students are used for stress tests, instructors should check to see if there are students with medical histories indicating that they should not participate in certain experimental situations.

Thermometers for oral temperature measurements must be sterilized in a beaker of 95% ethanol after each use.

Be sure that students do not attempt to inhale without removing from their mouths the straws or other tubing immersed in solutions of CO_2 absorbants.

Care must be exercised in "dipping" paper into KOH solutions. Potassium hydroxide can travel to the fingers by capillary action. Caution students to use tongs or forceps.

When dissecting, use extreme care in handling the dissecting instruments. Remember that formalin is 37% formaldehyde and is toxic and flammable.

Experiments involving the eye require that students use great care. Caution should be used when shining a light into the subject's eye. Caution is also required when holding anything close to the eye for observation. Even a piece of paper can severely injure the eye.

Care must be exercised when inserting glass tubing into rubber stoppers. Be sure that the holes are properly bored and that glass tubing has been thoroughly lubricated with glycerine prior to insertion.

Boring stoppers is also a procedure which involves a potential hazard. When hand boring, be sure that the cork-borer is sharp and firmly attached at the handle.

Some procedures call for the student to taste solutions of certain substances. In a laboratory environment there are many hazards involved with this technique; such testing is better done in another room. If other rooms are used, be sure the solutions are the only ones available in that room. When testing in the

TABLE 6.1-1

CHEMICAL AND MATERIAL HAZARDS FOR ANIMAL PHYSIOLOGY/ANATOMY/EMBRYOLOGY

Health/Safety Hazard	Chemical	Registry Number	Rat Oral LD_{50} (mg/kg)	OSHA TWA	NFPA Code
2/2	Acetic Acid	AF12250	3310	10 ppm	221
1/3	Alcohol (Ethanol)	KQ63000	14000	1000 ppm	030
3/3	Hydrochloric Acid	MW40250	900	5 ppm CL	300
3/3	Iodine	MN15750	NA	0.1 ppm CL	300
2/3	Isopropyl Alcohol	NT80500	5840	400 ppm	130
2/0	Lactic Acid	OD28000	3730	NA	NA
3/0	Nicotine	QS52500	53	500 μ/m^3	NA
3/3	Potassium Hydroxide	TT21000	365	2 mg/m^3	301
3/0	Quinine Sulfate	VA84400	NA	NA	NA
1/0	Sodium Chloride	VZ47250	3000	NA	NA
3/3	Sodium Hyroxide	WB49000	NA	2 mg/m^3	301
0/0	Sucrose	WN65000	29700	10 mg/m^3	NA
3/2	Formaldehyde (37%)	LP89250	800	3 ppm	37% 220
2/4	Ether	KI57750	1700	400 ppm	241

laboratory, make sure everyone understands the need for proper labeling and that the label on the substance tested describes all necessary detail, and also that only those reagents specifically suggested by the instructor should be tested. Cotton swabs and applicators should be sterilized in an autoclave before use. Open solutions in the laboratory can often absorb reagents from the air, possibly in toxic amounts. If solutions are poured into beakers or watchglasses before being placed on the tongue, be sure the beakers or watchglasses are sterilized before use. Q-Tip-type applicators are suggested and they too should be sterile.

Watchglasses are particularly easy to break into pieces that will severely cut the flesh. Students and faculty should use care in manipulating watchglasses as well as other laboratory glassware.

When preserved specimens are used, be sure to completely wash off all the formaldehyde. Wash in a hood or very well-ventilated area. Formaldehyde is toxic and flammable.

When investigating shellfish, care must be taken in opening the shells; a screwdriver or knife used to pry can be jabbed into the hand.

When handling live specimens, the students should use appropriate personal protection against bites and disease.

When using ether as an anesthetic, remember that it is moderately toxic and extremely flammable.

Access to drugs such as pilocarpine and adrenalin should be carefully controlled.

In taking blood samples, sterile lancets must be used. The use of spring-loaded lancets should be avoided. Be sure to use sterile techniques in securing the sample and treating the wound. Be sure that the student is not a hemophyliac. Also, be aware that many people faint at the sight of blood – especially their own. Do not force students to participate. It is a good practice to obtain a parent's permission before drawing a sample from a student. Control the disposal of the lancets. Suggest that students do *not* inject their blood into other students.

Overall Rating

An overall hazard rating of 1 for health and 1 for safety can be assigned to this class of experiment types, assuming that dilute solutions are available, solutions are strictly controlled, and sterile procedures are employed.

6.2 EXPERIMENT CLASS: ANIMAL TAXONOMY

Overview

Observational skills are developed by animal taxonomy experiments. Students learn to use a key to identify animals and to place them in their proper taxonomic group.

Chemical and Material Hazards

No specific chemical or hazardous materials are involved in any of these experiments.

Procedural Hazards

Care must be exercised to prevent students from being bitten by the small animals used.

Specimens preserved in formaldehyde must be handled with great care; formaldehyde is a very toxic material. A quantity of 5g (5 ml) vaporized in a room 20′×40′×8′ would exceed OSHA standards.

Plenty of room must be allowed around each of the observation stations.

Care must also be taken with respect to dissection experiments. Any cutting instrument represents a potential hazard.

Overall Rating

This work has no particular hazards of significance, and has a health/safety rating of 0/0.

6.3 EXPERIMENT CLASS: BACTERIOLOGY AND MICROBIOLOGY

Overview

This class of experiments illustrates the classic concepts of bacteriology. Included are samples of many diverse bacterial types. Although experiments vary widely in this class, most have similar procedures and hazards.

Chemical and Material Hazards

Little chemical hazard exists in these experiments. Alcohol, glycerol, and sodium hypochlorate give little cause for concern. Care must be exercised to keep the flames away from any alcohol that is used.

It is possible to use many bacteria types in these experiments. All are safe. However, good practice calls for treating the bacteria as though they were all pathogenic.

Procedural Hazards

Students should be cautioned about hazards involved in manipulation of glassware, particularly inserting tubing and thermometers in rubber stoppers. Lubrication should be with glycerol where appropriate or with water when glycerol would cause problems.

The cutting of glass tubing is always a problem. Only a single firm scratch to crystallize the glass is needed. Students should protect their hands when breaking the glass. See Chapter 3 for detailed instructions on glassworking procedures.

Faculty are urged to observe good safety practices and be good examples to their students.

Flaming slides must be done with care, so as not to burn oneself or cut the hand on broken glass from shattered slides. Care must be used in heating paraffin. Remember paraffin is flammable.

Faculty should advise students as to the hazards of hot glassware, inoculating loops, and other laboratory equipment. Sterilize inoculation loops before use by heating with a flame until they glow red.

Students must take care that their hair is not ignited by the flame of an alcohol lamp or burner. Long hair must be contained while students are working in the laboratory.

Time should be taken from class to discuss safety procedures side-by-side with the entire sterile technique procedures.

Pipette bulbs should be used instead of the mouth. Be sure to use the releasing-type pipette bulbs.

Treat all cultures as though they are pathogenic.

Colonies on plates should be counted on closed plates. Pathogens grow on agar as well as other organisms. Tape the plates of petri dishes together. The systems should be sterilized with an autoclave before opening. Proper procedure for disposal of the organisms must be followed.

It is suggested that students wear safety glasses when they are in the laboratory.

Equipment

Mercury thermometers are a particularly insidious hazard. The proper technique for cleaning up spilled mercury is as follows:

1. Clean up liquid with an aspirator of the design shown in Figure 6.3-1.
2. Dust the affected area with sulfur or with wet sawdust.
3. Vacuum.
4. Repeat steps 2 and 3 at least two times.

Autoclaves

Each autoclave has its own operational and safety systems. Faculty members should refer to the specific instruction manual for the safest means of handling the school's autoclave.

Microscopes

Microscopes offer little hazard other than using sunlight sources and focusing the sun's ultraviolet rays into the eyes.

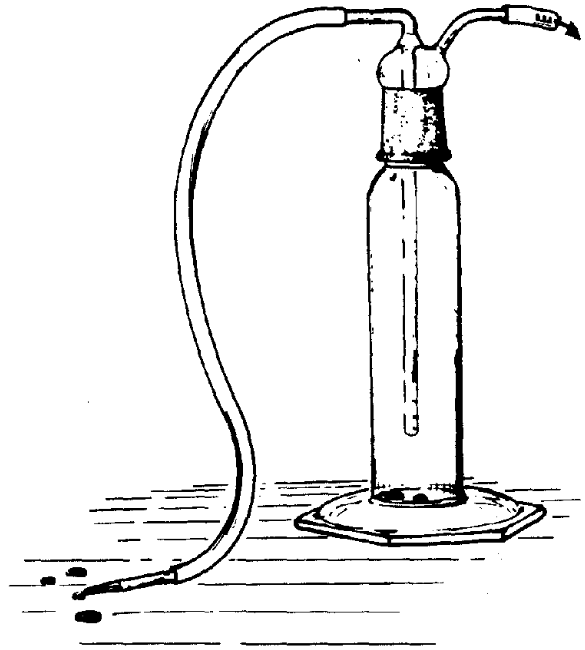

Figure 6.3-1

Overall Rating

The bacteriology and microbiology experiment class has an overall health/safety hazard rating of 0/1.

6.4 EXPERIMENT CLASS: BEHAVORIAL STUDIES

Overview

The students' abilities of observation and experiment design are developed by behavioral studies. Most such experiments make no use of toxic chemicals; they consist of observation in which stimuli produce specific responses.

Chemical and Material Hazards

No significant chemical hazard exists in this class of experiments.

Procedural Hazards

No specific procedural hazards exist in these experiments.

Equipment Hazards

When working with aquariums, be sure electrical systems are well-insulated, out of the water, and hazard-free.

Overall Rating

The overall rating of this class of experiments is 0 for health, and 0 for safety hazards.

6.5 EXPERIMENT CLASS: BIOCHEMISTRY

Overview

Biochemistry experiments introduce students to the chemistry of living systems; e.g., enzymes, bacteria, plants and animals. Specific tests for sugars, enzyme activity, and separation of natural products are included.

A wide range of experimental hazards is found in this class of experiments. The degree of hazard depends on the exact nature of the procedure.

Chemical and Material Hazards

Many reagents in this class of experiments can be hazardous, both from a safety and a health viewpoint. Most are included in Table 6.5-1.

Particularly noteworthy is iodine. Iodine is used in a variety of laboratory procedures. The extreme toxicity of iodine is reflected in the OSHA exposure limit of a 0.1 ppm ceiling. This is tantamount to evaporating 35 mg of iodine in a room 33'×42'×9'. Thirty-five milligrams is not very much iodine.

Care should be taken in the use of biuret reagent.

Procedural Hazards

Students should wear safety glasses and suitable clothing protection. Proper manipulation of glassware should be stressed. Pipette manipulation bulbs should be used.

Test tubes should be checked for cracks before use.

When heating test tubes in a hot water bath, care must be taken not to tip over the bath. Test tubes should not be allowed to bang into each other.

When drawing blood, sterile techniques must be followed. Disposable lancets should be used. Students should be cautioned against injecting their blood into another student.

The proper use of a Tirril burner can reduce accidents. Take the time to instruct students in the details of operating a Tirril burner.

Be sure students are instructed in the proper cleanup of mercury. Do not allow thermometers to be used as stirring rods.

In diluting acids and bases remember that the more concentrated reagent is poured into the less concentrated reagent or the diluting water.

When working with gases be sure that there are no constrictions or closed systems that can result in explosions.

Petroleum ether, alcohol, and acetone are extremely flammable liquids. Use caution when storing and handling these liquids.

Use a small beaker or Erlenmeyer flask rather than a test tube for extraction of pigment from colored leaves. The crushed leaves can form a mat and blow out of the test tube.

Other Hazards

In constructing models it is not good practice to use gum drops or jelly beans. Be professional, use styrofoam balls and sticks.

Overall Rating

Overall, a rating of 1 for health and 1 for safety hazards is given.

TABLE 6.5-1

BIOCHEMISTRY CHEMICAL HAZARDS

Health/Safety Hazard	Chemical	Registry Number	Rat Oral LD_{50} (mg/kg)	OSHA TWA	NFPA Code
1/3	Acetone	AL31500	9750	1000 ppm	130
3/3	Ammonium Hydroxide	BQ96250	350	50 CL	210
NA	Biuret	NA	NA	NA	NA
2/1	Calcium Hydroxide	EW28000	7340	2 mg/m^3	NA
2/0	Copper Sulfate	GL89000	300	1 mg/m^{3}as Cu	NA
1/3	Ethanol	KQ63000	14000	1000 ppm	030
0/0	Glucose	LZ66000	25800	NA	NA
1/1	Glycerol	MA80500	12600	NA	110
3/3	Hydrochloric Acid	MW40250	900	5 ppm CL	300
3/3	Hydrogen Peroxide	MX09000	NA	1 ppm	203
3/3	Iodine	NN15750	NA	0.1 ppm CL	300
3/1	Manganese Dioxide	OP03500	NA	NA	NA
2/1	Paraffin Wax	RV03500	NA	2 mg/m^3	NA
2/3	Petroleum Ether	SE75550	500	NA	NA
3/0	Potassium Iodide	TT29750	NA	NA	NA
2/0	Sodium Hydrogen Carbonate	VZ17500	4220	NA	NA
2/0	Sodium Carbonate	VZ40500	4000	NA	NA
2/0	Sodium Citrate	GE75800	NA	NA	NA
3/3	Sodium Hydroxide	WB49000	NA	2 mg/m^3	301
2/0	Sodium Potassium Tartasate	NA	NA	NA	NA

6.6 EXPERIMENT CLASS: CELLULAR BIOLOGY

Overview

High school experiments in cellular biology are designed to improve the students' powers of observation. In addition, the experiments illustrate the nature and structure of the living cell with all the similarities and differences found within them. The relationship of structure and function is also illustrated.

Hazards

Little significant hazard confronts students in this class of experiments. The greatest hazard is the potential for injury by cutting. Sections of cork and onion are cut from stock with a scalpel or razor blade. There are experiments calling for human blood cells or epithelial cells to be taken from the lining of the mouth. Care must be taken that good clinical, sterile technique is followed. Puncture wounds for blood should be made with sterile disposable lancets.

