Laboratory Resource Manual

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Notice

This laboratory manual should not be considered all-inclusive regarding safe chemical use. The laboratory manual is designed to be as objective as possible and works in conjunction with standard accepted practices and regulatory standards and laws. Users of this laboratory manual shall be well versed in the assigned duties and understand the hazards presented by the chemicals and related materials associated with chemical use. This laboratory manual does not replace the responsibilities of training and nothing in this laboratory manual shall take the place of legal assistance. No representation can be made or responsibility undertaken by Ward's Science, Ward's Science distributors and the author(s) regarding the completeness, accuracy or continuing validity of the information in this publication.

Ward's Science
Laboratory Reference Manual for Teachers

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I. Introduction

Ward's Science – All You Need for High School Chemistry

Save prep time in your laboratory while ensuring student safety with pre-organized activities for the most popular introductory chemistry topics.

Ward's Science products and services provide you with:

- **Bi-lingual Chemical Labels – English and French**
  Affords a safer learning experience for your ESL students. Labels are GHS-compliant and WHMIS 2015-compliant.
- **Comprehensive Laboratory Manual for Teachers**
  Written by certified chemistry safety specialists for today's teaching challenges, the Ward's Science manual has indispensable information on acquiring chemicals; interpreting labels; storing, using, and disposing of chemicals; lab safety and spill control; government regulations; regulatory resources; and more.
- **GHS-Compliant, Industry-Standard Chemical Storage System**
  No more cross-referencing your chemicals to a catalog storage guide! Color-coded storage information right on the bottles lets you visually segregate the chemicals on your storage shelves.
- **Package Sizes That Reduce Waste and Expense**
  "Right-sized" packaging lowers hazardous shipping charges and disposal quantities.
- **Chemical Inventory and Management Software**
  Easy-to-use software for all your school's labs. Track, add, and deduct quantities for the most efficient and safe use of chemicals.

- **Expert Technical Service**
  Contact the Ward's Science Plus Us team for one-on-one support, from our science lab to yours.
  Live Chat: Go to wardsci.com
  Phone: (866) 260-0501
  Email: sciencehelp@vwr.com
  Video-chat or in-person: call or email to schedule.

Purpose of This Laboratory Manual

The purpose of the Ward's Science Laboratory Manual is to provide the science teacher with comprehensive support and a beneficial resource towards managing usage of chemicals in chemistry education. There are thousands of chemicals available. Understanding the chemical qualities and using the chemicals safely is essential in preventing accidents. Following the policies and resources found in this laboratory manual wisely, will assist you and your students in enjoying a stimulating, educational and safe classroom experience.

The layout of the laboratory manual precisely follows the process experienced by a chemistry teacher throughout the school year, from the first step of budgeting to the final step of disposing of chemical waste. Depending upon the phase of your chemical use, the Ward's Science Teachers Laboratory Manual is designed so that you can readily reference the laboratory manual appropriate to your immediate need.

Responsibilities and Regulations

The following are the primary regulatory agencies that mandate safe chemical use and are referenced throughout this laboratory manual. As a science teacher, you are an employee of the school district. The science teacher and the school are responsible for complying with and enforcing these regulations. The description of each of the following associations was taken from the introduction or mission statement found on the association's website.

Regardless of mandated compliance issues and regulations, it is up to the individual to be aware of the hazards involved and in maintaining a safe working environment when managing the use of chemicals in the laboratory and classroom. Forms and checklists are provided within this laboratory manual to assist you in providing a safe chemical work environment.

For specific regulatory requirements, please refer to the regulatory websites listed in *Section XVIII. Internet Resources and Addresses*.

Occupational Safety and Health Administration (OSHA)

The mission of the Occupational Safety and Health Administration (OSHA) is to save lives, prevent injuries, and protect the health of America's workers. To accomplish this, federal and state governments must work in partnership with the more than 100 million working men and women and their six and a half million employers who are covered by the Occupational Safety and Health Act of 1970.

OSHA and its state partners have approximately 2100 inspectors, plus complaint discrimination investigators, engineers, physicians, educators, standards writers, and other technical and support personnel spread over more than 200 offices throughout the country. This staff establishes protective standards, enforces those standards, and reaches out to employers and employees through technical assistance and consultation programs. The intent of the Occupational Safety and Health Act is to enforce safe practices on the employer (school district) where the employer is required to provide safe working conditions, safety polices, information and training regarding safety and health. As an employee, safety and health regulations apply to the science teacher and to the school facility regarding safe use and storage of chemicals. OSHA makes neglect of safety precautions a criminal offense. There have been cases where teachers have been prosecuted as a result of blatantly disregarding common-sense safety precautions. OSHA regulations do not directly apply to students, but negligence on the part of teachers has been ruled to be actionable at law.

An overview of some regulatory standards regarding school science rooms and laboratories.

OSHA 29CFR 1910	*General Industry*
OSHA 29CFR 1910.1450	*Occupational exposure to hazardous chemicals in laboratories.*
OSHA 29CFR 1910.1200	*Hazard Communication / Right-to-Understand Laws*
OSHA 29CFR 1910.120	*HAZWOPER - Hazardous waste operations and emergency response.*

Health Canada - Workplace Hazardous Materials Information System (WHMIS)

Health Canada has established the *Occupational Health and Safety Act* and the intention of this act is the same as found under OSHA above. Health Canada's *Workplace Hazardous Materials Information System (WHMIS),* updated in 2015, is Canada's hazard communication standard. WHMIS is now aligned with the Globally Harmonized System (GHS) of Classification and Labeling of Chemicals.

WHMIS is implemented through coordinated federal, provincial, and territorial legislation. Supplier labeling and SDS requirements are set out under the *Hazardous Products Act* (*HPA*) and associated *Controlled Products Regulations*. The *Hazardous Products Act* and its regulations are administered by the Government of Canada Department of Health, commonly referred to as Health Canada.

Each of the thirteen provincial, territorial, and federal agencies responsible for occupational safety and health has established employer WHMIS requirements within their respective jurisdiction. These requirements place an onus on employers to ensure that controlled products used, stored, handled, or disposed of in the workplace are properly labeled, SDS's are made available to workers, and workers receive education and training to ensure the safe storage, handling, and use of controlled products in the workplace.

WHMIS balances workers' right-to-know with industry's right to protect confidential business information and includes a mechanism for ruling on claims for exemption from disclosure of confidential business information as well as appeals to these rulings.

OCCUPATIONAL HEALTH AND SAFETY ACT	*Regulation 857 – Teachers* *Regulation 860 - Workplace Hazardous Information System (WHMIS)*

National Fire Protection Association (NFPA)

NFPA is an international nonprofit membership organization founded in 1896 as the National Fire Protection Association. Today, with more than 75,000 members representing nearly 100 nations and 320 employees around the world, NFPA serves as the world's leading advocate of fire prevention and is an authoritative source on public safety. In fact, NFPA's 300 safety codes and standards influence every building, process, service, design, and installation in the United States, as well as many of those used in other countries.

NFPA codes and standards, including those for labeling and placarding, have helped save lives and protect property around the world. The volunteers and staff of NFPA are dedicated to the single mission of continually enhancing public safety. From Dallas to Dusseldorf, that dedication can be seen in the codes and standards that are adopted – documents developed through NFPA's commitment to creating a true consensus among those interested in safety.