The finger should be sterilized with alcohol or other materials before puncture. The lancet should be disposed of immediately.

Care should be taken with staining materials. Remember that stains are solutions of toxic materials and should be respected as such.

When flaming slides, the slide should be held with forceps. Slides can shatter under these conditions.

Students should wear safety glasses at all times in the laboratory.

Be sure that an artificial light is used with the microscopes; sunlight can damage the eye with focused ultraviolet rays.

Overall Rating

An overall rating of 0 for health hazards and 0 for safety hazards is assigned to this class of experiments.

6.7 EXPERIMENT CLASS: ECOLOGY

Overview

Ecology experiments offer little hazard but much learning experience. This class affords students some first-hand experience in observing the intertwining factors of ecology. Experiments deal with the food chain, population, ecosystems, and other concepts.

Hazards

Students should wear safety glasses even when outdoors. Care must be taken when using mercury thermometers in the field because if they are broken cleanup is almost impossible. Clothing and personal protection should be appropriate to the task. Heavy leather gloves should be worn when handling small animals.

Some procedures require centrifuges. Remember to balance the centrifuge with a dummy container. If not balanced, a centrifuge can explode.

Some comments regarding formalin are in order. Formalin is 37% formaldehyde, which is extremely toxic. Formalin is an irritant and a lachrymator. In a room 10×20×3 m (a volume of 600 m^3), a level of 1,800 mg formaldehyde is tolerable. This corresponds to about *5 ml* of the 37% solution. Obviously, formaldehyde exposure should not be considered lightly.

Instructors are referred to Chapter 3 for proper handling of glass tubing.

Salmonella bacteria can be found on many wild animals and insects. Snails are a particularly significant carrier of this bacterium. Because of the acute pathogenicity of Salmonella and its infectious nature, a great deal of care should be exercised. Any potential source of a pathogen should be treated as though it were dangerous.

Concern should be expressed for allergic reactions to insect bites and stings. Contact with poisonous plants must also be avoided as much as possible.

In cases where the use of pesticides is suggested, pyrethrins are probably the safest to use. The type of pesticide to be used should be decided upon and its hazards reviewed.

Personal hygiene procedures should be detailed for cleanup after these experiments.

In the winkler titration for dissolved oxygen, faculty and students should find a chemicals list and determine the toxicity of the method. A Dissolved Oxygen meter makes a sensible substitute provided it is properly calibrated.

Overall Rating

The hazards in these experiments are slight. An overall rating of 0 for health and 0 for safety is appropriate, provided all precautions are taken.

6.8 EXPERIMENT CLASS: EVOLUTION

Overview

These experiments give students further insight into the concepts of genetics, developmental biology, and selective adaptation. A wide variety of exercises are available, ranging from "dry" labs to direct observation.

Hazards

Little or no significant hazards or specific problems exist that warrant any special considerations. However, caution is urged in handling live animals.

Overall Rating

An overall rating of 0 for health and 0 for safety is assigned to this class of experiments.

6.9 EXPERIMENT CLASS: EXPERIMENTAL PROCEDURES

Overview

These exercises illustrate proper techniques of manipulation of common biological equipment. The best methods of recording and processing of data are discussed.

Hazards

Potential hazards center on the use of the microscope and the use of dissecting equipment. Care must be taken in cutting and pinning and use of the probe needle. Only artificial light should be used with a microscope; sunlight has potentially dangerous ultraviolet rays. Although unlikely, the rays could create problems and burns in the eyes.

Overall Rating

This class of experiments has a rating of 0 for health and 0 for safety.

6.10 EXPERIMENT CLASS: GENETICS

Overview

Genetics experiments range from "dry" laboratory experiments to sophisticated work using *Drosophila*. The experiments illustrate genetic principles and the concept and role played by chance.

Chemical and Material Hazards

The only chemical hazard of note in these procedures is use of diethyl ether. Ether is both toxic and flammable and is, in fact, explosive.

The OSHA exposure to ether is 400 ppm. The NFPA lists the substance with a 4 for flammability.

Some hazard exists with the use of dissecting materials since they are sharp and capable of inflicting wounds.

Paraffin, used to seal slides and tubes, should be heated to melting on a double boiler over a hot plate. Never use an open flame with paraffin.

Students should always wear safety glasses in the laboratory.

Overall Rating

Genetics experiments can be rated with a 0 for health hazard and a 0 for safety hazard.

6.11 EXPERIMENT CLASS: PLANT ANATOMY AND PHYSIOLOGY

Overview

Experiments of this class allow students to secure a first-hand understanding of the structure, metabolism, and reproduction of plants. The experiments are generally well planned and written, and include the role of light and photosynthesis. Usually they are free of significant hazard.

Chemical and Material Hazards

Many chemicals used in this class of experiments are fairly toxic. Attention should be given to using a substitute for benzene. Toluene can do most of the work of benzene with only a fraction of the toxicity.

The reagents called for in these experiments are summarized in Table 6.11-1.

Be aware that ethanol and methanol have the same general flammability properties as gasoline.

Procedural Hazards

Students and faculty should wear safety glasses in the laboratory at all times.

Care must be used when working with cutting instruments so as to lessen injuries to the hands and fingers. A slicing motion rather than a crushing motion should be used.

Make sure that there is no direct source of flame when working with alcohol extractions of leaves. In addition, the surface temperature of the hot plate should not exceed 500°F.

Care must be taken in the use of pipettes. Valved rubber bulbs must be used and not the mouth.

Cork-borers are hazardous instruments. If used improperly they can cause severe wounds. Be sure that fingers and hands are out of the way of blades.

If mercury is spilled from equipment or thermometers it must be cleaned up using the method described in Chapter 3.

Hoods should be used when solvents such as alcohol, methanol, acetone, and petroleum ether is used.

Hot beakers should be manipulated with tongs.

Overall Rating

An overall rating of 0 for health hazards and 1 for safety hazards is assigned to the plant anatomy and physiology experiment class.

TABLE 6.11-1

CHEMICAL HAZARDS IN PLANT PHYSIOLOGY EXPERIMENTS

Health/Safety Hazard	Chemical	Registry Number	Rat Oral LD_{50} (mg/kg)	OSHA TWA	NFPA Code
2/2	Acetic Acid	AF12250	3310	10 ppm	221
1/3	Acetone	AL31500	9750	1000 ppm	130
4/1	Barium Hydroxide	CQ98000	NA	0.5 mg/m^3 as BA	NA
*4/3	Benzene	CY14000	3800	10 ppm	230
1/3	Formaldehyde	LP89250	800	3 ppm	240
1/0	Gibberellic Acid	LY89900	6300	NA	NA
3/3	Hydrochloric Acid	MW40250	900	5 ppm CL	300
3/3	Iodine	NN15750	NA	0.1 ppm	NA
1/3	Methanol	PC14000	13000	200 ppm	130
2/2	Napthalene	OJ05250	1780	10 ppm	220
2/3	Petroleum Ether	SE75550	500	NA	NA
1/0	Sodium Chloride	VZ47250	3000	NA	NA
2/0	Sodium Hydrogen Carbonate	VZ17500	4220	NA	NA
3/1	Sodium Nitrate	WC56000	NA	NA	NA
0/0	Surcrose	WN65000	29700	NA	NA

*Suspected Carcinogen

6.12 EXPERIMENT CLASS: PLANT TAXONOMY

Overview

Plant taxonomy experiments offer little hazard. The purpose of these experiments is to classify plants based on various aspects of structure.

Hazards

The only significant hazard is in collection of plant leaves that are irritants to the skin.

Overall Rating

A rating of 0 for health and 0 for safety hazards can be assigned.

6.13 EXPERIMENT CLASS: REPRODUCTION

Overview

These experiments offer students an overview of various kinds of reproductive processes. Few sources of hazard exist in this class.

Hazards

Care must be taken that students do not injure themselves with dissection equipment. Few other problems exist.

Instructors should give proper directions for disposal of used samples, particularly chick embryos. Embryos are hosts for bacteria, including pathogenic bacteria.

Overall Rating

Overall hazard ratings of 0 for health and 0 for safety are assigned.

CHAPTER 7

PHYSICS EXPERIMENTS

CHAPTER 7

PHYSICS EXPERIMENTS

7.1 EXPERIMENT CLASS: DATA ANALYSIS AND MEASUREMENT

Overview

Experiments in this class expose students to the concepts of critical observation, the measurement of data, the interpretation of data, and the relationship of variables. Usually very simple systems are employed or some phenomenon in nature is selected.

Hazards

Most data analysis and measurement experiments are free from any significant hazard.

Rating

A health/safety rating of 0/0 is assigned to this class of experiments.

7.2 EXPERIMENT CLASS: ELECTRICITY AND MAGNETISM

Overview

Experiments with electricity and magnetism include work in the following areas:

- Electrostatics and Electrical Properties of Matter
- Ohm's Law: Voltage, Resistance and Current
- Series, Parallel, and Simple Circuits
- Electrolytic Cells
- Magnetic Fields
- Electromagnetic Experiments
- Electronics

A very wide variety of concepts is introduced to the students through these critical experiments.

Chemical and Material Hazards

No significant chemical hazard exists in this class if flammable chemicals are avoided.

Equipment and Procedural Hazards

A general description of electrical hazards is given in Chapter 3 of this manual. Remember that it is the current that kills. High voltages can produce significant currents through the body.

Exposed circuitry and connections pose a substantial hazard in all of these experiments. In electronics, currents of 500 volts or more can be found, and extreme hazards exist when they are exposed. Instructors should inspect wiring before plugging in the apparatus and turning on the equipment.

Make sure that hands and feet are dry when working with electrical equipment. Before manipulating the circuit or components, disconnect power and allow a few minutes for capacitors to discharge.

Exercise care with vacuum tubes. Mechanical shock can cause them to implode with sometimes violent effects. Old Crookes tubes or discharge tubes should not be used, because many produce hazardous amounts of x-ray radiation and are dangerous.

Power supplies should be appropriately grounded. Autotransformers should be used in place of open transformers.

Experiments with resistive heating can cause high temperatures. Be careful to avoid burns.

Overall Rating

If proper safety procedures are established a health hazard rating of 0 and a safety hazard rating of 3 can be assigned to these experiments.

7.3 EXPERIMENT CLASS: HEAT

Overview

Experiments with heat focus on calorimetry and thermal expansion. These experiments offer students the opportunity of becoming involved in the measurement of temperature and experience in producing cooling and heating in baths.

Chemical and Material Hazards

Metals that are easy and safe to handle should be used in calorimetry experiments. Otherwise there are no chemical hazards except those associated with the use of mercury thermometers and J-tube manometers. Teachers should refer to Chapter 4.8 for safety information relative to mercury spills.

Procedure and Equipment Hazards

Burns from handling steam or hot water are of primary concern in heat experiments. Burns resulting from a steam or water spill can frequently be quite serious. Teachers should make sure equipment is secure and will not topple over if bumped. Partially closed systems should be checked for blockages. Hazards due to open flames can be reduced by using hot plates.

In expansion of gases, it is recommended that the mercury system be replaced by a syringe. See Chapter 4.8.

Also, a caution regarding dry ice and acetone is necessary. This mixture can cause frostbite burns and is flammable. Do not use around open flames.

Overall Rating

Because of the potential for hot water spills and resulting burns, a safety hazard rating of 1 is assigned. The health hazard rating is 0.

7.4 EXPERIMENT CLASS: LIGHT (OPTICS)

Overview

The classic concepts of the wave character of light and the properties of light waves are dealt with by these experiments. They can be organized into subgroups as follows:

- Wave Phenomenon
- Sources of EMR
- Refraction and Reflection
- Interference of Waves
- Mirrors and Lenses
- Colors and Spectra
- Polarized Waves
- Photoelectric Effect

Chemical and Material Hazards

The experiments that involve determination of refractive indices possess the only significant chemical hazard in this class. Care must be taken to select chemicals considered relatively safe, such as glycols and glycol ethers, alcohol, glycerol, cyclohexane, cyclohexanone, toluene, and perchloroethylene. Avoid chloroform, carbon tetrachloride, benzene, ethylene chloride, trichloroethane, and dichlorobenzene.

Procedure and Equipment Hazards

Incandescent bulbs are often potentially hazardous in the laboratory. The light emitted should not be viewed directly through convergent lenses; the focused energy can damage the eye.

Incandescent bulbs get hot from their infrared output resulting in the possibility of burns. They can explode if water contacts them. Candles should be used with care because of the possibility of burns.

Sources rich in ultraviolet radiation must be handled with care. Eyes and skin can be burned if the exposure time or intensity is sufficiently great. Common ultraviolet sources are mercury discharge lamps.

The sun should *never* be directly viewed through lenses of any kind. The sun can be safely viewed by reflection off of a white surface. Eyes should be protected by appropriate glasses from ultraviolet and infrared radiation. Safety glasses are recommended at all times.

Cuts can occur from the edges of mirrors, lenses, razor blades, and slits.

Some hazard due to electrical shock also exists, especially when dealing with wave tanks. Dry hands and walking spaces are essential in these areas.

Overall Rating

These experiments have an overall rating of 0 for health and 1 for safety hazards.

7.5 EXPERIMENT CLASS: MECHANICS

Overview

Experiments considered in this section are examples of classical mechanics. They may be roughly subdivided into the following groups:

- Fundamental Units
- Concepts of Force and Second Law
- Concepts of Momentum
- Circular Motion
- Simple Harmonic Motion
- Energy Concepts
- Third Law Considerations

Chemical and Material Hazards

There are no significant chemical hazards in this collection of experiments. The use of glycerol and water is suggested for densimetry.

Procedural Hazards and Equipment Hazards

Many experiments require application of motion to systems comprising springs, metal objects, metal balls, weights, etc. High velocities can be achieved, especially when dealing with centripetal acceleration and centrifugal force equipment. Weights and objects liable to become airborne should be secured. Flying objects can cause serious injuries to the body, especially around the head. Safety glasses should be worn to protect the eyes.

Weights or bricks placed on elevated surfaces should be secured using C-clamps or other devices. These objects can easily smash fingers and toes. The teacher can usefully explain the effects of a 1-kg weight falling onto the toe from table height.

Experiments involving weight-bearing trolleys should be conducted on a massive table with stops clamped to the edges if possible.

Students should not look directly into strobe lights when conducting experiments to freeze motion. Strobes can have an ill effect on students who have preconditions of psychological or heart problems.

Mercury J-tubes should not be used in experiments to illustrate Boyle's Law. Substitute a piston and bricks. The hazards of mercury and appropriate housekeeping techniques are discussed in Chapter 4.8.

Overall Rating

Assuming that mercury is not to be used on Boyle's Law experiments, a rating of 0 for health hazards is given. Because the danger of injury from flying objects is substantial, a safety rating of 1 is assigned to this class of experiments.

7.6 EXPERIMENT CLASS: NUCLEAR EXPERIMENTS

Overview

Teachers should be aware of Federal and State regulations concerning isotopes and their control. See Chapter 3 for a thorough discussion of this topic. Typical experiments involve student use of Geiger counters and cloud chambers and determination of half-life.

Chemical and Material Hazards

Materials used in nuclear experiments are not chemically toxic but could pose a substantial health hazard if handled improperly. Care must be exercised so that only small quantities of radioactive materials are kept.

Cloud chambers use dry ice (solid carbon dioxide). Frostbite and burn hazards exist when working with dry ice; it should be handled with tongs or insulated fiberglass gloves. Methanol used in cloud chamber experiments is extremely flammable.

All glassware must be decontaminated after use. A Geiger counter should be used to survey the equipment and work area.

Equipment and Procedural Hazards

Cautions relative to high voltage equipment apply here. Be sure that all equipment is in safe, proper operating condition. Disconnect the equipment before making adjustments.

Neither teachers nor students should eat, drink, or apply cosmetics where radioactive materials are being used.

Safety glasses should be worn at all times, particularly when handling isotopes.

7.7 EXPERIMENT CLASS: SOUND

Overview

Experiments in sound deal with the use of tuning forks and resonance. Both the velocity of sound and the frequency of sound waves are determined.

Hazards

There are no significant hazards in any of these experiments. High frequency forks may offend a student's hearing but no real injury is to be expected.

Overall Rating

Ratings of 0 for health hazard and 0 for safety hazard are assigned.

APPENDIX I

FIELD TRIPS

Preliminary Site Visit

It is usually recommended that teachers visit the sites of field trips before class visits. However, teachers generally know the objectives or reasons for visits but, if "methods" texts are any indication, do not visit the sites to note any hazards. Preliminary visits should include notation of any dangers inherent in the area. Such dangers could include steep dropoffs, rocky areas that may give way to rock slides, deep or swift water hazards, plants to which students could react or be allergic (golden rod, poison ivy, stinging nettle, etc.) and certain animals (snakes, ticks, bees, etc.).

A safety inspector or industrial hygienist employed by an industry to be visited can inform the teacher beforehand about potential hazards and precautions to be taken.

Planning for the Visit

To be prepared for the unexpected, teachers can request that the school nurse check records of students participating in the trip. Teachers should know of student allergies to plants and insects; more people in the United States die each year of allergic reactions to insect bites and stings than die from snake bites.

Teachers should also be aware of students who have health problems such as heart disease, epilepsy, and diabetes or who may be subject to blackouts or dizzy spells. Each teacher should seek advice from the school nurse or doctor as to how best to deal with these potential problems. Knowledge of students who have such health problems enables the teacher to be more alert to and prepared for their occurrence.

First-aid kits should be complete and can be supplemented with supplies necessary for certain visits or individual students. Supplements for individuals should be added upon the advice of the school doctor or nurse. Teachers should know how to use the first-aid kit and should probably have a course in first aid, including artificial respiration.

Teachers should also send announcement notes home to parents. These notes should include the location, purpose, date and time, mode of transportation, adult supervision, and other items of local or specific need such as appropriate clothing. There should be a place for a parent signature of approval as well as a request for parents to apprise the teacher of individual health problems.

The parental signature does not remove responsibility of the student from the teacher, but does ensure that the teacher attempted to inform the parents about the trip and gain input from them about pertinent health concerns.

When containers for collecting are necessary, plastic jars and bottles are preferred over glass. Similarly, students should be cautioned about carrying lunch drinks in glass containers; cans and Thermos-type bottles are preferred for safety reasons.

In the Field

Buddy systems should be used by students, and periodic checks by teachers are almost mandatory in some instances.

Proper clothing and insect repellent reduce any likelihood of insect bites and stings.

"High risk" areas for students with allergies or other health hazards should be pointed out to those students. These areas should be considered as off-limits for such students.

Students should be cautioned about any hazards noted during the teacher's earlier visit.

Common sense rules should be noted for all students and might include:

- —Never put hands into holes or crevices.
- —Never turn over rocks or logs by putting hands underneath. Always use a lever.
- —Never place hands on ledges above where one can see.
- —It is preferable to step on tops of logs and then away rather than to step over logs.
- —Never eat anything that has not been positively identified as being harmless.
- —Never drink any water from springs, streams, ponds, or lakes.
- —Stay away from steep dropoffs, ledges, or loose-rock inclines.
- —Know where the teacher and the first aid kit will be.

Returning from the Trip

Students should wash their hands, arms, and faces with soap and water. A change of clothing frequently prevents the spread of contamination from poison ivy or tick, mite, or chigger bites. All cuts, scrapes, blisters, etc. should be treated. Any accidents should be reported to the school administration, school nurse, and perhaps to parents.

The following is a partial list of plants of which some parts may be toxic or cause an allergic reaction:

Akee
Allamanda
Aloe
Angel's Trumpet (Datura)
Aspidium
Azalea
Black Locust
Bleeding Heart
Bracken Fern
Brazilian Pepper
Cajeput (Punk)
Candlenut Tree
Cashew
Cassava
Castor Bean
Century Plant
Chenille Plant
Chinaberry
Copper Leaf
Coral Plant
Crepe Jasmine
Crinum Lily
Croton
Crown of Thorns
Daffodil
Daphne
Dasheen
Derris
Dieffenbachia (Dumb Cane)
Elderberry
Elephant's Ear
English Ivy
Fishtail Palm
Four O'Clock
Foxglove
Gloriosa Lily
Golden Dewdrop
Ground Cherries
Hemlock
Holly
Horsetails
Hydrangea
Iris
Jack-in-the-Pulpit
Jessamine (Jasmine)
Jimson Weed
Johnson Grass
Lantana
Larkspur
Laurel
Leadwort (plumbago)
Lily of the Valley
Marihuana
Matrimony Vine
Mayapple
Mexican Prickle Poppy
Milkbush (Pencil Cactus)
Mistletoe
Monkshood
Monseed
Necklace Pod
Night Blooming Jasmine
Nightshade
Oak
Ochrosia
Oleander
Palm Seeds and Fruit
Physicnut
Plumeria (Frangipani)
Poinsettia
Poison Ivy
Poison Oak
Poison Sumac
Poisonwood
Pokeweed
Poppy
Potatoes (sprouting)
Primrose
Rattle Box (crotalaria)
Rhododendron
Rhubarb
Rosary Pea
Sand Box Tree
Seven Minute Nettle (Tread Softly)
Silk Oak
Sorghum
Spider Lily
Spring Nettles
Star of Bethlehem
Sudan Grass
Thevetia (Lucky Nut)
Toadstools
Tobacco
Tung oil Tree
Velvet Bean
Water Hemlock
Wild Croton
Wisteria
Yew

SCIENCE FIELD TRIPS

Field experiences are an integral part of many science courses. The importance and relationship of field work to the curriculum of the natural or environmental sciences cannot be minimized and, in many cases, is essential for the application of key concepts.

Field trips to industries, governmental agencies, energy and utility companies, and natural areas can help students see applications of science in technology and research and provide career awareness essential to the total development of the student. Field trips can be misused however, and should be carefully integrated into the instructional program. In reviewing the research, Ramsey and Howe state that: "Field experiences are only likely to be successful in producing significant learning gains if the outcomes required cannot be taught effectively and efficiently in another way."[1] This underscores the importance of careful planning if the field trip is to be a meaningful experience for the student.

A field experience can have a number of purposes and serve a variety of instructional objectives. Field trips may be used to:

a. motivate students when introducing a new unit;
b. provide opportunity to collect "real data" about the natural environment;
c. integrate consumer and career education into the curriculum;
d. relate science instruction to industrial research and technology.

Abraham, Kennedy, and Liebher encouraged biology teachers to use field trips in instruction when they wrote: "A study of organisms in their natural environment brings students closer to an understanding of the interrelationships that exist between living things and their environment and provides a learning experience that has both immediate and lasting value. Experiences gained during a field trip can motivate students to read about what they have observed and can serve to bridge the gap between the written text and the actual experiences of observing and working with organisms under natural conditions."[2]

The following questions should be answered when considering implementing field experiences into the curriculum.

1) Does the field experience being contemplated significantly contribute to the education of the student?
2) Will the field experience contribute to the instructional program and is it consistent with the goals and objectives of the course?
3) How much time is involved and what must students sacrifice (i.e., other classes, music, etc.), for the field experiences?
4) What travel arrangements are necessary?
5) What is the minimum level of supervision necessary and available?
6) What hazards are associated with the field experience and what precautions should be taken in preparing for the safety of each student?

If the field experience has educational value based upon these criteria and can be conducted without fear of serious injury to the students, the preliminary planning should proceed.

Preliminary Planning

The law generally has held that teachers are responsible for three areas regarding safety.

1) They are responsible for adequately instructing students about hazardous materials, procedures or situations.
2) They are responsible for properly supervising the students and enforcing safety standards.
3) They are responsible for maintaining equipment so that danger from its use is minimized.

Injuries resulting from failure to do any one of the above three could lead to a lawsuit against the teacher and a possible court decision against the teacher. These same three areas of responsibility extend into field work. Proper instruction as to potential hazards can only be given if the teacher has visited the area prior to the trip as preliminary visitation to the site will enable the teacher to identify potential hazards.

Preliminary Plans and Site Visitation

It is recommended that teachers visit the sites of field trips prior to class visits. Ordinarily, teachers are cognizant of the content associated with the objectives or reasons for visiting the sites. It is suggested that a preliminary visit include notation of any dangers inherent in the area to be visited. Such dangers might include steep dropoffs, rocky areas that may give way to rock slides, deep or swift water, hazards associated with plants to which students might react or be allergic (golden rod, poison ivy, stinging nettle, etc.) and animals which might present hazards (snakes, ticks, bees, etc.).

A safety inspector or industrial hygienist employed by an industry which is to be visited can inform the teacher about potential hazards and precautions to take prior to the visitation.

After the preliminary visit teachers are in a position to instruct students properly about the potential safety/health hazards. Specific and accurate instruction sheets, parent consent forms, rules and regulations and schedules can then be prepared.

Teachers should send field announcement forms home to parents. These forms should include the location, purpose, date/time, mode of transportation, adult supervision, brief itinerary and other items of local or specific need such as appropriate clothing to be worn by students. There should be a place for a parent's signature of approval as well as a request for parental input concerning student health concerns about which the teacher should be apprised. (see illustrations).

The parental signature does not remove responsibility for the student from the teacher, but does ensure that the teacher made a reasonable attempt to inform the parents about the trip and gain input from them about pertinent health concerns.

Teachers would be well advised to request that the school nurse check records of any students participating in the trip. Teachers should know of student allergies to plants and insect bites. They should also be aware of students who have health problems such as heart disease, epilepsy, and diabetes or who may be subject to blackouts or dizzy spells. Each teacher should seek advice from the school nurse or doctor as to how he or she might best deal with such an event should one occur. The teacher also has the knowledge of necessary items to add to the first aid kit. Such supplements should be used only upon the prior advice of the school doctor or nurse and with written parental permission. Teachers should know how to use the first aid kit and preferably have had a course in first aid, including mouth-to-mouth breathing and cardio pulmonary resuscitation.

Special equipment needed should be obtained in advance of the trip. Eye protective devices should be provided if any danger exists from flying objects such as rock chips or industrial "splinters." Water craft, hard hats, life jackets may be needed in some instances. Once the equipment list is formulated and the equipment is obtained each item should be checked to see that it is in good condition. Students should receive instructions in using the equipment *prior* to the trip. On a separate student handout specific duties should be listed and assignments made. Equipment such as animal cages, sweep nets and other items should be checked for sharp edges or potentially hazardous parts. Plastic containers are not subject to breaking and should be substituted for glass containers whenever possible.

Written permission should be secured from the landowner prior to making a field trip on private land. Check with local authorities when visiting sites that are located on state or federal land. Hiking or caving plans and permits are frequently required.

Transportation

Transportation to and from field trips should be authorized by school authorities. Whenever possible, school buses or vans with a driver employed by the school should be used for field activities. The use of student drivers is discouraged; however, parents or other adult chaperones are considered appropriate choices. Authorization for a student to travel with a teacher or parent may not relieve the driver of liability in case of an auto accident.

Site Safety

Upon reaching the field trip site, specific hazards should be pointed out to the students. Students should also be given specific accident instructions. What are they to do if an accident occurs? Where will the nearest teacher or supervising adult be located? Where will the first aid kit be located? Who may or may not use the kit to treat an injury? Review the use of safety equipment. A "buddy system" is a way to minimize students "getting lost" or drifting away from the group. Once students are moving through the site, periodic supervisory checks by the teacher or other adult will be necessary. These checks should be made to insure that students are in the proper location, on task and using the equipment properly.

1 Gregor Ramsey and Robert W. Howe, "An Analysis of Research Related to Instructional Procedures in Secondary School Science, Part 1," *The Science Teacher*, March 1969.

2 N. Abraham, M. Kennedy and H. Liebher, 1966. "High School Biology Field Expeditions," *The American Biology Teacher*, 28 (5): 381-387.