Department of Employment and Social Development Canada (ESDC)

The Fire Prevention staff, as the federal government's technical authority on fire protection, is responsible for the administration and enforcement of standards, codes, and regulations that cover fire protection under the Canada Labour Code. The mandate of the Fire Prevention Unit is to ensure the protection, conservation, and minimization of risks to life, property, and the Government's financial position.

The Labour Program provides specialized fire protection engineering and inspection services for major public band buildings in First Nation communities. These services assist First Nations to protect, conserve, and minimize fire risks to life and property. The services are provided with the approval or at the request of the Chief and Band Council or their designates. The services cover everything related to preventing, detecting, containing, and extinguishing fires, and alerting people to a fire.

U.S. Department of Transportation (USDOT)

Consult State DOT for specific local requirements

The United States Department of Transportation touches the public through its mission of ensuring that our various modes of transportation operate safely on an individual basis and together as an interlinked transportation system.

An overview of the major regulatory standards applicable to shipment and handling of chemicals.

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Transport Canada

Transport Canada works to help ensure that Canadians have the best transportation system by developing and administering policies, regulations and programs for a safe, efficient and environmentally friendly transportation system; contributing to Canada's economic growth and social development; and, protecting the physical environment. The department employs approximately 5400 people at headquarters in Ottawa and in locations across Canada.

Transport Canada's policy is to develop, recommend, and coordinate modal and multi-modal policies. To provide advice, analysis, and intelligence on transportation issues, system performance, and stakeholder positions. Advice on policy options is based on efficiency, competitiveness, safety and security, environmental sustainability, and inter-modal integration. This role is fulfilled through a multi-modal program of policy analysis, briefings, coordination, consultations, evaluation, and economic analysis, which develops and utilizes necessary data, forecasts, models, research, and intelligence.

An overview of the major regulatory standards applicable to shipment and handling of chemicals.

Transportation of Dangerous Goods Act

Environmental Protection Agency (EPA)

EPA provides leadership in the nation's (USA) environmental science, research, education, and assessment efforts. EPA works closely with other federal agencies, state and local governments, and Indian tribes to develop and enforce regulations under existing environmental laws. EPA is responsible for researching and setting national standards for a variety of environmental programs and delegates to states and tribes responsibility for issuing permits, and monitoring and enforcing compliance. Where national standards are not met, EPA can issue sanctions and take other steps to assist the states and tribes in reaching the desired levels of environmental quality. The Agency also works with industries and all levels of government in a wide variety of voluntary pollution prevention programs and energy conservation efforts.

Environment Canada

Environment Canada's mandate is to preserve and enhance the quality of the natural environment, including water, air, and soil quality; conserve Canada's renewable resources, including migratory birds and other non-domestic flora and fauna; conserve and protect Canada's water resources; carry out meteorology; enforce the rules made by the Canada - United States International Joint Commission relating to boundary waters; and coordinate environmental policies and programs for the federal government (*Department of Environment Act*).

When Things Go Wrong!

As a science teacher your objective is providing your students with an educational and enlightening class year. Science teachers have access to an abundant number of chemicals, many of which if handled incorrectly can be hazardous to you and your students. This Ward's Science Laboratory Manual is designed to provide you with a piece of mind in chemical use. If followed closely and in conjunction with standard practices and regulations, the Ward's Science Laboratory Manual will provide you with the necessary information to safely use these chemicals and provide you and your students with an enjoyable and rewarding educational experience. Education in safe use of chemicals is mandatory for a science teacher. Complacency and, to a fair degree, ignorance of the potential hazards involved in using chemicals can be disastrous. The following are three separate demonstrations, under similar conditions, that required the chemical methanol to be ignited to show a specific reaction and examples of where each variation led to an undesirable outcome. The Ward's Science Laboratory Manual is dedicated to preventing these types of accidents.

<u>Explosion Rocks Science Class</u>
Filed: *August 31, 1999*
By AMANDA GAUTHIER and KERRY CAVANAUGH

Tuesday was just the second day of class at East Bakersfield High School when teacher John McCormick began his science experiment, which had always been exciting but safe. That day, however, a 5-gallon glass water cooler bottle shattered, sending shards of glass flying across the room and 22 students to local emergency room. No one suffered major injuries in the 8:25 a.m. explosion, but it shook up students, parents, and school officials on campus.

The Tuesday morning lesson for 33 students at East Bakersfield High was supposed to be about observation and inference, a demonstration the 10-year veteran teacher had performed for years. A few milliliters of methanol, also known as wood alcohol, sat in the bottom of the glass bottle. McCormick turned the lights off, lit a match, and lifted the lid off the bottle. The students heard a crack before a flame shot out of the top and the bottle exploded — shooting bits of glass around the room. Glass flew in every direction, breaking a plastic ceiling light cover, hitting the back wall cabinets, and piercing the vinyl drapes.

Igniting methanol is a common lab demonstration, said Roy LaFever, a professor of chemistry at Cal State Bakersfield. "It's used in a variety of experiments because it burns clean and, under normal circumstances, is quite controllable."

Officials quickly determined that the explosion was simply an unfortunate accident.

Mary Martinez, 39, expressed concern about McCormick when she came to pick up her son, Erik Martinez, from San Joaquin Hospital. While Erik wasn't seriously injured, Mary Martinez was concerned about the safety of the science lab experiments. She said she was upset that McCormick was wearing protective goggles, gloves and earplugs while the students were not. "If he (Erik) had lost his eyesight over this" she said, and stopped. "An accident isn't really an accident. It's someone else's mistake."

Students Recount Chemistry Accident

November 8, 2000

By Lisa O'Neill Hill and Monique Henderson
The Press-Enterprise
RIVERSIDE

One minute, Josh Ramirez was watching a chemistry experiment give off blue, red, and green flames. The next minute, the 16-year-old high school junior was patting out fire from the right leg of his jeans. Josh, a Martin Luther King High School honors student and athlete, was one of two students injured in an experiment gone awry. He suffered burns to his shin and face. His friend Minh Vuong, also 16, was hospitalized.

"There was a big whoosh and it happened like in a split second," Josh said from his home. "I just tried to get out of the way and I noticed my leg was kind of burning and so I put it out with my hand."

The accident occurred while the teacher demonstrated an experiment called a flame test for her Advanced Placement chemistry class. The purpose of the flame test, a common science activity that has been conducted for decades, is to identify distinct elements. With the classroom lights turned off, the chemistry students were instructed to look for the different flame colors coming from seven dishes containing a variety of chloride salts and methyl alcohol, fire officials said.

One by one, the teacher lighted each dish on fire. When one dish failed to light, she added extra methyl alcohol. A dish that was already lighted ignited the methyl alcohol and there was a small flash of fire.

Minh stood up and jumped up and down to try to extinguish the flames, while her teacher threw a fire-retardant blanket around her. She was burned on her forearms, chest, hands, and face, fire officials said. Hospital officials estimated the burns cover 4 percent to 5 percent of her body. A hospital spokesman said it was too early to say whether the burns will leave the honor student with scars.

Sandra S. West, an associate professor of biology at Southwest Texas State University, said little research has been done on safety in high school science labs. She said some studies have shown there are more accidents in classrooms when there is less than 41 square feet for each student, when there are more than 22 students in the class, and when teachers have had insufficient safety training.

Josh, a member of numerous campus clubs and a school baseball and football player, said he believes everything happens for a reason. "Thank God it was just what it was and not anything more serious. I guess it just goes to show you how fast your life can be taken away," he said.