SAMPLE PARENT LETTER

Dear Parent,

On Friday, March 13, 1984, we will be taking a field trip to Dark Cave. The objective of the trip is to study cave formation. We will be leaving at 7:00 a.m. from the school entrance and returning at 3:00 p.m. We will be traveling by school bus and Mrs. Bat, Mr. Bell, and Mr. Fry will provide adult supervision for the trip.

We should arrive at the cave at 9:00 a.m. A state guide will conduct our tour of the cave. Our tour will end at noon. After lunch we will have a short presentation on cave formation and local geology. We will leave the area at 1:00 p.m.

In an emergency you will be able to reach your child at the cave area headquarters. The number is (333) 241-7300.

Students should wear clothes that they can get dirty. Long sleeve shirts and jeans would be appropriate. They should also bring a light jacket. If pictures are to be taken, a camera with flash attachment will be needed.

Enclosed you will find a permission slip and other forms. Please complete, sign and return to Mr. Dark by Thursday of the week.

Sincerely,

PERMISSION SLIP

I have read the description of the field trip to be taken by members of __________'s science class/science club to ______________________________ on the following day(s) ______________.

Write in your son's or daughter's name into the *one* appropriate blank below:

________________________ (student's name) *has* permission to participate in this activity.

________________________ (student's name) *does not have* permission to participate in this activity.

____

Parent signature

____

Date

EMERGENCY MEDICAL TREATMENT FORM

In case of medical emergency and we are not immediately available for consultation, I hereby give permission to the physician selected by the teacher-in-charge to administer proper treatment or hospitalize my child/ward as named below with the exceptions noted here:

(e.g. insulin) ____

____

____

____

SIGNATURE OF PARENT/GUARDIAN

The term of this agreement shall be from _______ to _______, both dates inclusive and in my absence.

____

NAME OF STUDENT

"Guidelines for Out-of-School Experiences," Science Resource Centre at Queens, Queen's University, Kingston, Canada, 1973.

STUDENT INFORMATION FORM
RESIDENTIAL FIELD STUDIES AND OVERNIGHT TRIPS

Student's Name ______________________________

Name of Parent or Guardian ______________________________

Home Address ______________________ Business Address ______________________

Phone ______________________ Phone ______________________

If your child has recently been under the care of a physician please indicate information that we should know about your child.*

____

____

List the details of any physical handicap* ______________________________

____

List the details of medication that must be administered:*

____

____

List the details of any allergies* ______________________________

List other factors that require special consideration for field studies/trips.*

____

____

______________________ DATE ______________________ SIGNATURE OF PARENT OR GUARDIAN

* In order to provide the teacher in charge with information that may be necessary to the health and safety of your child, please provide the information requested. All information will be considered confidential.

SAMPLE ITINERARY

______________	______________	______________
Teacher	Class/Group	Date
______________	bus/van/private auto	Chaperone
Destination	Mode of Transportation	______________
		______________

8:00 a.m.	Depart from school parking lot
8:45 a.m.	Arrive at field site
8:45 a.m.	Organize into groups/teams – receive instructions
9:00 a.m.	Participate in field activity
12:00 noon	Wash-up (lunch)
12:45 p.m.	Participate in field activity
2:00 p.m.	Conclude field activity and organize equipment
2:15 p.m.	Load vehicles for return trip
3:00 p.m.	Arrive at school – return equipment and materials to the science classroom
3:15 p.m.	School dismissed

NATURAL AREA FIELD TRIPS

Field work associated with biology and life science classes may expose students to hazards from poisonous plants and venomous animals. Environmental studies are an important aspect of these courses and field work is highly recommended, however, the teacher should be aware and knowledgeable of plants, animals, and other hazards to avoid.

PLANT POISONING

Potential plant poisoning occurs in three different forms: allergies, dermatitis and ingestion. Dermatitis is probably the most common type of plant poisoning occurring as a result of field work. Almost everyone is aware of the dangers of poison ivy; however, it is just one of a number of irritating species. Poison oak, poison sumac, spotted spurge, various nettles, and others are also poisonous and may cause severe dermatitis. It is important that students avoid contact with these plants. To help reduce the chance of infection, students should always *wash with soapy water immediately after contact or at least upon their return from the field experience*. A fresh change of clothes is recommended when students have been in heavily infested areas.

Hardin and Arena[3] list the following as the "most troublesome" dermatitis causing plant species:

Heracleum mantegazzianun (giant hogweed) – *say*
Hesperocnide spp. (western Stinging Nettle) – stinging hairs
Laportea canadensis (wood nettle) – stinging hairs
Metapium toxiferum (poisonwood) – all parts
Toxicodendron spp. (poison ivy, poison oak, poison sumac) – all parts
Urtica diocia (stinging nettle) – stinging hairs

More than eighty additional plants are listed as "suspected" of causing dermatitis.

The degree of plant poisoning can range from minor skin irritation to long lasting inflammation or blisters and depends largely upon an individual's personal sensitivity to the poison. The degree of sensitivity seems to be determined by previous exposure, extent and duration of contact with the plant. Teachers should identify students with known dermatitis problems. If the problem is severe or if a plant known to cause the allergic reaction is abundant, the teacher may want to excuse the student from the field work activity or choose an alternate site.

Allergies are a result of an individual's sensitivity to the various substances. Algae, fungus spores and pollen of seed plants are the usual culprits of allergic reactions. Although it is probably impossible to protect students from their allergies, field trips taken in the fall (during the peak of ragweed season) will almost certainly increase the irritation to many students. Hay fever, asthma and other allergy related respiratory diseases can cause serious complications and students who suffer from these allergic reactions should be identified and, if possible, protected from exposure to their irritant(s).

Many plants are highly toxic when ingested. The specific part of the plant containing the toxin varies with the species. Seeds, fruits, stems, leaves, flowers, berries, etc., can be toxic and should not be eaten. The state of plant growth, size and physical condition of the individual person and the time of year also can be factors in the seriousness of the poisoning.

In case of internal poisoning, the following steps should be taken:[4]

1) Call a physician.
2) Be prepared to provide the following information:
   a) Name of the plant – (if you don't know the name of the plant, collect samples for positive identification by a trained botanist).
   b) A good description of the plant if the name is unknown. Save the plant for later identification.
   c) How long ago it was eaten.
   d) Age and approximate weight of the individual.
   e) Symptoms observed. Note all unusual symptoms and describe carefully.
   f) How much and which parts of the plant were eaten.
3) If a physician cannot be contacted have the individual drink a glass of water and then try to induce vomiting by tickling the back of the victim's throat with your finger or blunt spoon. Drinking a solution of two tablespoons of salt in a glass of water may also induce vomiting.[5]

The following types of plants are known poisons if ingested and should be avoided:

Algae – "Blooms" of blue-green algae or water obviously "polluted" must be avoided.

Fungi – Many species of "toadstools" are poisonous and it is difficult to distinguish these from non-poisonous, edible varieties. *Amateurs should not collect, cook and eat mushrooms or toadstools collected in the wild*. Some poisonous genera are: *Amanita, Clitocybe, Lactarius, Lepiota* and *Russula*. Symptoms of mushroom poisoning vary from extreme abdomnial pain and vomiting to loss of muscular coordination and hallucinations. It is extremely important that an accurate identification of the ingested species be made so that the proper treatment can be administered.

Flowering and Cone Bearing Plants

A large number of herbaceous and woody plants are also extremely dangerous when ingested. The following list identifies some of the most common poisonious plants, the toxic parts, and symptoms.[6]

Akee
Allamanda
Aloe
Angel's Trumpet (Datura)
Aspidium
Azalea
Black Locust
Bleeding Heart
Bracken Fern
Brazilian Pepper
Ca jeput (punk)
Candlenut tree
Cashew
Cassava
Castor Bean
Century Plant
Chenille Plant
Chinaberry
Copper Leaf
Coral Plant
Crepe Jasmine
Crinum Lily
Croton
Crown of Thorns
Daffodil
Daphne
Dasheen
Derris
Dieffenbachia (Dumb Cane)
Elderberry
Elephant's Ear
English Ivy
Fishtail Palm
Four O'Clock
Foxglove
Gloriosa Lily
Golden Dewdrop
Ground Cherries
Hemlock
Holly
Horsetails
Hydrangea
Iris
Jack-in-the-Pulpit
Jessamine (Jasmine)
Jimson Weed
Johnson Grass
Lantana
Larkspur
Laurel
Leadwort (Plumbago)
Lily of the Valley
Marijuana
Matrimony Vine
Mayapple
Mexican Prickle Poppy
Milkbush (Pencil Cactus)
Mistletoe
Monkshood
Moonseed
Necklace Pod
Night Blooming Jasmine
Nightshade
Oak
Ochrosia
Oleander
Palm Seeds and Fruit
Physicnut
Plumeria (Frangipani)
Poinsettia
Poison Ivy
Poison Oak
Poison Sumac
Poisonwood
Pokeweed
Polly
Potatoes (sprouting)
Primrose
Rattle Box (Crotalaria)
Rhododendron
Rhubarb (leaves)
Rosary Pea
Sand Box Tree
Seven Minute Nettle (Tread Softly)
Silk Oak
Sorghum

Spider Lily
Spring Nettles
Star of Bethlehem
Sudan Grass
Thevetia (Lucky Nut)
Toadstools
Tobacco
Tung Oil Tree
Velvet Bean
Water Hemlock
Wild Croton
Wisteria
Yew

[3]James M. Hardin and Jay M. Arena, *Human Poisoning from Native and Cultivated Plants*. Durham, North Carolina: Duke University Press, 1974. pp. 12-15.

[4]Division of Science Education: *Safety First in Science Teaching*. Burlington, North Carolina: Caroline Biological Supply Company, pp. 13-14.

[5]Joel Hartley. *New Ways in First Aid*, (New York) Hart Publishing Company, 1971 p. 265.

[6]Division of Science Education: *Safety First in Science Teaching*. Burlington, North Carolina: Carolina Biological Supply Company, pp. 13-14.

Trees and Shrubs

Wild and Cultivated Cherries	Twigs, foliage	Fatal. Contains a compound that releases cyanide when eaten. Gasping, excitement and prostration are common symptoms that often appear within minutes.
Oaks	Foliage, acorns	Affects kidneys gradually, symptoms appear only after several days or weeks. Takes a large amount for poisoning. Children should not be allowed to chew on acorns.
Elderberry	Shoots, leaves, bark	Children have been poisoned by using pieces of the pithy stems for blowguns. Nausea and digestive upset.
Black Locust	Bark, sprouts, foliage	Children suffered nausea, weakness, and depression after chewing the bark and seeds.

Wooded Area Plants

Jack-in-the-pulpit	All parts, especially roots	Like dumb cane, contains small needle-like crystals of calcium oxalate that cause intense irritation and burning of the mouth and tongue.
Moonseed	Berries	Blue, purple color, resembling wild grapes. Contains a single seed. (True wild grapes contain several small seeds.) May be fatal.
Mayapple	Apple, foliage, roots	Contains at least 16 active toxic substances, primarily in the roots. Children often eat the apple with no ill effects, but several apples may cause diarrhea.

Swamp or Moist Area Plants

Water hemlock	All parts	Fatal. Violent and painful convulsions. A number of people have died from hemlock.

Field Plants

Buttercup	All parts	Irritant juices may severely injure the digestive system.
Nightshade	All parts, especially the unripe berry	Fatal. Intense digestive disturbances and nervous symptoms.
Poison hemlock	All parts	Fatal. Resembles a large wild carrot. Used in ancient Greece to kill condemned prisoners.
Jimson weed (thorn apple)	All parts	Abnormal thirst, distorted sight, delerium, incoherence, and coma. Common cause of poisoning. Has proven fatal.

The following plants may be toxic or cause an allergic reaction if ingested or if students come into contact with them. The following general rule should be observed: *No plant parts are eaten or chewed while on a field trip.*

The following common rules proposed by the National Science Teacher's Association in its publication, *Safety in the Secondary Science Classroom*,[7] should prove invaluable to teachers and students in working with plants.

1) Never eat unknown berries, seeds, fruits, or other plant parts.
2) Never rub any sap or fruit juice into or on the skin or into an open wound.
3) Never inhale or expose your skin or eyes to the smoke of any burning plant or plant parts.
4) Never pick any strange wildflowers or cultivated plants unknown to you.
5) Never eat food after handling plants without first scrubbing your hands.

HARMFUL ANIMALS

Students will probably encounter one or more kinds of animals while on a field trip. Various insects, snakes and mammals can be hazardous to the health and safety of students.

It should be noted that more people in the United States *die each year of allergic reactions to insect bites and stings* than *die* from snake bites. Long sleeve shirts and blouses will reduce the chance of bites and stings from mosquitoes, ticks, mites, and chiggers.

The threat of injury to students from venomous snakes is a serious problem in some areas of the country. Rattlesnakes, copperheads, cottonmouths and coral snakes are residents of forests and swamplands and will bite when disturbed. Handling of snakes is discouraged and students should *never* attempt to handle venomous snakes.

To avoid snake bites some common sense rules for students include the following:

1) Never put hands into crevices or holes.
2) Never turn over rocks or logs by putting hands underneath. Always use a stick or pole for a lever.
3) Never place hands on ledges above where one can't see.
4) It is preferable to step on tops of logs and then away rather than to step over logs.
5) Stay away from steep dropoffs, ledges, or loose-rock inclines.

The following is a partial list of organisms known to cause harmful reactions:[8]

Ants
Bedbugs
Bees
Black Widow Spider
Blister Beetles
Brown Recluse Spider
Centipedes
Chiggers
Clams*
Copperhead snake
Coral Snake
Cottonmouth Snake
Fleas
Gnats
Ioa Caterpillar
Jelly Fish
Millipede
Mosquitoes
Mussels*
Nettling Caterpillar (Slug Caterpillar)
Oysters*
Potato Beetles
Rattlesnake
Ticks (Dermacenter & Ixodidae)
Wasps
Yellow Jackets

*Toxic when living in polluted water or feeding on certain dinoflagellates

Some fishes have been known to cause poisoning. This usually depends on where the fish has been caught and its diet.

Barracuda
Butterfly Fish
Goat Fish
Moon Fish
Moray Eel
Parrot Fish
Perch
Pompano
Porcupine Fish
Puffers
Sea Bass
Snapper
Sting Rays
Sturgeon Fish
Triggerfish
Wrasse

Students should be discouraged from *catching and handling mammals*. Bites from mammals can result in infections and there is the potential hazard of contracting *rabies from mammal bites*.

AQUATIC BIOLOGY

A survey of water activities in a number of texts and workbooks reveals some common dangers. First, many aquatic areas available to teachers contain metal, glass, and trash such as old fence, barbed wire, cans and broken glass. Natural hazards include pointed sticks and underwater brush. For this reason students should not be allowed to enter aquatic environments barefoot. Waders or tennis shoes should be worn. Waders should not be worn, however, in areas where deep drop-offs or swift water occur for the waders may fill with water pulling the person under. Students should not be allowed to wade in murky water in which the bottom strata cannot be seen. Work areas should be specifically designated and delineated.

Equipment and its use can also present a hazard. Secchi disks, algae tows and other equipment are frequently used from boats. All students in the boats should be able to swim and must wear life jackets. Collecting and test vials should be of plastic material to minimize breakage hazards. Mercury filled thermometers should not be used in field situations. In the event of breakage, there is no way to contain the mercury. Alcohol thermometers are adequate substitutes and will cause less environmental damage.

Certain aquatic insects may cause painful bites. Students should be aware of their presence and able to identify these insects. Students should also be made aware of poisonous water snakes and other animals that may present a hazard.

The aquatic environment may be polluted. Dangers from poisons or infections can be minimized or avoided if students keep hands (contaminated during collecting) away from food and mouth. Students with cuts or open sores should not make contact with the water. Swimming or diving while on a field experience is not recommended.

CAVING FIELD TRIPS

Caving field trips can be a valuable teaching/learning experience for the science teacher and student. In order to make the activity worthwhile, extensive planning is required. *Clearly defined objects, appropriate follow-up discussion and activities are essential ingredients of the caving trip*. In order to insure the safety of students and teacher a visit should be made and a list of general guidelines developed prior to the trip.

[7] National Science Teacher's Association, 1978. *Safety in the Secondary Classroom*, p. 83.

[8] Dean, Robert A., Melanie Messer Dean, La Moine Motz, *Safety in the Secondary Classroom*, National Science Teacher's Association 1978.

Hazards of caving expeditions include: 1) contaminated food and/or water, 2) wild animals, 3) drop offs, 4) low clearances, 5) cave-ins, 6) high water, and 7) getting lost.

All groups entering a cave should be led by an experienced leader. The leader should be familiar with the physical characteristics of individuals, the group, the general objectives of the activity, and the cave being visited.

Groups entering a cave should be small in number and must have adequate supervision. Caution students about movement within the cave in total darkness. Unexplored caves should not be entered by student groups.

Teachers and students should rely on instruction from the experienced leader as to the type of equipment needed for the activity (e.g., rope, light sources, proper clothing, hard hats, etc.). Equipment for the instructional activity should be organized by the teacher and distributed among the students in convenient field sacks. As with most field trips, glass containers are discouraged. Always carry alternate light sources when visiting a cave. Candles and dry matches (in sealed containers) provide reliable light sources in emergency situations. Flammable liquid light sources (lanterns) should not be used.

Eating while in a cave is discouraged. Students must not drink cave water and each student should carry his or her own canteen. Students should take precautions so that food and water are not contaminated by guano deposits, etc., found in caves. *Microbiology activities in which agar plates are exposed in a cave should be done with extreme caution*. Plates should be taped shut after exposure as pathogenic bacteria as well as non-pathogenic bacteria can be cultured.

As previously stated, written permission should be secured from the landowner prior to making the field trip if the cave is located on private land. Permission may need to be obtained from local authorities when visiting sites that are located on state or federal land. The filing of hiking or caving plans and permits are frequently required. Notify someone outside exactly where you are going, when you expect to return and the names of all those entering the cave. Visiting abandoned mines should never be considered as an instructional activity. Mine visitation should be done only with company/industry personnel in those mines which schedule visitors on a regular basis.

Safety Precautions for Geology Activities

Road cuts, however, are productive sites for collecting fossils, observing stratification, weathering, succession and other physical phenomena. It should be noted that work along highways can be extremely dangerous and should be conducted only under very highly controlled situations. Consult local traffic authorities before making a visit to a road cut. In some cases highway patrol officers may provide traffic control for the field study. In any event, positioning of flares and/or signs several hundred feet on either side of the collecting area is a precautionary measure that should be taken. Caution students not to stand on or near the road surface and have students watch for poisonous snakes and insects while collecting rock specimens.

Students should also be cautioned not to climb the face of the road cut. Weathering loosens the rock layers and students can lose their footing and/or hand hold seriously injuring themselves and others. Also climbing can trigger larger rock slides. For these reasons rock climbing should be discouraged on the geology field trip. Such activity by the inexperienced persons with inadequate equipment is extremely hazardous.

Students should wear eye protection with side shields or chipper goggles while cracking or chipping rocks or minerals. While working in or around areas with high rock outcroppings, hard hats should be worn by the teachers and *ALL THE STUDENTS*.

ASTRONOMY ACTIVITIES

Astronomy activities can occur either day or night; each time has its inherent dangers. When making night observations of the sky, try to get the equipment and students to the site during daylight hours. Locate potential hazards (holes, cliffs, etc.) prior to dusk. Have students become familiar with their surroundings. Avoid shining bright light sources or reflecting bright light sources into participants' eyes.

When making rooftop observations, define working area perameters during daylight hours. Make students aware of potential hazards and emergency escape routes.

Avoid using ladders to gain access to rooftops. Only *inside stairs* or elevators should be used for getting students and equipment to the roof. Make certain that the roof will support the weight of the students and always secure permission from the building supervisor before using the area.

Daytime astronomy presents another type of hazard. To observe solar eclipses, focus an image on a piece of cardboard with a small telescope or "pin hole apparatus" and observe the image of the eclipse as it occurs on the cardboard screen. *Avoid looking directly at the sun during a solar eclipse or on any occasion.* Sunglasses, smoked glasses, exposed photographic film and welder's goggles *are not safe* for observing the sun or a solar eclipse. Use only indirect methods or simple projection in order to avoid damage to the eyes.

INDUSTRIAL FIELD TRIPS

Potential Hazards

1) Unsafe walking areas
2) Unguarded machinery
3) Electrical equipment/wiring
4) Air Contaminants
5) Flying objects (eye safety)
6) Moving vehicles (industrial trucks)
7) Eating, drinking (contaminated area)
8) Falling objects, low walkways (head, foot protection)
9) Noise – Light sources
10) Slips, trips, falls

While most industries have strict rules governing visitors the teacher is still responsible for the safety of his or her students. Teachers should, therefore, be fully aware of potential hazards and be prepared to follow and enforce rules governing industrial visitors.

Eye and face protection must be provided if there is any chance of injury from flying objects, sparks, glare, chips or splashes from caustics or solvents. Students should be especially careful if visiting an area where grinding or drilling is being done. Hard hats or other head protection must be provided in situations where objects might fall on the student or where the student might bump his/her head.

In some industrial settings, noise may be of sufficient level to cause injury to students' ears. If students visit such an area, ear protection devices (ear plugs or muffs) must be provided and used.

Students should follow the same general hygiene rules as employees when visiting an industrial site. These rules include:

1) Not eating or drinking in the work area, especially if the food or drink could be exposed to toxic materials.
2) Students should wash their hands carefully following the field trip and definitely before eating.

During the pre-trip visit to the industrial setting, the teacher should note all machines and processes which are potential hazards to students. Machines involving cutting action such as band and circular saws, milling, planing, boring, drilling, and grinding, all have hazard potential as do conveyor belts, chains, elevators and chutes. Chemical exposures and electrical hazards should be avoided. Stairs, steps and platforms may not be adequate for group movement and could present hazards for students.

Student behavior on an industrial field trip is critical for a safe experience. Students should not climb on or operate any equipment or machinery without authority and supervision of an employee. They should wear any personal protective equipment needed such as goggles, hard hats, etc. Students should be warned in advance to stay clear of machines, to stay with the group and to stay in marked observation/walk areas. It should be noted that disregard for instruction and lack of knowledge about existing dangers frequently contribute to accidents. Special plans may be needed to accommodate handicapped students.

SUMMARY

Field trips are an integral part of science instruction. Observing the previously mentioned safety precautions can help insure a successful experience in a natural or industrial setting. Viewing the field experience as simply an extension of the classroom instructional program requiring good planning and prudent supervision should result in a meaningful and productive educational experience for all participants.

Appendix II

List 1

Substances with greater hazardous nature than potential usefulness.

Assessment of the chemicals in this list indicates that their hazardous nature is greater than their potential usefulness in many secondary school science programs. Evaluation included toxicity, carcinogenicity, teratogenicity, flammability, and explosive propensity.

Acrylonitrile
Ammonium chromate
Aniline
Aniline hydrochloride
Anthracene
Antimony trichloride
Arsenic
Arsenic chloride
Arsenic pentoxide
Arsenic trioxide
Asbestos
Ascarite
Benzene
Benzoyl peroxide
Calcium cyanide
Calcium flouride
Carbon tetrachloride
Chlorine
Chloral hydrate
Chloretone
Chloroform
Chloropromazine
Chromium
Chromium oxide
Chromium potassium sulfate
Chromium trioxide
Colchicine
Dichlorobenzene
Dichloroethane
Dimethylaniline
p-Dioxane
Diphenyl ester carbonic acid
Ethylene dichloride
Ethylene oxide
Gunpowder
Hexachlorophene
Hydrobromic acid
Hydrofluoric acid
Hydrogen
Hydriodic acid
Indigo carmine
Lead arsenate
Lead carbonate
Lead (VI) chromate
Lithium, metal
Lithium nitrate
Magnesium, metal (powder)
Mercury
Mercuric chloride
Mesitylene
Methyl iodine
Methyl methacrylate
Methyl orange*
Methyl red*
Nickel, metal/Nickel oxide
Nicotine
Osmium tetroxide
Oxygen, tank
Paris green
Phenol
Phosphorus, red, white
Phosphorus pentoxide
Phthalic anhydride
Picric acid
Potassium metal
Potassium oxalate
Potassium sulfide
Pyridine
Pyrogallic acid
Saccharin
Selenium
Silver cyanide
Silver oxide
Silver nitrate
Sodium arsenate
Sodium arsenite
Sodium azide
Sodium chromate
Sodium cyanide
Sodium dichloroindophenol
Sodium dichromate
Sodium, metal
Sodium ferrocyanide
Sodium nitrite
Sodium sulfide
Sodium thiocyanate
Stannic chloride
Stearic acid
Strontium
Strontium nitrate
Sudan IV

Sulfuric, acid fuming
Talc*
Tannic acid
Tetrabromoethane
Thermite and compounds
Thioacetamide
Thiourea
Titanium trichloride
o-Toluidine
Uranium
Uranyl acetate
Uranyl nitrate
Urethane
Vinylite
Wood's metal

*Suggested alternatives:
Methyl orange and
Methyl red: Bromo-
phenol blue and
Bromothymol blue Talc:
starch talc

List 2

Evaluation included toxicity, carcinogenicity, teratogenicity, flammability and explosive propensity. These chemicals should be removed from the schools if alternatives can be used. For those that must be retained, amounts should be kept to a minimum.

Acetamide
Acid green
Aluminum chloride
Ammonium bichromate
Ammonium oxalate
Ammonium vanadate
Antimony
Antimony oxide
Antimony potassium tartrate
Barium chloride
Barium oxalate
Benzone
Beryllium carbonate
Bonine fluid
Bromine
Cadmium acetate
Cadmium bromide
Cadmium carbonate
Cadmium chloride
Cadmium, metal
Cadmium sulfate
Carmine
Catechol
Chromic acid
Chromium acetate
Cobalt, metal
Cobalt, nitrate
Cyclohexane
Cyclohexene
Dichloroindophenol sodium salt
2, 4,-Dinitrophenol
Ferrous sulfate
Formaldehyde
Formalin
Fuchsin
Gasoline
Hematoxylin
Hydrogen sulfide
Hydroquinone
Iso-amyl alcohol
Iso-butyl alcohol
Iso-pentyl alcohol
Magnesium chlorate
Mercuric bichloride
Mercuric iodide
Mercuric nitrate
Mercuric oxide
Mercuric sulfate
Mercuric sulfide
Mercurous chloride
Mercurous nitrate
Mercurous oxide
Methyl ethyl ketone
Methyl oleate
Nickel carbonate
Nickelous acetate
Paradichlorobenzene
Pentane
Petroleum ether
1-phenyl-2-thiourea
Phenylthiocarbamide
Potassium chlorate
Potassium chromate
Potassium periodate
Potassium permanganate
Salol
Sodium bromate
Sodium chlorate
Sodium Fluoride
Sodium oxalate
Sodium nitrate
Sodium silicofluoride
Sudan III
Sulfamethazine
Toluene
Trichloroethylene

Urethane
Xylene

Part 1 Positive Carcinogens

Anthracene: recognized carcinogen of skin, hands & forearms; neoplastic in rats; tolerance 0.2mg/m^3 (air); moderate fire hazard.

Asbestos: positive human carcinogen; OSHA std. air-TWA 2FB/cc, C1 10FB/cc.

Ascarite: Sodium hydroxide-asbestos absorbent.

Part 2 Potential or Suspected Carcinogens

Acetamide: positive animal carcinogen; oral rat TDLo 456gm/kg 52WC, toxic effects: carcinogenic.

Acrylonitrile: toxic by inhalation and skin absorption; severe skin and eye irritant; tolerance (air) decreased to 2ppm 11/2/78 due to data indicating that this may be carcinogenic; flammable.

Ammonium chromate: recognized carcinogen according to SAX; toxic by inhalation; strong irritant.