Chemical Ignites During Science Class

November 25, 1999

Detroit News

One student was in critical condition and 13 others were treated for respiratory problems Wednesday after a chemical ignited during a science class at Waverly High School.

Christina Jurus, a junior, was being treated for burns at Sparrow Hospital in Lansing. School officials said she was in critical condition. The other 13 students were treated and released from another Lansing-area hospital.

The accident happened at 9:50 a.m. at the end of a second-hour advanced chemistry class. The demonstration used methanol gas to blow a cork from a plastic bottle. An electric coil attached to one of two nails in the bottle's sides creates a spark that jumps between them, igniting the vapor and blowing the cork out of the bottle. When the chemistry teacher was performing the experiment for the second time, some of the gas in the bottle might still have been burning, fire officials said. Jurus was closest to the flame; the other students were injured by breathing vapors.

Ryan said the teacher of the college preparatory chemistry class wasn't doing anything unusual. "I have high confidence that he was in command of that situation and doing the good job he normally does," Ryan said.

What Went Wrong?

You may never know the exact conditions that led to each of these accidents. Did the teacher use too much of a certain chemical? Were the demonstration materials cleaned thoroughly enough, and prepared properly for the demonstration? Was the procedure followed exactly as specified?

These teachers most likely performed the same demonstrations numerous times previous to these accidents. It does not take much deviation from the specified demonstration procedure to get a different result than intended.

The demonstrations provided in this laboratory manual have been used numerous times and are designed to be safe. They must be followed as written to maintain safe conditions. Understand the chemical that is being used and the full process of the demonstration. Whether it is being used in a demonstration, transported, stored, or being disposed of, know the right way to handle the chemical. Be clearly aware, at all times, of your next step – not complacent with your last.

II. Purchasing Your Chemicals

Purchasing Smart

The American Chemical Society (ACS) estimates that unused chemicals can account for up to 40% of the waste annually generated by a school laboratory. The buildup of unneeded chemicals results from purchasing chemicals arbitrarily and can often lead to hazardous storage conditions. Having a well thought out plan in place before ordering the year's chemical supply will help prevent such waste. This process should begin long before the school year does, and involves accurately estimating types and quantities of chemicals to be used throughout the school year. Ward's Science wants this process to be as trouble-free as possible so you can provide a successful educational experience.

The following procedures will help make your chemical purchase efficient and cost effective:

- Take stock of leftover and stored chemicals in your classroom/laboratory to help you figure out what you have and what you need to order. Establish an inventory control program to trace future chemical usage from delivery to disposal. A computer tracking/inventory system, such as the Ward's Chemical Inventory Management System (CIMS), is ideal since it allows easier sharing of in-house chemicals between classrooms. Avoid donated chemicals because source and quality can be questionable and they can become a future waste problem. Ordering chemicals in the amounts needed, and stocking smaller containers of chemicals, will help prevent waste due to shelf life expiration. Once the Ward's chemical container is opened, use a "date opened" section of the label on the container to track the date the bottle was originally used. This will help prevent waste due to shelf life expiration.

- Before ordering chemicals, check with other science teachers in the school to see if they have any surplus chemicals that you can use; but beware of old chemicals. Many schools have an inventory of unused chemicals forgotten in storage or left over by former teachers. These chemicals may be useless or unstable, and possibly dangerous. Establish an "approved" list of usable chemicals in the school, and standardize chemical purchases from one supplier. This will minimize freight charges, hazardous material charges, redundant ordering, etc.

- Use a "first in, first out" policy. Old stock should be depleted first, to avoid expiration of their shelf life.

- Evaluate special storage and/or handling requirements. Costs beyond the price of a chemical may be incurred to provide for special storage requirements. Arrangements must be made to separately store chemicals if they are incompatible with one another or are light sensitive. Special provisions for the separate storage of solid and liquid chemicals are sometimes necessary as well. If your school does not have adequate storage and safety provisions for a chemical, you should not purchase that chemical.

- Shorten the time frame you are stocking for to increase the accuracy of quantity estimates. For example, estimates of quantities to supply you for one quarter or one semester are usually more accurate than estimates for quantities to last an entire year.

- Consider a centralized purchasing program. If one person does all the purchasing, individual teachers may be able to take advantage of bulk pricing and supply sharing. The hub of this purchasing program is the Chemical Hygiene Officer (CHO). The CHO should be a qualified science teacher *(see Section VII)*, and will become the school's source for ordering chemicals. Before ordering a chemical, each teacher should work with the CHO to gain an understanding of possible hazards associated with that chemical and to establish any mandated emergency preparedness measures, including the procurement of any special neutralizing agents, fire extinguishing agents, and spill response materials. The CHO also ensures that Safety Data Sheets (SDS's) are obtained with each chemical purchase.

- Choose the demonstrations and experiments you will perform based on your budget, the chemicals you have on hand, and those you will purchase. When preparing to order chemicals, account for hidden costs, additional materials required, the initiation of special safety procedures, and the possibility of special clean-up and waste disposal requirements.

- Consider the disposal cost of a chemical at its time of purchase. Since many chemicals deteriorate with time, the disposal and waste costs may add significantly to the original purchase price. The actual cost of a chemical should be regarded as a combination of the initial purchase price plus the disposal costs, which can often offset the savings from buying in quantity. Ward's will provide chemicals in small amounts in an endeavor to support all of your chemical needs, including your waste minimization efforts.

- Try to use non-hazardous (or less hazardous) chemicals, or those that are suitable for reuse. See *Section III* for additional information.

- Purchase, store and dispense chemicals from the smallest bottle possible. For example, do not order or dispense from a 500-milliliter bottle if each student in a class needs only 1-milliliter.

- Purchase, store, and dispense chemicals in unbreakable plastic or PVC-coated glass bottles. Concentrated acids should never be stored in uncoated glass bottles.

- Purchase and store all highly toxic or reactive materials in a secondary device.

- Coordinate chemical delivery, when feasible, to occur during summer break. Make clear to school custodians that they may only deliver the chemical packages to the classroom/laboratory, and may not handle or unpack the chemicals. Custodians must have limited contact with chemical packages and should immediately contact the science teacher when the chemicals are delivered. Science teachers should be responsible for handling and unpacking their purchases.

Hazardous Material Surcharges

Transportation of *hazardous* chemicals in the United States and Canada is federally regulated. Ward's Science ships all chemicals in compliance with these regulations. As of January 1, 2002, shipping companies including United Parcel Service (UPS), Federal Express (FedEx), Loomis, and Purolator have instituted a per hazardous materials package shipment charge. This cost is in addition to normal shipping and handling charges. Ward's Science will consolidate hazardous materials into as few packages where possible to reduce this cost. Select chemicals are now available with Ward's Safety Packs to eliminate hazardous shipping fees and enable faster shipping. Previously, these chemicals shipped freight within 7-14 days and incurred a hazardous shipping fee added to your order total. Ward's Safety Packs eliminate hazardous shipping fees and allow your chemicals to be shipped via UPS within 3-4 days. For a list of chemicals that include Safety Packs, visit wardsci.com/chemicalship.

III. Ward's Science Chemicals

Ward's Science provides various grades of chemicals for use by chemistry teachers. Chemicals are graded based on various industry standards to identify quality and/or purpose of use. Selection of a chemical is based on the intended use of the chemical. Typical Secondary Chemistry chemicals are reagent or lab grades.