Arsenic: oral human LDLo 5mg/kg; shown to be teratogenic in mice; poison; some question that all inorganic arsenic compounds may be occupational carcinogens; allergen; OSHA std air-TWA 4μg/m^3; moderate fire hazard; Arsenic compounds: poisoning may be acute or chronic.

Arsenic trioxide: toxic by ingestion and dust inhalation; suspected human carcinogen; oral human LD_{50} 1430μg/kg; OSHA std air-TWA 4μg(As)/m^3. See arsenic.

Benzene: suspected human carcinogen; possible teratogen; oral human TDLo 130mg/kg, toxic effects: central nervous system; NTIS criteria document occupational exposure to benzene recommends std. air-C1 1ppm; OSHA std air-TWA 10 ppm; flammable.

Cadmium: highly toxic especially by inhalation of dust or fume, toxic effect: respiratory tract; soluble compounds are highly toxic; possible animal carcinogen; inhalation human TCLo 88μg/m^3/8.6Y, toxic effects: systemic; OSHA std air-TWA 200μg/m^3. Oral toxicity of cadmium and its compounds is high; fire hazard in powder form.

Cadmium chloride: positive animal carcinogen; oral rat LD_{50} 80mg/kg; teratogenic in rats; OSHA std air-TWA 200μg(Cd)/m^3; see cadmium.

Cadmium sulfate: positive animal carcinogen; subcutaneous rat TDLo 2mg/kg/10WI toxic effects: carcinogenic; see cadmium.

Carbon tetrachloride: positive animal carcinogen and teratogen; oral human LDLo 43mg/kg; inhalation human TCLo 20ppm, toxic effects: central nervous system; has been shown to cause liver & kidney damage in humans; OSHA std air-TWA 10ppm.

Chloroform: suspected animal carcinogen and teratogen; oral human LDLo 140mg/kg; inhalation human TCLo 10ppm/1Y, toxic effects. Systemic; toxic effect is exerted on heart muscle & on liver & kidney in humans; NTIS criteria document occupational exposure std air-TWA 10ppm.

Chromium: suspected carcinogen; hexavalent compounds have irritating and corrosive effect on tissue giving rise to ulcers and dermatitis on prolonged exposure; inhalation human TDLo 4500μg/m^3/5Y, toxic effects: pulmonary; OSHA std air-TWA lmg/m^3.

Chromium III oxide: suspected animal carcinogen; see chromium.

Chromium VI oxide (chromium trioxide): suspected carcinogen; inhalation human TCLo 110μg/m^3; see chromium.

Cobalt: suspected carcinogen; intramuscular rat TDLo 112mg/kg, toxic effects: carcinogenic; oral rat LDLo 1500mg/kg; allergen; OSHA std air-TWA 100μg/m^3; dust is flammable.

Colchicine: possible animal carcinogen, mutagen, teratogen; oral human LDLo 5mg/kg; 0.02 gm may be fatal within 24 hours if ingested; poisonous alkaloid; local irritant to skin.

1.2-dichloroethane (ethylene dichloride): NIOSH Current Intelligence Bulletin #27: should be treated as human carcinogen in workplace; inhalation human TCLo 4000ppm/H, toxic effects: central nervous system; oral human TDLo 428mg/kg, toxic effects: GI tract; irritant to eyes and skin; OSHA std air-TWA 50ppm; flammable.

p-Dioxane: possible animal carcinogen; inhalation human TCLo 470ppm; oral human LDLo 500mg/kg; absorbed by skin; repeated exposures to low concentrations has produced human deaths; kidneys & liver are the organs that are effected; OSHA std air-TWA 100ppm (skin); may form explosive peroxides.

Diphenyl ester carbonic acid: suspected animal carcinogen.

Lead arsenate (arsenic acid, lead (2+) salt): positive animal carcinogen; oral human LDLo 10mg/kg; poison; OSHA std air-TWA 150μg/m^3.

Lead chromate (VI): possible carcinogen; toxic by inhalation and ingestion; tolerance (air) 0.1mg/m^3.

Methyl iodide (iodomethane): positive animal carcinogen; neoplastic to rats and mice; oral human LDLo 50mg/kg; skin human 1gm/10M, toxic effects: mild irritant; narcotic & anesthetic; OSHA std air-TWA 5ppm (skin).

Nickel: positive animal carcinogen; inhalation rat TCLo 15mg/m^3, toxic effects: carcinogenic; allergen; OSHA std air-TWA 1mg/m^3 (skin); flammable (solid) and toxic as dust or powder.

Nickel II acetate: oral rat LD_{50} 350mg/kg; interperitoneal mouse TDLo 360mg/kg/30W-I, toxic effects: carcinogenic; intramuscular rat TDLo 350mg/kg/43W-I, toxic effects: carcinogenic; OSHA std air-TWA 1mg(Ni)/m^3.

Nickel carbonate: recognized carcinogen according to SAX; flammable and toxic as dust or powder; tolerance air 1mg/m^3 (metal and soluble compounds).

Nickel II oxide: suspected animal carcinogen; intramuscular rat TDLo 100mg/kg, toxic effects: carcinogenic; OSHA std air-TWA 1mg(Ni)/m^3.

Phenol: oral human TDLo 14mg/kg, toxic effect: GI tract; oral human LDLo 140mg/kg; strong irritant to tissue; poison; skin mouse TDLo 400mg/kg/20W-I, toxic effect: carcinogenic; absorbed in skin rapidly; dermatitis common in industry; OSHA std air-TWA 5ppm (skin).

Potassium chromate: suspected animal carcinogen; oral mouse TDLo 1600mg/kg/62WC, toxic effects; neoplastic; OSHA std air-C1 100μg (CrO_3)/m^3.

Saccharin: suspected animal carcinogen; oral rat TDLo 1820gm/kg/2Y, toxic effects: carcinogenic; implant mouse TDLo 8mg/kg, toxic effects: neoplastic.

Selenium: inhalation rat LDLo 33mg/kg/8H; oral mouse TDL 480mg/kg/60D-c, toxic effects: neoplastic; toxicity similar to arsenic; suspected carcinogen; selenium poisoning can result from inhalation or ingestion; OSHA std air-TWA 200μg/(Se)/m^3.

Sodium arsenate (arsenic acid, sodium salt): subcutaneous mouse TDLo 10mg(As)/kg/20D-I, toxic effects: carcinogenic; interperitoneal rat TDLo 45mg/kg (10D-preg.), toxic effects: teratogenic; oral human LDLo 5mg/kg; poison; OSHA std air-TWA 500μg(As)/m^3.

Sodium arsenite (arsenious acidomonosodium salt): suspected human carcinogen; oral human LDLo 5 mg/kg; OSHA std air-TWA 500μg(As)/m^3.

Sodium chromate: inhalation human TCLo 800μg/m^{3}7Y-I, toxic effects: carcinogenic; oral human LDLo 50mg/kg; NTIS criteria document occupational exposure to Chromium VI recommended std air-TWA 25μg(CrVI)/m^3.

Sodium dichromate: suspected animal carcinogen; oral human LDLo 50mg/kg; strong irritant; OSHA std air-C1 100μg(CrO_3)/m^3.

Sodium nitrite: potential carcinogen; oral human TDLo 14mg/kg, toxic effects: central nervous system; oral human LDLo 3mg/kg; oxidizer; moderate fire hazard.

Stearic acid: skin human 75mg/3D-I, toxic effect: mild irritant; implant mouse TDLo 400mg/kg, toxic effects: neoplastic.

Sudan IV: positive animal carcinogen.

Tannic acid: positive animal carcinogen; subcutaneous rat TDLo 4450mg/kg/17W-I, toxic effects: carcinogenic; subcutaneous mouse TDLo 750mg/kg/12W-I, toxic effects: neoplastic; oral human LDLo 500mg/kg.

Thioacetamide: positive animal carcinogen; oral rat TDLo 1600mg/kg/14W-C, toxic effects: carcinogenic; moderately toxic by ingestion and inhalation.

Thiourea: positive animal carcinogen; oral woman TDLo 1660mg/kg/5W, toxic effects: blood; allergen.

o-Toluidine: suspected human carcinogen; absorbed by skin; effects similar to aniline; threshold limit 5ppm.

Trichloroethylene: suspected animal carcinogen; oral human LDLo 857mg/kg; inhalation human TCLo 160ppm/83M, toxic effects: central nervous system; prolonged inhalation causes headache & drowsiness; use prohibited in some states; OSHA std air 100ppm.

Uranium: recognized carcinogen according to SAX; fire hazard (solid): ignites spontaneously in air; radioactive; source of ionizing radiation; tolerance uranium and all compounds 0.2mg/m^3 (air).

Uranyl acetate: carcinogenic according to SAX; OSHA std air-TWA 50μg(U)/m^3.

Uranyl nitrate: carcinogenic according to SAX; Class A explosive; severe fire and explosion risk when heated or in contact with organic materials; highly toxic.

Urethane (carbamic acid, ethyl ester): experimental carcinogen and mutagen; toxic by ingestion; oral rat TDLo 20gm/kg/39W-C, toxic effects: carcinogenic; oral mouse TDLo 160mg/kg, toxic effects: carcinogenic; can produce central nervous system depression.

Vinylite (chloroethylene polymer): possible carcinogen; implant rat TDLo 100mg/kg, toxic effects: neoplastic.

Part 3 Toxic and/or Fire Hazard

Aluminum chloride: (anhydrous) strong skin irritant; oral rat LD_{50} 3700mg/kg; reacts violently with water to give HCl; (hydrated) may be toxic.

Ammonium bichromate or dichromate (dichromic acid, diammonium salt): allergen; prolonged inhalation of dust can cause asthmatic symptoms; irritant to skin and eyes; NTIS criteria document on occupational exposure to CrVI recommended std air-TWA 25μg(CrVI)/m^3; oxidizer; dangerous fire hazard; may explode in contact with organic materials.

Ammonium vanadate: oral rat LDLo 18mg/kg; NTIS criteria document occupational exposure recommended std air-Cl 0.05mg(V)/m^3/15M.

Aniline: oral human LDLo 50mg/kg; allergen; may cause contact dermatitis; poison; action is the formation of methemoglobin yielding anoxemia and depression of central nervous system; may have direct toxic action causing fall in blood pressure and cardiac arrhythmia; acute exposure such as spill or inhalation can cause anoxemia; moderate fire hazard; OSHA std air-TWA 5ppm (skin).

Aniline hydrochloride: see aniline for toxicity data.

Antimony: inhalation human TClo 4700μg/m^3/20W, toxic effects: unspecified; oral rat LD_{50} 100mg/kg; toxic by fume; use with adequate ventilation; OSHA std air-TWA 500μg/m^3; antimony compounds irritant to skin and mucous membranes.

Antimony chloride (trichloride): inhalation human TDLo 73mg/kg, toxic effects: pulmonary system and GI tract; corrosive liquid; strong irritant to eyes and skin; reacts vigorously with moisture to yield heat and HCl.

Antimony oxide (trioxide): oral human LDLo 2mg/kg; may cause dermatitis; OSHA std air-TWA 500μg/(SB)/m^3.

Antimony potassium tartrate: oral human LDLo 2mg/kg; skin rash may occur; OSHA std air-TWA 500μg(SB)/m^3.

Arsenic chloride (trichloride): strong irritant to eyes and skin; poison; OSHA std air-TWA 4μg(AS)/m^3; see arsenic.

Arsenic pentoxide: oral humans LDLo 5mg/kg; poison; oral rat LD_{50} 8mg/kg; see arsenic.

Barium compounds: all barium compounds are toxic by ingestion and are skin irritants; tolerance for all soluble barium compounds is 0.5mg/m^3 (air).

Barium chloride: oral human LDLo 11.4mg/kg; oral human TDLo 80mg/kg, toxic effect: GI tract; see barium compounds.

Benzoyl peroxide (dibenzoyl): inhalation human TCLo 12mg/m^3, toxic effect ÷ pulmonary system; oral human LDLo 500mg/kg; possibly neoplastic in mice; OSHA std air-TWA 5mg/m^3; flammable; explosive: may explode spontaneously when dry (1% water).

Beryllium carbonate: highly toxic by inhalation and ingestion; NTIS criteria document occupational exposure to beryllium recommended std air-TWA 2μg(Be)/m^3; OSHA std air-TWA 2μg/m^3, Cl 5.

Bromine: severe skin irritant; OSHA std air-TWA 0.1ppm; oral human LDLo 14mg/kg; inhalation human LCLo 1000ppm; corrosive; strong oxidizing agent.

Butanol (n-butyl alcohol): toxic to prolonged inhalation; inhalation human TCLo 25ppm, toxic effect: irritant; irritant to skin and eyes; OSHA std air-TWA 100ppm.

Cadmium acetate: highly toxic especially by inhalation of dust or fume; soluble compounds of cadmium highly toxic; see cadmium.

Cadmium bromide: same as above.

Cadmium carbonate: same as above.

Calcium cyanide: oral human LDLo 5mg/kg; oral rat LD_{50} 39mg/kg; poison; decomposes in moist air to yield hydrogen cyanide; dissolves in water and weak acids to yield hydrogen cyanide; highly toxic.

Catechol (pyrocatechol): oral human LDLo 50mg/kg; oral rat LD_{50} 3890mg/kg; allergen; strong irritant; threshold limit value-air 1ppm (skin); can react with oxidizing materials.

Chloral hydrate: oral human LDLo 4mg/kg; oral human TDLo 300mg/kg, toxic effect: central nervous system; hypnotic drug; commonly called "knockout drops"; liquid and vapor dangerous to eyes.

Chloretone: trademark for chlorobutanol: toxic action similar to chloral hydrate; oral human LDLo 50mg/kg.

Chlorpromazine: oral human LDLo 50mg/kg, toxic effect: central nervous system; tranquilizer; possible teratogen.

Chromic acid: corrosive to skin; NTIS criteria document occupational exposure to chromic acid recommended std air-TWA 50μg/m³, Cl 100; OSHA std air-Cl 100μg(CrO_3)/m³; fire hazard; powerful oxidizing agent.

Cobalt nitrate: moderately toxic; oxidizing agent; dangerous fire risk in contact with organic materials.

Cyclohexane: oral human LDLo 500mg/kg; can cause skin irritation; OSHA std air-TWA 300ppm; fire hazard.

Cyclohexene: OSHA std air-TWA 300ppm (skin); dangerous fire hazard.

n,n-Dimethylaniline: oral human LDLo 50mg/kg; absorbed by skin; acts as depressant on central nervous system; use with proper ventilation; physiological action similar to that of aniline; tolerance air 5ppm.

2,4-Dinitrophenol: oral human LDLo 4300μg/kg; oral human LDLo 36mg/kg; highly toxic; absorbed by skin; may cause dermatitis; dust inhalation may be fatal; damages liver; severe explosion hazard when dry.

Ethylene oxide: hypersensitization shown in humans; skin human 1%/75 sec., toxic effect: irritation; inhalation mammal TCLo 30mg/m³, toxic effect: mutagenic; restricted use; OSHA std air 50ppm; fire hazard.

Ether: powerful narcotic in large doses; fire hazard; explosion risk due to formation of peroxides.

Formaldehyde: (gas) highly toxic by inhalation; strong irritant; (solution) avoid breathing vapor and skin contact; inhalation human TCLo 13.8ppm, toxic effect: irritant; skin human 150μg/3D-I, toxic effect: mild irritant; OSHA std air-TWA 3ppm, Cl 5ppm; combustible.

Gasoline: fire hazard

Gunpowder: explosive

Hexachlorophene: fatal oral adult 300mg/kg; oral child LDLo 250mg/kg; oral woman TDLo 600mg/kg, toxic effect: central nervous system; oral woman LDLo 50mg/kg; restricted use.

Hydriodic acid (HI): corrosive; strong irritant to eyes and skin; reacts with water or steam to produce toxic and corrosive fumes.

Hydrobromic acid: inhalation human TCLo 300m, toxic effect: irritant; corrosive; reacts with water or steam to produce toxic and corrosive to skin and mucous membranes; inhalation of vapors may cause ulcers of upper respiratory tract; reacts with water or steam to produce toxic and corrosive fumes; OSHA std air-TWA 3ppm.

Hydrogen sulfide: inhalation human LCLo 600ppm/30M; strong irritant to eyes and mucous membranes; both irritant and asphyxiant; OSHA std air-Cl 20ppm; flammable gas.

Hydroquinone (1,4-dihydroxybenzene): oral human LDLo 29mg/kg; irritant; allergen; OSHA std air-TWA 2mg/m³.

Iodine crystals: highly toxic by ingestion and inhalation; strong irritant to eyes and skin; oral human LDLo 2000mg/kg; when heated yields toxic fumes; OSHA std air-Cl 0.1ppm.

Lead compounds: highly toxic by ingestion and inhalation.

Lead carbonate: OSHA std air-TWA 200μg (Pb)m/³; see lead compounds.

Lithium: possible animal teratogen; fire hazard (solid); explosion risk when exposed to water, nitrogen, acids, or oxidizing agents.

Magnesium: (powder): dangerous fire hazard.

Magnesium chlorate: oral human LDLo 50mg/kg; strong oxidizing agent; dangerous fire risk in contact with organic materials.

Mercury: toxic by skin absorption and inhalation of fume or vapor; absorbed by respiratory and intestinal tract; all inorganic mercury compounds are highly toxic by ingestion, inhalation, and skin absorption; OSHA std air-Cl 1mg/10m³.

Mercuric chloride (bichloride): oral human LDLo 29mg/kg; poison; NTIS criteria document occupational exposure to inorganic mercury recommended std air-TWA 50μg(hg)/m³; see mercury.

Mercuric iodide: oral human LDLo 357mg/kg; poison; NTIS same as above; see mercury.

Mercuric nitrate: highly toxic; NTIS same as above; dangerous fire risk in contact with organic materials; see mercury.

Mercuric oxide: oral rat LD_{50} 18mg/kg; NTIS same as above; poison; dangerous fire risk in contact with organic materials; see mercury.

Mercuric sulfate: oral rat LD_{50} 57mg/kg; poison; NTIS same as above; see mercury.

Mercuric sulfide: toxic by ingestion, inhalation, and skin absorption; see mercury.

Mercurous chloride: oral human LDLo 5mg/kg; NTIS same as above; see mercury.

Mercurous nitrate (hydrated): highly toxic; NTIS same as above; see mercury.

Mercurous oxide: poison; NTIS same as above; see mercury.

Mesitylene: inhalation human TCLo 10ppm, toxic effect: central nervous system; threshold limit value air 25ppm.

Methyl ethyl ketone: eye human 350ppm, toxic effect: irritant; oral human LDLo 500mg/kg; inhalation human TCLo 300ppm, toxic effect: peripheral nervous system; narcotic by inhalation; OSHA std air-TWA 200ppm; fire hazard; explosion limits air 2-10%.

Methyl methacrylate: inhalation human TCLo 150mg/m^3, toxic effect: central nervous system; oral human LDLo 5000mg/kg; fire hazard; explosion limits air 2.1-12.5%.

Methyl orange: oral human LDLo 50mg/kg; oral rat LD_{50} 60mg/kg.

Nicotine: oral human LDLo 1mg/kg; poison; oral LD_{50} 53mg/kg; shown to be teratogenic in mice; absorbed by skin; OSHA std air-TWA 500μg/m^3 (skin); moderate fire hazard.

Osmium tetroxide (osmic acid anhydride): inhalation man TCLo 133μg/m^3, toxic effect: eye; inhalation human TCLo 0.1mg/m^3, toxic effect: irritant; strong eye and mucous membrane irritant; OSHA std air-TWA 2μg/m^3.

Paris green (bis[aceto] hexametaarsenitotetra copper): poison; oral human LDLo 5mg/kg; oral rat LD_{50} 22mg/kg.

Pentane: inhalation human LDLo 90,000ppm/5M, toxic effect: central nervous system; narcotic in high concentrations: OSHA std air-TWA 1000ppm; highly flammable dangerous fire and explosion risk; explosive limits 1.4-8%.

Perchloric acid: strong irritant to skin and mucous membranes; strong oxidizing agent; explosion hazard with organic materials.

Petroleum ether: oral human LDLo 50mg/kg; inhalation human LCLo 3ppm/5M; inhalation of concentrated vapor causes intoxication similar to alcohol; OSHA std air-TWA 500ppm (skin); dangerous fire hazard; moderate explosion hazard; made from American coal oil and consists chiefly of pentane, hexane, and heptane.

Phosphorus: red: flammable; moderate explosion hazard; reacts with oxygen and water to yield phosphine (highly toxic by inhalation). white: flammable and poison; oral human LDLo 1400μg/kg; hazardous to eyes; oral human TDLo 16mg/kg, toxic effect; systemic; OSHA std air-TWA 100μg/m^3; ignites spontaneously at 86 °F; store under water.

Phosphorus pentoxide (phosphoric anhydride): strong caustic irritant; reacts violently with water to yield heat; fire hazard.

1-phenyl-2-thiourea (phenyl thiocarbamide): oral mouse LD_{50} 10mg/kg; oral rat LD_{50} 3mg/kg.

Phthalic anhydride: skin irritant; OSHA std air-TWA 2ppm.

Picric acid: oral human LDLo 5mg/kg; absorbed by skin; can cause dermatitis; OSHA std 100μg/m^3 (skin); explosive when heated; reactive with metals or metallic salts; more powerful explosive than TNT.

Potassium: fire hazard; can ignite spontaneously in moist air; store under oxygen-free liquids; may explode when handled or cut.

Potassium chlorate: unreported human LDLo 429mg/kg; oral rat LDLo 700mg/kg; flammable; strong oxidizing agent; forms explosive mixtures with combustible materials.

Potassium oxalate: toxic by inhalation and ingestion; corrosive.

Potassium periodate: strong tissue irritant; fire hazard in contact with organic materials.

Potassium permanganate: strong irritant; oral rat LD_{50} 1090mg/kg; fire hazard in contact with organic materials; oxidizing agent; spontaneously flammable on contact with glycerine and ethylene glycol.

Potassium sulfide: oral human LDLo 50mg/kg; fire hazard; may ignite spontaneously; explosive in form of dust or powder.

Pyridine: oral human LDLo 500mg/kg; oral rat LD_{50} 891mg/kg; mildly irritating to skin and can cause central nervous system depression; OSHA std air-TWA 5ppm; fire hazard; explosive limits in air 1.8-12.4%.

Pyrogallic acid (pyrogallol): oral human LDLo 50mg/kg; highly toxic by ingestion and skin absorption.

Salol (phenyl salicylate): oral human LDLo 50mg/kg.

Silver compounds: may be irritating to skin and mucous membranes; absorption of silver compounds may lead to deposition of silver in various body tissues.

Silver cyanide: oral rat LD_{50} 123mg/kg; poison; highly toxic by ingestion and inhalation; tolerance 0.01mg/m^3 (air); see silver compounds.

Silver nitrate: oral mouse LD_{50} 50mg/kg; possibly neoplastic in mice; highly toxic and strong irritant to skin and tissue; OSHA std air 10μg(As)/m^3.

Silver oxide: moderately toxic; fire and explosion risk when in contact with organic materials or ammonia; see silver compounds.

Sodium: caustic irritant to tissue; severe fire hazard with water; flammable solid and dangerous when wet; store under liquid hydrocarbons.

Sodium azide: poison; oral human LDLo 5mg/kg; threshold limit value air-Cl 100ppb; explosion risk when heated.

Sodium chlorate: can cause irritation to skin, eyes and mucous membranes; dangerous fire risk; strong oxidant.

Sodium cyanide: Oral human LDLo 2857μg/kg; very poisonous; OSHA std air-TWA 5mg(Cn)/m^3 (skin).

Sodium fluoride: lethal dose 75-100mg/kg; oral human TDLo 4mg/kg; toxic effect: central nervous system; oral human LDLo 75mg/kg; tissue irritant; OSHA std air-TWA 2500μg(F)/m^3.

Sodium permanganate: oral human TDLo 2400μg/kg/D, toxic effect: GI tract; strong irritant to skin; oxidizer; fire hazard in contact with organic materials.

Sodium silicofluoride: oral rat LD_{50} 125mg/kg; strong irritant to tissue: OSHA std air-TWA 2500μg(F)/m^3.

Sodium sulfide: oral human LDLo 50mg/kg; strong irritant to skin and tissue; liberates HS on contact with acids; fire hazard (solid); unstable material.

Sodium thiocyanate (thiocyanide): oral human LDLo 50mg/kg.

Stannic chloride: with moisture or heat yields HCl; corrosive liquid; OSHA std air-TWA 2mg(Sn)/m^3.

Strontium: powder form spontaneously flammable; store under naphtha.

Strontium nitrate: moderately toxic; strong oxidizing agent; fire hazard in contact with organic materials.

Sulfuric acid, fuming (oleum): highly toxic; strong irritant to tissue; reacts violently with water; inhalation rat LC_{50} 347ppm/1H; NTIS criteria document occupational exposure recommended std air-TWA 1mg/m^3.

Tetrabromoethane (acetylene tetrabromide; 1, 1, 2, 2-tetrabromoethane): toxic and irritant by inhalation; skin rabbit 100%/24H, toxic effect: mild irritation; OSHA std air-TWA 1ppm.

Thermite and compounds: mixture of ferric oxide and powdered aluminum; dangerous fire risk; used to make incendiary bombs in 1900.

Titanium trichloride: irritant to skin and tissue; fire hazard in presence of organic materials.

Toluene: inhalation human TCLo 200ppm, toxic effect: central nervous system; inhalation man TCLo 100ppm, toxic effect: psychotropic; OSHA std air-TWA 200ppm; fire hazard explosive limits air 1.27-7%.

2, 2, 4-trimethylpentane (isooctane): moderately toxic by ingestion and inhalation; dangerous fire hazard.

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APPENDIX III

SCHOOL SCIENCE PROGRAM
CHEMICAL INVENTORY

Name of School ______________________________

Street Address ______________________________

City/County ______________________ **Zip Code** __________

Chemical Name	Amount		Chemical Name	Amount	
Acetamide			Ammonium chloride		
Acetanilide			Ammonium chromate		
Acetic acid			Ammonium citrate		
Acetic acid, glacial			Ammonium dichromate		
Acetic anhydride			Ammonium hydroxide		
Aceto carmine (Natural Red 4)			Ammonium iodide		
Acetone			Ammonium molybdate		
Aceto-orcein (orcinol)			Ammonium nitrate		
Acetylcholine			Ammonium oxalate		
Acetylcholine bromide			Ammonium oxide		
Acridine orange			Ammonium persulfate		
Acrylonitrile			Ammonium phosphate		
Adenine			Ammonium potassium sulfate		
Adrenaline			Ammonium sodium sulfate		
Agar			Ammonium sulfate		
Alanine			Ammonium sulfide		
Alizarine yellow			Ammonium sulfite		
Alizarine red (Red #1)			Ammonium tartrate		
Albumin			Ammonium thiocyanate		
Alum			Ammonium trichloride		
Aluminum ammonia sulfate			Amyl acetate		
Aluminum chloride			n-Amyl alcohol		
Aluminum hydroxide			Aniline		
Aluminum, metal			Aniline blue		
Aluminum nitrate			Aniline hydrochloride		
Aluminum oxide			Aniline violet		
Aluminum potassium sulfate			Anthracene		
Aluminum sodium sulfate			Antimony		
Aluminum sulfate			Antimony oxide		
Aluminum sulfide			Antimony potassium tartrate		
Amberlite			Antimony sulfide		
Ammonia, liquid			Antimony trichloride		
Ammonium acetate			Antimony trisulfide		
Ammonium bicarbonate			Arabic gum		
Ammonium bichromate			Arabinose		
Ammonium bromide			Arsenic		
Ammonium carbonate			Arsenic chloride		