The following organizations have set grading systems that are recognized industry standards for classification of chemical purities:

A.C.S - The American Chemical Society Committee
F.C.C - Food Chemical Codex
N.F. - National Formulary
U.S.P. - US Pharmacopeia

Chemical Grades

Chemical grades of purity have been adapted to indicate a chemical's quality and primary uses. The grades listed below, in order of purity (with •••• being the purest, and • being least pure), are available through Ward's Science. The higher the purity, the higher the relative cost of the chemical.

Purity/Grade

••• **ACS** are chemicals that meet the requirements of the American Chemical Society Committee on Analytical Reagents.

••• **Reagent Analyzed or Reagent Grade** are chemicals of an analytical grade acceptable for all general laboratory use, certified to have impurities below specific levels set by the Committee on Analytical Reagents of the American Chemical Society. Analytical methods used for these determinations are based on standard chemical industry test procedures.

•• **Lab Grade** are chemicals meeting a minimum purity standard suitable for histology methods, general laboratory applications, and demonstrations that do not require qualitative results.

Acids and Bases

Ward's Science provides a full line of acids and bases for laboratory use. Getting a better understanding of what an acid and a base is, and how they work, will give you a better understanding of what acids you should use in your classroom.

Acids

Acids are solutions that donate protons and have a pH less than 7 in a water solution. The lower the pH, the stronger the acidity and corrosiveness. The word acid comes from the Latin word *acere*, which means "sour." All acids taste sour. Well known acids include vinegar (5% acetic acid), lactic acid (in buttermilk), citric acid (from certain fruits and vegetables, notably citrus fruits), ascorbic acid (vitamin C, as from certain fruits) and carbonic acid (for carbonation of soft drinks). Aspirin (acetosalicylic acid) tastes sour if you don't swallow it fast enough.[1]

Properties of Acids

- Acids change litmus (a blue vegetable dye) from blue to red.
- Their aqueous (water) solutions conduct electric current (are electrolytes).
- React with bases to form salts and water.

[1] Source – The ChemTeam

- Acids neutralize the chemical properties of bases.
- Evolve hydrogen gas (H_2) upon reaction with an active metal (such as alkali metals, alkaline earth metals, zinc, aluminum).

Strong Acids

Strong acids react completely with water, leaving no undissociated molecules in solution. As solutions become more concentrated, dissociation progresses toward 100%. Typically, once the acid is 100% dissociated in solutions of 1.0-molar or less, it is called strong. The most common strong acid used by chemistry teachers is hydrochloric acid (HCl).

Strong acids include the following:

HCl	Hydrochloric acid
HNO_3	Nitric acid
H_2SO_4	Sulfuric acid
HBr	Hydrobromic acid
HI	Hydroiodic acid
$HClO_4$	Perchloric acid
H_3PO_4	Phosphoic acid

Weak Acids

With the exception of those listed above, nearly all other acids are weak.

Bases

Bases are solutions that can accept protons. Basic solutions have a pH greater than 7. Concentrated bases (alkalis) are more corrosive to tissue than most concentrated inorganic acids and dissolve the fatty acids and oils in your skin. They feel slippery or soapy to the touch and are actually a primary ingredient in the production of soap. Some bases, such as lye (NaOH) and household ammonia (aqueous), are detergents. All bases taste bitter, and many foods and medicines are bases, including mustard and cough syrup.

Properties of Bases

- They don't change the color of untreated litmus, but can turn red (acidified) litmus back to blue.
- They neutralize the chemical properties of acids.
- Their aqueous (water) solutions conduct and electric current (are electrolytes).
- They react with acids to form salts and water

Strong Bases

Strong bases dissociate almost completely in water. In aqueous solution, they are the only significant source of OH^-. The most common soluble strong bases are the hydroxides of group 1A (the *alkali metals*) and group 2A (the *alkaline earth metals*).

Strong bases include the following:

LiOH	Lithium hydroxide
NaOH	Sodium hydroxide
KOH	Potassium hydroxide
RbOH	Rubidium hydroxide
CsOH	Cesium hydroxide
*$Ca(OH)_2$	Calcium hydroxide
*$Sr(OH)_2$	Strontium hydroxide
*$Ba(OH)_2$	Barium hydroxide

** Completely dissociated in solutions of 0.01 M or less.*
These are insoluble bases that ionize 100%.

The most commonly used bases in teaching are NaOH and KOH. There are other strong bases, such as Na_2O or CaO, and the amides. However, these substances are seldom used in Secondary Chemistry classes. With the exception of those listed above, nearly all other bases are considered weak.

Most metal oxides are basic oxides. One example is: NA_2O (S) + $H_2O \Rightarrow$ 2 NAOH (aq).

Acid and Base Chart

Ward's Science supplies several common acids and bases as concentrated solutions in water. The table below gives approximate molarities for these materials.

Chemical	Formula	Molecular weight	Molarity	Specific gravity	Weight %
Acetic acid (ethanoic acid)	CH_3COOH	60.05	17.5	1.05	99-100
Ammonium hydroxide	NH_4OH	35	14.8	0.88	28-30
Formic acid	HCOOH	46	23	1.22	88
Hydrochloric acid	HCl	36.5	12	1.18	36-38
Nitric acid	HNO_3	63	15.6	1.42	69
Phosphoric acid	H_3PO_4	98	14.7	1.7	85
Sulfuric acid	H_2SO_4	98	18	1.84	95-98

Chemical Quality and Characteristic Changes

As expressed throughout the Ward's Science Laboratory Manual, proper handling and storage of your Ward's chemicals is essential to keep them fresh and potent. Conditions such as exposure to sunlight or air, and improper handing resulting in exposure to impurities, will have an effect on many chemicals. Frequently these exposures change or deteriorate a chemical's qualities and shelf life. Some chemicals, such as hypochlorite, will crystallize over time if improperly stored. And contact with organic material, such as paper or oil, may cause some acids to change color in the bottle (though the acid is probably still usable).

There are also a few chemicals that have melting points near room temperature and may change from liquid to solid (or the reverse) depending on the temperature of the room. Examples include t-Butyl alcohol with a melting point of 25 °C and glacial acetic acid with a melting point of 16 °C. Both t-Butyl alcohol and Glacial acetic acid could be a solid in some instances, or a liquid in others, depending on your storage area or the temperature of the room. It is important that you have a full understanding of the chemicals you will be purchasing, handling, and using. Much of this information is found on the Safety Data Sheets (SDS's). You can find a detailed breakdown and description of SDS's in *Section IV*.

Safer Chemical Substitutions

You can reduce waste and improve classroom safety by substituting environmentally safer materials and chemicals when preparing for your chemistry demonstrations and experiments. The following substitutions are recommended by Ward's Science:

Hazardous Chemical	Substitute	Practice
Benzene	Cyclohexane, alcohols	
2 – Butanol	n-Butyl alcohol	
Carbon tetrachloride	Cyclohexane	Non-polar solvent
Carbon tetrachloride	Isopropyl alcohol	Vapor pressure-temperature
Chlorinated solvents	Non-chlorinated solvents	
Chloroform	1,1,1 – Trichloroethane	
Chromate ion	Hypochlorite ion	Organic synthesis
Chromic-sulfuric acid, alcoholic potassium hydroxide	Enzymatic cleaners, aqueous solvents, and biodegradable detergents	Glassware cleaning
Conventional acids Conventional bases	Vinegar Ammonia	Acid-base experiments
1,4 – Dioxane	Tetrahydrofuran or 1, 2Dimethoxyethane	
Ethanol-base baths.	Biodegradable detergents	
Ethyl ether	Methyl t-butyl ether	Organic synthesis
Formaldehyde	Ethanol or other preservatives	Specimen storage
Halogenated hydrocarbons	Trichloroethylene, methylene chloride & perchloroethylene	Heavier-than-water, non-polar solvents,
Heavy metals	Iron, cobalt, copper, etc.	Qualitative test for heavy metals
Methanol solution	Sugar water	Density determination
Mercury thermometers	Accurate non-mercury or digital thermometer.	Temperature
P - dichlorobenzene	Napthalene	
Potassium	Calcium	
Sulfide ion	Hydroxide ion	Qualitative test for heavy metals
Xylene or toluene-based mixtures.	Biodegradable liquid scintillation mixtures. Limonene based extracts	

IV. Where to Find Information on the Chemicals You Just Purchased

What is a Safety Data Sheet (SDS)?