Name of School ____________________

Street Address ____________________

City/County ____________________ **Zip Code** ____________

Chemical Name	Amount	Chemical Name	Amount
Arsenic pentoxide		Bromophenol blue	
Arsenic trioxide (arsenous acid)		Bromothymol blue	
Asbestos		Butanol	
Ascarite (asbestos)		Butyric acid	
Ascorbic acid		Cadmium acetate	
Balsam		Cadmium bromide	
Barium		Cadmium carbonate	
Barium acetate		Cadmium chloride	
Barium carbonate		Cadmium, metal	
Barium chlorate		Cadmium nitrate	
Barium chloride		Cadmium oxide	
Barium hydroxide		Cadmium sulfate	
Barium nitrate		Calcium	
Barium oxalate		Calcium acetate	
Barium oxide		Calcium bromide	
Barium peroxide		Calcium carbide	
Barium sulfate		Calcium carbonate	
Barium sulfide		Calcium chloride	
Bauxite		Calcium cyanamide	
Beeswax		Calcium cyanide	
Benedicts solution		Calcium Fluoride	
Benzaldehyde		Calcium hydroxide	
Benzene		Calcium hypochlorite	
Benzene hexachloride		Calcium nitrate	
Benzoic acid		Calcium oxide	
Benzoyl peroxide		Calcium phosphate	
Beryllium carbonate		Calcium sulfate	
Bismark brown		Calcium sulfide	
Bismark black		Camphor gum	
Bismuth		Carbolfuchsin (Ziehl's stain)	
Bismuth chloride		Carbon	
Bismuth nitrate		Carbon dioxide	
Bismuth oxide		Carbon disulfide	
Bismuth trichloride		Carbon disulfite	
Bonine fluid		Carbonic acid	
Boric acid		Carbon tetrabromide	
Boron		Carbon tetrachloride	
Brilliant green		Carborundum	
Bromine		Carmine	
Bromine water		Carnoy fixative (mixture of absolute alcohol and glacial acetic acid)	
Bromocresol green			
Bromocresol purple		Casein	

Name of School ______________________________

Street Address ______________________________

City/County ______________________________ **Zip Code** ____________

Chemical Name	Amount		Chemical Name	Amount	
Catechol (o-dihydroxy-benzene)			Cupric nitrate		
Cerium oxalate			Cupric oxide		
Cerium sulfate			Cupric sulfate		
Charcoal			Cuprous chloride		
Chloral hydrate			Cuprous oxide		
Chloroetone			Cuprous sulfate		
Chlorine			Cyclohexane		
Chlorine water			Cyclohexene		
Chlorobenzene			Dextrin starch		
Chloroform			Dextrose		
Chromic acid			Disastase		
Chromium			Dichlorobenzene		
Chromium acetate			Dichloroethane		
Chromium chloride			Dichloroindophenol sodium salt		
Chromium nitrate			Dichloromethane		
Chromium oxide			Diethyl ether		
Chromium potassium sulfate			Dimethylaniline		
Chromium sulfate			Dimethylglyoxime		
Chromium trioxide			EDTA		
Citric acid			Eosin red		
Clayton yellow			Epsom salt		
Clove oil			Erythrosine		
Cobalt chloride			Ethyl acetate		
Cobalt, metal			Ethyl alcohol		
Cobalt nitrate			Ethylene dichloride		
Cobalt oxide			Ethylene glycol		
Cobalt sulfate			Fehling's solution		
Cochineal			Ferric ammonium acetate		
Coconut oil			Ferric ammonium citrate		
Colchicine			Ferric ammonium sulfate		
Collodion			Ferric chloride		
Congo red			Ferric nitrate		
Copper, metal			Ferric oxide		
Copper sulfide			Ferric phosphate		
Corn starch			Ferric pyrite		
Cottonseed oil			Ferric sulfate		
Cresol red			Ferrous ammonium sulfate		
Crystal violet			Ferrous chloride		
Cupric acetate			Ferrous cyanide (Iron Ferrocyanide, Prussian blue)		
Cupric bromide					
Cupric carbonate			Ferrous sulfate		
Cupric chloride			Ferrous sulfide		

Name of School ______________________________

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City/County ______________________ **Zip Code** __________

Chemical Name	Amount	Chemical Name	Amount
Fluorescein		Kaloin	
Formaldehyde		Kerosene	
Formalin		Lactic acid	
Formic acid		Lactose	
Fructose		Lauric acid	
Fuchsin		Lauryl alcohol	
Fumaric acid		Lead acetate	
Gasoline		Lead carbonate	
Gelatin		Lead chromate	
Genetian violet (Methyl violet)		Lead dioxide	
Gibberellic acid		Lead iodide	
Giemsa stain		Lead, metal	
Glucose		Lead monoxide	
Glycerin		Lead nitrate	
Glycerol		Lead oxide	
Gold foil		Lead peroxide	
Gram's iodine stain		Lead sulfate	
Graphite		Lead sulfide (Galena)	
Gum Traggacanth		Lead tetraoxide	
Gunpowder		Lime water	
Gypsum		Linseed oil	
Helium		Lithium carbonate	
Hematoxylin		Lithium chloride	
Heptane		Lithium hydroxide	
Hexane		Lithium, metal	
Hydriodic acid (HI)		Lithium nitrate	
Hydrochloric acid		Lithium sulfate	
Hydrofluoric acid		Litmus	
Hydrogen		Logwood extract	
Hydrogen peroxide		Lugol's iodine	
Hydrogen sulfide		Lycopodium powder	
Hydroquinone		Lye	
Indigo		Manganesium acetate	
Indigo carmine		Magnesium bromide	
Indolacetic acid		Magnesium carbonate	
Iodine		Magnesium chloride	
Iron acetate		Magnesium dioxide	
Iron, metal		Magnesium hydroxide	
Isoamyl alcohol		Magnesium, metal	
Isobutyl alcohol		Magnesium nitrate	
Isopentyl alcohol		Magnesium oxide	
Isopropyl alcohol		Magnesium phosphate	

Name of School ____________________

Street Address ____________________

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Chemical Name	Amount	Chemical Name	Amount
Magnesium sulfate		Molybdate reagent	
Magnesium trisilicate		Molybdic acid	
Malachite green		Monochloroacetic acid	
Maleic acid		Napthalene	
Malonic acid		-Naphtol	
Maltose		Nessler's reagent	
Manganese bromide		Nichrome	
Manganese chloride		Nickel ammonium sulfate	
Manganese carbonate		Nickel chloride	
Manganese dioxide		Nickel hydroxide	
Manganese, metal		Nickel, metal	
Manganese nitrate		Nickel nitrate	
Manganese oxide		Nickel oxide	
Manganese sulfate		Nickel sulfate	
Methanol		Nicotine sulfate	
Mercuric chloride		Nicotinic acid	
Mercuric iodide		Nigrosine black	
Mercuric nitrate		Ninhydrin	
Mercuric oxide		Nitric acid	
Mercuric sulfate		Nitrobenzene	
Mercuric sulfide		Nitrobenzerie-azo- resorcinol	
Mercurous chloride		Nitrogen	
Mercurous nitrate		Oleic acid	
Mercurous oxide		Olive oil	
Mercury bichloride		Orange IV (Torpeolin 00)	
Mercury, metal		Oxalic acid	
Methyl alcohol		Oxygen	
Methyl cellulose		Pancreatin	
Methylene blue		Paradichlorobenzene	
Methylene chloride		Paraffin	
Methylene red (Methyl red)		Paraformaldehyde	
Methyl ethyl ketone		Peanut oil	
Methyl green (triphenyl methane dye)		Pentane	
Methyl iodine		Peppermint oil	
Methyl methacrylate		Pepsin	
Methyl orange		Peptone	
Methyl red		Perchloric acid	
Methyl salicylate		Perchloroethylene	
Methyl sulfoxide		Persian blue	
Methyl violet		Petroleum ether	
Mineral oil		Phenol	
Molasses		Phenolphthalein	

Name of School ______________________________
Street Address ______________________________
City/County ______________________ **Zip Code** __________

Chemical Name	Amount	Chemical Name	Amount
Phenol salicylate		Potassium phosphate	
Phenylthiocarbamide		Potassium phthalate	
Phosphoric acid		Potassium pyrosulfate	
Phosphoric anhydride		Potassium sodium tartrate	
Phosphorus, red		Potassium sulfate	
Phosphorus, white		Potassium sulfide	
Phosphorus pentoxide		Potassium sulfocyanide	
Phloroglucinol		Potassium tartrate	
Phthalic anhydride		Potassium thiocyanate	
Picric acid		Potassium thiochromate	
Potash alum (aluminum potassium sulfate)		Propane	
Potassium acetate		Propionic acid	
Potassium acid phthalate		Propyl alcohol	
Potassium bicarbonate		Pyridine	
Potassium bichromate		Pyrogallic acid	
Potassium binoxalate		Quinine salicylate (saloquinine)	
Potassium biphthalate		Quinine sulfate	
Potassium bisulfate		Resorcinol	
Potassium bitartrate		Ringer's solution	
Potassium bromate		Rosin	
Potassium bromide		Saccharin	
Potassium carbonate (potash)		Safarin	
Potassium chlorate		Salicylic acid	
Potassium chloride		Sand	
Potassium chromate		Selenium	
Potassium cyanide		Sesame oil	
Potassium dichromate		Silicic acid	
Potassium ferricyanide		Silicon dioxide	
Potassium ferrocyanide		Silicon, metal	
Potassium hexacyanoferrate		Silver acetate	
Potassium hydrogen phthalate		Silver chloride	
Potassium hydroxide		Silver cyanide	
Potassium iodate		Silver iodide	
Potassium iodide		Silver, metal	
Potassium metaperiodate		Silver nitrate	
Potassium, metal		Silver oxide	
Potassium nitrate		Silver sulfate	
Potassium oxalate		Soda	
Potassium oxide		Sodium acetate	
Potassium permanganate		Sodium aluminum sulfate	
Potassium periodate		Sodium ammonium phosphate	
		Sodium arsenate	

Name of School ______________________________
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Chemical Name	Amount		Chemical Name	Amount	
Sodium arsenite			Sodium salicate		
Sodium azide			Sodium salicylate		
Sodium benzoate			Sodium sulfate		
Sodium biborate (sodium borate)			Sodium sulfide		
Sodium bicarbonate			Sodium sulfite		
Sodium binoxalate (oxalic acid, Na salt)			Sodium tartrate		
Sodium bismuthate ($NaBiO_3$)			Sodium tetraborate		
Sodium bisulfate			Sodium thiocyanate		
Sodium bisulfite			Sodium thiophosphate		
Sodium bromate			Sodium thiosulfate		
Sodium bromide			Sodium triphosphate		
Sodium carbonate			Sodium trisulfate		
Sodium chlorate			Sodium tungstate		
Sodium chloride			Starch		
Sodium chromate			Stannic chloride		
Sodium citrate			Stannic oxide		
Sodium cyanide			Stannous chloride		
Sodium dichloroindophenol			Stearic acid		
Sodium dichromate			Steel		
Sodium ferrocyanide			Strontium		
Sodium fluoride			Strontium bromide		
Sodium hydroxide			Strontium chloride		
Sodium hydrosulfite			Strontium nitrate		
Sodium hydrochlorite			Succinic acid		
Sodium hyposulfate			Sucrose		
Sodium hyposulfite			Sudan Black B		
Sodium iodide			Sudan III		
Sodium lauryl sulfate			Sudan IV		
Sodium metabisulfite			Sugar		
Sodium, metal			Sulfamethazine		
Sodium metaphosphate			Sulfamic acid		
Sodium molybdate			Sulfanilic acid		
Sodium nitrate			Sulfanilamide		
Sodium nitrite			Sulfite		
Sodium oxalate			Sulfur		
Sodium perborate			Sulfur black dye		
Sodium peroxide			Sulfur blue dye		
Sodium phosphate			Sulfur yellow dye (Napthol yellow, citronin)		
Sodium potassium tartrate			Sulfuric acid		
Sodium pyrophosphate			Sulfuric acid, fuming		
Sodium pyrosulfate			Sulfurous acid		

Name of School ______________________________
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City/County ______________________________ **Zip Code** __________

Chemical Name	Amount		Chemical Name	Amount	
Talc			Uranyl		
Tannic acid			Uranyl nitrate		
Tartaric acid			Ultramarine blue		
Tetraacetic acid (tetracetate)			Urea		
Tetrabromoethane			Urethane		
Thermite			Vegetable oil		
Thermite black			Vinylite		
Thermite igniting mixture			Wood's metal		
Thioacetamide			Wright's stain		
Thiourea			Xylene		
Thymol blue indicator			Yeast		
Tin, metal			Zeolite		
Titanium, metal			Zinc acetate		
Titanium dioxide (titanium oxide)			Zinc carbonate		
Titanium trichloride			Zinc chloride		
Toluene			Zinc, metal		
o-Toluidine			Zinc nitrate		
Trichloroacetic acid			Zinc oxide		
Trichloromethylpropanol			Zinc stearate		
Triethanolamine			Zinc sulfate		
Trisodium phosphate			Zinc sulfide		
Tumeric powder			Zirconium nitrate		
Tungsten, metal			Zirconium oxychloride		
Turpentine			Other		
Uranium					

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15. Supplementary Notes

16. Abstract (Limit: 200 words) This manual was intended to provide high school science teachers with a compact reference to hazards encountered while performing experiments in the areas of chemistry, the earth sciences, biology, and physics. A health and safety hazard code was used so that the teacher can at a glance determine the relative danger of a given experiment. Two of the chapters provide an abbreviated course in toxicology and selected safety topics that will be of value to teachers who do not have a background in those areas. Hard to find health and safety information was also included. Teachers were urged to locate the relevant experimental class using the table of contents when preparing experiments. By reviewing these sections the sources of hazards in the experiments can be identified. The work plan then developed should include appropriate corrective and protective action. Potential hazards should be discussed with the students and a professional atmosphere established for conducting the experiments.

17. Document Analysis a. Descriptors

b. Identifiers/Open-Ended Terms NIOSH-Publication, NIOSH-Author, Education, Safety-education, Chemical-burns, Hazardous-materials, Accident-prevention, Safety-research

c. COSATI Field/Group

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