The United States Department of Labor Occupational Safety and Health Administration (OSHA) are responsible for the *Hazard Communication Standard* 29 Code of Federal Regulations (CFR) 1910.1200. The purpose of this standard is "to ensure that the hazards of all chemicals produced or imported are classified, and that information concerning the classified hazards is transmitted to employers and employees. The requirements of this section are intended to be consistent with the provisions of the United Nations Globally Harmonized System of Classification and Labeling of Chemicals (GHS), Revision 3. The transmittal of information is to be accomplished by means of comprehensive hazard communication programs, which are to include container labeling and other forms of warning, safety data sheets and employee training".

Effective June 1, 2015, OSHA required the adoption of Globally Harmonized System (GHS), the hazard communication system used worldwide for the classification and labels of chemicals. Safety Data Sheets (SDS's) replaced Material Safety Data Sheets (MSDS's) for all hazardous materials. Revisions transformed the *Hazard Communication Standard (HCS),* commonly known as the *Right-to-Know Law*, into the *Right-to-Understand Law,* and specify the content that must be on an SDS. For American teachers this is a very applicable standard and Ward's Science suggests that any American chemistry teacher using SDS's referred to and understand the content and purpose of this standard.

In 2015, Canada, through Health Canada, updated the Workplace Hazardous Materials Information System (WHMIS) to comply with the Globally Harmonized System (GHS). WHMIS is a Canadian national system that provides information on hazardous materials used in the workplace, recognizing the interests of workers, employers, suppliers, and regulators, balancing workers' right-to-know with industry's right to protect confidential business information. A product which falls within any of the hazard criteria set out in the *Hazardous Products Regulations (HPR*) is a WHMIS "controlled product" and, unless exempt under the *Hazardous Products Act (HPA)*, is subject to the SDS and labeling requirements of the HPA.

Safety Data Sheets (SDS's) are designed to provide teachers, workers and emergency personnel with the proper procedures for handling or working with a particular substance. SDS's include important information such as the substance's physical data, melting point, boiling point, flash point, toxicity, health effects, first aid, reactivity, storage, disposal, required protective equipment, and spill/leak procedures.

Where Can I Get SDS's?

There are numerous places you can get the required SDS's

- All chemicals ordered from Ward's Science have SDS's available on wardsci.com/sds.
- There are commercial services that can be used to obtain printed, FAX, or online copies of SDS's.
- You can purchase software or Internet subscription services.

What Chemicals Require a SDS?

OSHA requires SDS's for materials that a) meet the *OSHA* definition of *hazardous* and b) are "known to be present in the workplace in such a manner that employees may be exposed under normal conditions of use or in a foreseeable emergency".

Hazardous Materials

***Health hazard** means a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees. The term "health hazard" includes chemicals which are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, hepatotoxins, nephrotoxins, neurotoxins, agents that act on the hematopoietic system and agents which damage the lungs, skin, eyes, or mucous membranes.*

***Physical hazard** means a chemical for which there is scientifically valid evidence that it is a combustible liquid, a compressed gas, explosive, flammable, an organic peroxide, an oxidizer, pyrophoric, unstable (reactive) or water-reactive.*

In Canada a product which falls within any of the hazard criteria set out in Part IV of the *Controlled Products Regulations* (*CPR*) is a WHMIS "controlled product" and, unless exempt under Section 12 of the *Hazardous Products Act* (*HPA*), is subject to the SDS requirements of the *HPA*.

Ward's Science chemicals SDS's are available for download on its website at wardsci.com/sds. You have the responsibility to understand the information on the applicable SDS's and keep them filed or in immediate proximity to the related material at all times.

Are SDS's Copyrighted?

Manufacturers, distributors, etc., are required to give SDS's to end users at no charge. SDS's follow a standard 16-section OSHA standard heading format and language and are supplied as factual information on the material involved.

Ward's Science provides the SDS's in compliance with the applicable regulatory standards and for the safe transportation, handling, use, storage, emergency response, and disposal to protect the individuals and environments involved with these chemicals. The SDS's can be used as defined by their content and can be copied without modification.

How Do I Use a SDS?

The formats of SDS's follow GHS requirements and are made up of 16 sections. There are a number of versions of each chemical's SDS; however, they typically convey the same basic information. In no instance, however, can an SDS have blank sections and/or missing information.

SECTION 1 – Company and Product Identification

Section 1	Chemical Product and Company Information	Page E1 of E2

ward's science+
5100 West Henrietta Rd
PO Box 92912
Rochester, NY 14692-9012
Tel: (800) 962-2660

CHEMTREC 24 Hour Emergency Phone Number (800) 424-9300
For laboratory use only.
Not for drug, food or household use.

Product	**ACETIC ACID, GLACIAL**
Synonyms	Ethanoic Acid / Methanecarboxylic Acid / Glacial Acetic Acid

Section 1 indicates the product's name, in this case Acetic Acid Glacial, as it appears on the container label. This section shall also have the name, address and telephone number of the manufacturer or distributor, along with an emergency phone number. In some cases, the SDS may include commonly used trade names, synonyms, and material uses.

A 24-hour emergency assistance Chemical Transportation Emergency Center (CHEMTREC) phone number is listed for the purpose of reporting significant emergency spills where chemicals are being transported.

SECTION 2 – Hazard(s) Identification

Section 2	Hazards Identification

Signal word: DANGER
Pictograms: GHS02 / GHS05
Target organs: Respiratory system, Eyes, Skin, Teeth

GHS Classification:
Flammable liquid (Category 3)
Skin corrosion (Category 1A)
Eye damage (Category 1)

GHS Label information: Hazard statement:
H226: Flammable liquid and vapour.
H314: Causes severe skin burns and eye damage.

Precautionary statement:
P210: Keep away from heat/sparks/open flames/hot surfaces. No smoking.
P233: Keep container tightly closed.
P241: Use explosion-proof electrical/ventilating/lighting equipment.
P242: Use only non-sparking tools.
P243: Take precautionary measures against static discharge.
P260: Do not breathe mist/vapours/spray.
P264: Wash hands thoroughly after handling.
P280: Wear protective gloves/protective clothing/eye protection/face protection.
P301+P330+P331: IF SWALLOWED: Rinse mouth. Do NOT induce vomiting.
P303+P361+P353: IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/shower.
P363: Wash contaminated clothing before reuse.
P304+P340: IF INHALED: Remove person to fresh air and keep comfortable for breathing.
P310: Immediately call a POISON CENTER or doctor.
P305+P351+P338: IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
P370+P378: In case of fire: Use dry chemical, alcohol foam, carbon dioxide or water spray to extinguish.
P403+P235: Store in a well-ventilated place. Keep cool.
P405: Store locked up.
P501: Dispose of contents/container to a licensed chemical disposal agency in accordance with local/regional/national regulations.

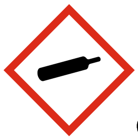
Ca Prop 65 - This product does not contain any chemicals known to the State of California to cause cancer, birth defects, or any other reproductive harm.

Section 2 identifies hazards associated with the listed chemical, along with any necessary warnings for those hazards. GHS requires Hazard Communication Standard (HCS) pictograms be used to convey a chemical's distinct hazards. HCS pictograms consist of a symbol on a white background framed by a red border. The nine pictograms and hazards, as described by OSHA, are as follows:


Exploding Bomb: explosives, self-reactives, and organic peroxides


Flame: flammables, pyrophorics, self-heating, emits flammable gas, self-reactives, organic peroxides


Flame Over Circle: oxidizers


Gas Cylinder: gases under pressure


Corrosion: skin corrosion/burns, eye damage, corrosive to metals


Skull and Crossbones: acute toxicity (fatal or toxic)


Exclamation Mark: irritant (skin and eye), skin sensitizer, acute toxicity (harmful), narcotic effects, respiratory tract irritant, hazardous to ozone layer (non-mandatory)


Heath Hazard: carcinogen, mutagenicity, reproductive toxicity, respiratory sensitizer, target organ toxicity, aspiration toxicity


Environment (non-mandatory): aquatic toxicity

A SDS is required to list:

- Chemical hazard GHS classification, such as flammable liquid
- Hazard word, such as Danger
- Pictograms, symbols that represent present hazards, such as  for flammable and  for corrosive.
- Precautionary statements relative to the chemical, as seen listed in the above figure of Section 2 on the right hand side.
- Description of any additional hazards not covered by GHS classification system
- For mixtures containing ingredients with unknown toxicity: a statement describing the percentage of the ingredient in the mixture (not present in example).

SECTION 3 – Composition/Information on Ingredients

Section 3	Composition / Information on Ingredients		
Chemical Name	**CAS #**	**%**	**EINECS**
Acetic acid	64-19-7	99.8%	200-580-7

Section 3 identifies the ingredients of chemicals, substances, and mixtures contained in the item indicated on the SDS. Information found in Section 3 includes, chemical/substance/mixture name, synonyms, Chemical Abstract Service (CAS) number, impurities, additives, and concentration.

SECTION 4 – First Aid Measures

Section 4 First Aid Measures

INGESTION: HARMFUL IF SWALLOWED. Call physician or Poison Control Center immediately. Induce vomiting only if advised by appropriate medical personnel. Never give anything by mouth to an unconscious person.

INHALATION: HARMFUL IF INHALED. MAY CAUSE RESPIRATORY TRACT IRRITATION. Remove to fresh air. If not breathing, give artificial respiration. If breathing is difficult, give oxygen. Get medical attention.

EYE CONTACT: MAY CAUSE CORNEAL BURNS. Check for and remove contact lenses. Flush thoroughly with water for at least 15 minutes, lifting upper and lower eyelids occasionally. Get immediate medical attention.

SKIN ABSORPTION: MAY CAUSE SKIN IRRITATION AND/OR BURNS. Remove contaminated clothing. Flush thoroughly with mild soap and water. If irritation occurs, get medical attention.

Section 4 gives instructions for untrained responders to provide immediate care in case of an accident. First-aid instructions are given for each possible route of exposure, along with immediate, acute and delayed symptoms. Recommendations for further treatment are given when necessary.

SECTION 5 – Fire Fighting Measures

Section 5 Fire Fighting Measures

Suitable Extinguishing Media: Carbon dioxide, dry chemical, dry sand, alcohol foam.

Protective Actions for Fire-fighters: In fire conditions, wear a NIOSH/MSHA-approved self-contained breathing apparatus and full protective gear. Use water spray to keep fire-exposed containers cool.

Specific Hazards: During a fire, irritating and highly toxic gases may be generated by thermal decomposition or combustion. This chemical reacts violently with strong oxidizers, generating a fire and explosion hazard. Reacts violently with strong bases, strong acids and many other compounds.

Section 5 provides information about how to fight a potential fire. Recommendations for suitable extinguishing equipment are provided, along with information about any equipment that should NOT be used to fight the fire. This section also provides information about any specific hazards that may occur, such as hazardous combustion, and protective equipment that should be worn while fighting the fire.

SECTION 6 – Accidental Release Measures

Section 6	Accidental Release Measures

Personal Precautions: Evacuate personnel to safe area. Use proper personal protective equipment as indicated in Section 8. Provide adequate ventilation.

Environmental Precautions: Avoid runoff into storm sewers and ditches which lead to waterways.

Containment and Cleanup: Remove all sources of ignition. Absorb with inert dry material, sweep or vacuum up and place in a suitable container for proper disposal. Wash spill area with soap and water.

Section 6 provides information for responding to spills, leaks, and releases to minimize exposure to people, the environment, and property. Information will include:

- any personal precautions one should take.
- any protective clothing or equipment that should be worn/used.
- emergency procedures, including evacuation if necessary.
- information on how to contain spill, leak , or release including methods and materials.
- Clean-up procedures and techniques.

SECTION 7 – Handling and Storage

Section 7	Handling & Storage	Page E2 of E2

Precautions for Safe Handling: Read label on container before using. Do not wear contact lenses when working with chemicals. Keep out of reach of children. Avoid contact with eyes, skin and clothing. Do not inhale vapors, spray or mist. Use with adequate ventilation. Avoid ingestion. Wash thoroughly after handling. Remove and wash clothing before reuse.

Conditions for Safe Storage: Store in a cool, well-ventilated area away from incompatible substances. Keep away from ignition sources.

Section 7 contains tips for the safe handling and storage of chemicals. Safe handling recommendations include storage and handling of incompatible chemicals, how to minimize risk of spills, leaks, or releases into environment, and hygiene tips. Safe storage recommendations include chemical incompatibility and special storage instructions, such as ventilation.

SECTION 8 – Exposure Controls / Personal Protection

Section 8	Exposure Controls / Personal Protection			
Exposure Limits:	**Chemical Name**	**ACGIH (TLV)**	**OSHA (PEL)**	**NIOSH (REL)**
	Acetic acid	TWA: 25 mg/m^3 STEL: 37 mg/m^3	TWA: 25 mg/m^3	TWA: 25 mg/m^3 STEL: 37 mg/m^3

Engineering controls: Facilities storing or utilizing this material should be equipped with an eyewash facility and a safety shower and fire extinguishing material. Personnel should wear safety glasses, goggles, or faceshield, lab coat or apron, appropriate protective gloves. Use adequate ventilation to keep airborne concentrations low.

Respiratory protection: None should be needed in normal laboratory handling at room temperatures. If misty conditions prevail, work in fume hood or wear a NIOSH/MSHA-approved respirator.

Section 8 explains exposure limits and how to protect yourself while handling the chemical. OSHA Permissible Exposure Limits (PELs) and any other appropriate exposure limit information are provided. This section lists any personal protective equipment (PPE) recommendations, along with equipment specifications and limitations. There will also be a list of any necessary engineering controls, such as the need for ventilation.

SECTION 9 – Physical and Chemical Properties

Section 9 Physical & Chemical Properties		
Appearance: Clear, colorless liquid.	**Evaporation rate (Butyl acetate = 1):** 0.97	**Partition coefficient:** Data not available
Odor: Strong, acrid, vinegar-like odor.	**Flammability (solid/gas):** Data not available.	**Auto-ignition temperature:** 464°C (869°F)
Odor threshold: Data not available.	**Explosion limits: Lower / Upper:** 4.0% / 19.9%	**Decomposition temperature:** Data not available.
pH: <2	**Vapor pressure (mm Hg):** 11.4 @ 20°C	**Viscosity:** Data not available.
Melting / Freezing point: 16.7°C (62°F)	**Vapor density (Air = 1):** 2.07	**Molecular formula:** CH_3COOH
Boiling point: 118.1°C (244°F)	**Relative density (Specific gravity):** 1.049 @ 20/4°C	**Molecular weight:** 60.05
Flash point: 39°C (102.2°F) TCC ASTM D 56	**Solubility(ies):** Soluble in water.	

Section 9 provides information on physical and chemical properties of the listed chemical. A SDS must contain the following information:

- Appearance (physical state, color, etc.)
- Odor
- Odor threshold
- pH
- Melting/Freezing point
- Boiling point
- Flash point
- Evaporation rate
- Flammability (solid/gas)
- Explosion limits: Lower/Upper
- Vapor pressure
- Vapor density
- Relative density (Specific gravity)
- Solubility(ies)
- Partition coefficient
- Autoignition temperature
- Decomposition temperature
- Viscosity

If any of these items do not apply to or are not available for the chemical in question, a notation must be made. See viscosity as an example in the above figure. Manufacturers may also include any other relevant information. Ward's Science SDS's also include:

- Molecular formula
- Molecular weight

SECTION 10 – Stability and Reactivity

Section 10 Stability & Reactivity	
Chemical stability: Stable	**Hazardous polymerization:** Will not occur.

Conditions to avoid: Excessive temperatures, heat, sparks, open flame and other sources of ignition.

Incompatible materials: Bases, strong oxidizers, chromic acid, nitric acid, sodium peroxide, carbonates, hydroxides, phosphates. Corrosive to some metals. Potentially violent reaction with acetaldehyde and acetic anhydride. Ignites on contact with potassium-tert-botoxide.

Hazardous decomposition products: Carbon monoxide, hydrogen sulfide and other harmful gases or vapors including oxides and/or other compounds of sulfur and sodium.

Section 10 identifies chemical stability, reactivity and other hazard information. Chemical stability information is provided for ambient conditions while a chemical is being stored or handled. If a chemical stabilizer is necessary or if changes in physical appearance indicate a hazard, this information will also be provided. Reactivity information will include incompatible chemicals and conditions that could potentially cause a hazardous reaction.

SECTION 11 – Toxicological Information

Section 11 Toxicological Information

Acute toxicity: Oral-rat LD50: 3,310 mg/kg ; Inhalation-rat LC50: 11.4 mg/L/4 hours ; Dermal-rabbit LD50: 1,060 mg/kg
Skin corrosion/irritation: Skin-rabbit - Severe irritant.
Serious eye damage/irritation: Eyes-rabbit - Severe irritant.
Respiratory or skin sensitization: Data not available
Germ cell mutagenicity: Data not available
Carcinogenity: Data not available
NTP: No component of this product present at levels greater than or equal to 0.1% is identified as a known or anticipated carcinogen by NTP.
IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.
OSHA: No component of this product present at levels greater than or equal to 0.1% is identified as a carcinogen or potential carcinogen by OSHA.
Reproductive toxicity: Data not available
STOT-single exposure: Data not available
STOT-repeated exposure: Data not available
Aspiration hazard: Data not available
Potential health effects:
Inhalation: Exposure to vapor may cause irritation of the eyes, nose, and respiratory tract. May cause asthma-like symptoms, including coughing, wheezing, tightness of chest, shortness of breath, and headache.
Ingestion: May cause burns of the mouth, throat, esophagus, and stomach. Signs and symptoms may include pain, nausea, vomiting, diarrhea, dizziness, drowsiness, faintness, weakness, collapse and coma.
Skin: Contact with skin causes pain, redness, burns, and blisters.
Eyes: Contact with eyes may cause redness, pain, corneal burns, and loss of vision.
Signs and symptoms of exposure: See Potential health effects above. Exercise appropriate procedures to minimize potential hazards.
Additional information: RTECS #: AF1225000

Section 11 explains toxicological and health effects that could if chemical exposure occurs. This section is required to reveal:

- likely exposure routes (inhalation, ingestion, skin contact, eye contact) or notification that the information is unknown.
- results of short- and long-term exposure, including immediate, delayed, acute, and chronic effects.
- description of symptoms for a range of exposure levels.
- numerical measures of toxicity, such as median lethal dose.
- whether or not the chemical is a known carcinogen.

SECTION 12 – Ecological Information

Section 12 Ecological Information

Toxicity to fish: Gambusia affinis (fish, fresh water), LC50 = 251 mg/L/24 hours
Toxicity to daphnia and other aquatic invertebrates: Daphnia magna (Crustacea), EC50 = 95 mg/L/24 hours
Toxicity to algae: Euglena gracilis (Algae), EC100 = 720 mg/L
Persistence and degradability: Easily biodegradable **Bioaccumulative potential:** Not expected to bioaccumulate
Mobility in soil: No data available **PBT and vPvB assessment:** No data available
Other adverse effects: An environmental hazard cannot be excluded in the event of unprofessional handling or disposal.

Section 12 contains environmental impact information should the chemical be released into the environment. The data given may include:

- toxicity test data on both aquatic and terrestrial organisms.
- potential for chemical to persist in the environment.
- bioaccumulation/bioconcentration positional.
- potential for groundwater contamination.
- other potential adverse effects such as ozone depletion, etc.

Section 12 is a non-mandatory section.

SECTION 13 – Disposal Considerations

Section 13 Disposal Considerations

These disposal guidelines are intended for the disposal of catalog-size quantities only. Federal regulations may apply to empty container. State and/or local regulations may be different. Dispose of in accordance with all local, state and federal regulations or contract with a licensed chemical disposal agency.

Section 13 provides chemical disposal, recycling and reclamation guidance for the chemical and its container. This may include proper disposal container use, appropriate disposal methods, any physical or chemical properties that may affect disposal, discouragement of sewage disposal, and special precautions for landfill or incarnation disposal methods. This section may refer to Section 8 of the SDS (Exposure Control / Personal Protection). Section 13 is a non-mandatory section.

SECTION 14 – Transport Information (US DOT / CANADA TGD)

Section 14 Transport Information (US DOT / CANADA TDG)

UN/NA number: UN2789 **Shipping name:** Acetic acid, glacial
Hazard class: 8, (3) **Packing group:** II **Reportable Quantity:** 5,000 lbs (2270 kg) **Marine pollutant:** No
Exceptions: Limited quantity equal to or less than 1 L **2012 ERG Guide #** 132

Section 14 includes classifications for shipping and transporting the chemical provided by USDOT and Transport Canada, along with any special precautions that should be taken when shipping the chemical.

SECTION 15 – Regulatory Information

Section 15 Regulatory Information

A chemical is considered to be listed if the CAS number for the anhydrous form is on the Inventory list.

Component	TSCA	CERLCA (RQ)	RCRA code	DSL	NDSL	WHMIS Classification
Acetic acid, glacial	Listed	5,000 lbs (2270 kg)	D001, D002	Listed	Not listed	B3; E

Section 15 provides information about safety, health, and environmental regulations not located in other sections of the SDS. This will include national and regional regulations that apply to the chemical.

SECTION 16 – Additional Information

Section 16 Additional Information

The information contained herein is furnished without warranty of any kind. Employers should use this information only as a supplement to other information gathered by them and must make independent determinations of suitability and completeness of information from all sources to assure proper use of these materials and the safety and health of employees. NTP: National Toxicology Program, IARC: International Agency for Research on Cancer, OSHA: Occupational Safety and Health Administration, STOT: Specific Target Organ Toxicity, SE: Single Exposure, RE: Repeated Exposure, ERG: Emergency Response Guidebook.

Revision Date: September 18, 2013 **Supercedes:** January 5, 2011

Section 16 provides information on when the SDS was created and/or the date of the last revision. There may also be details on what has changed since the previous version was released. Any other information the manufacturer wishes to convey that does not fit into other sections will be included in this section.

When Must a Supplier Revise a SDS?

When new information becomes available for a controlled product or an ingredient in that product, the supplier must revise the SDS and the date thereof. Such revisions must be made prior to sale of the product subsequent to the new information's availability. A supplier is not obliged to send a revised SDS to a previous customer in the absence of a subsequent sale to that customer.

Suppliers are prohibited from supplying SDS's that have a preparation date exceeding three years (3 X 365 days) prior to the sale or importation of the controlled product. Thus, if a supplier has not changed any information on its SDS for three years, it must review that information to ensure its continued accuracy and that there is no new information to be disclosed. In absence of new information, the SDS must be revised to reflect the review date.

Ward's Science SDS's meet date of preparation requirements. The latest SDS is always available online for viewing or download at wardsci.com/sds.

V. Chemical Labeling

Communication and clarity are essential factors in establishing safety in the classroom and laboratory. Clearly understanding the hazards involved in using chemicals in the laboratory begins with the knowledge of the characteristics of the chemicals that you are using. Establishing this understanding begins with safety data sheets (SDS's) and proper comprehensive labeling of the chemicals.

OSHA

In 1983, the Occupational Safety and Health Administration (OSHA) implemented the Hazard Communication Standard (Right-to-know law). OHSA revised the Hazard Communication Standard to incorporate the Globally Harmonized System (GHS), which in part created more structured chemical label requirements, staring June 2015. Health Canada also revised their 1988 implementation of the Workplace Hazardous Materials Information System (WHMIS). These revised standards give employers and industries, along with teachers, the right to understand the hazards associated with the chemicals they use or work around, including in the classroom and laboratory setting. Both OSHA and Health Canada WHMIS recognized that labels might not be large enough to list every possible warning; however, the new regulations provide vital information on the label that is easy to identify and understand. The related SDS, with its own new format, contains more detailed information and should be used in conjunction with the labels.

The teacher is responsible for ensuring that all hazardous chemicals in their control are properly labeled when purchased and the labels are maintained and updated as required. OHSA requires that all chemicals received by the school must list the following at a minimum:

- **Name, Address, and Telephone Number** of the chemical manufacturer, importer, or other responsible party.
- **Product Identifier**, as decided by the manufacturer, importer, or other responsible party. This may include chemical name, code or batch number. The same product identifier must be on the label and Section 1 of the SDS.
- **Signal Word** signifies the level of hazard severity. "Danger" indicates a more severe hazard and "Warning" indicates a less severe hazard. There will only be one signal word. If there is more than one hazard, the higher of the warnings present takes precedence.
- **Hazard Statement(s)** describe the hazard(s) and the degree of hazard. Multiple hazards statements conveying the same information may be combined to improve readability. Hazard statements should be consistent for a particular hazard classification, no matter the manufacturer.
- **Precautionary Statement(s)** provide recommended safety measures to reduce adverse effects from exposure. Multiple statements may be combined to improve readability.
- **Pictograms** relay a hazard as a black image on a white background and a red border. Pictograms provide a quick and easily noticeable way to alert the chemical handler to hazards. For more on pictograms see *Section IV- Where to Find Information on the Chemical You Just Purchased*.

Health Canada Workplace Hazardous Materials Information System (WHMIS)

The following are the specific requirements of the Health Canada Workplace Hazardous Materials Information System (WHMIS) Label Language Requirements:

Labels must be in both English and French. It is acceptable to have both English and French information together on one label or to have two separate labels, one in English and one in French. WHMIS requires similar label information to the OHSA requirements with these notable exceptions:

- **Initial Supplier Information** must include the name, address, and telephone number of the Canadian manufacturer or Canadian importer with two exceptions:
  - If the hazardous product is sold by a distributor, the distributor's contact information may replace the initial supplier's contact information.
  - If an importer imports hazardous products that are for their own use and which are not for sale, the foreign supplier contact information may remain on the label.
- **Supplemental Label Information** may include additional information on ingredients with unknown toxicities and hazard information not yet included in the GHS.

Ward's Science Chemical Labeling System

Ward's Science provides chemicals using a comprehensive labeling system, which meets the OSHA/WHMIS labeling requirements in a clear and concise format. Figure 1 is an example of a Ward's Science chemical label. The storage code, color, chemical name, and supplier information are all on the left side of the label. Pictograms are located to the right of the chemical and supplier information. Signal word, hazard statements, and precautionary statements take up the remainder of the label. If you have older chemicals in your inventory that are still suitable for use, Ward's Science can provide you or your Chemical Hygiene Officer with materials to color code these chemicals and streamline your chemical organization. A Ward's Science Color-Coded Storage of Chemicals poster is presented at the end of this section.

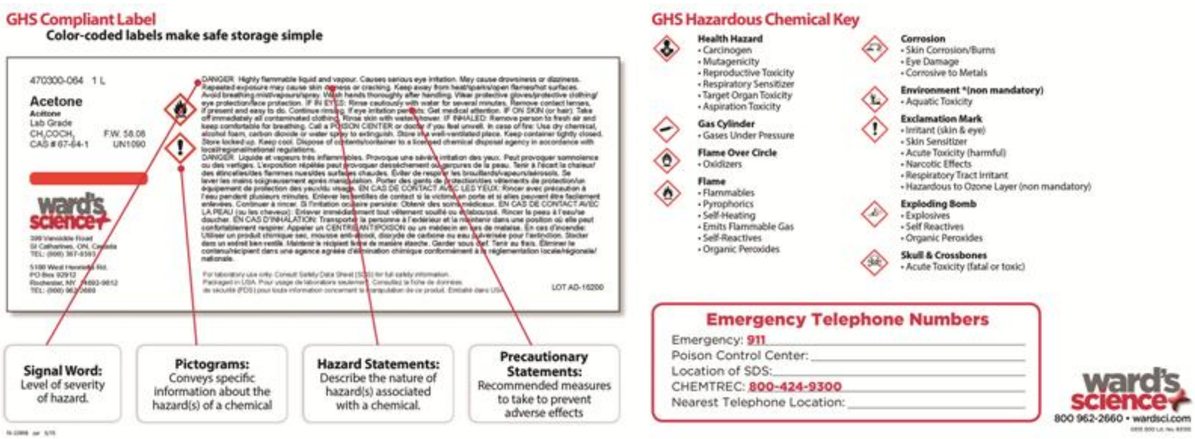


Figure 1. Ward's Science GHS Compliant Chemical Label

Teacher Classroom / Laboratory Labeling Responsibilities

The teacher is responsible for all chemicals under their control and will maintain the labeling of all chemicals and regularly refer to the corresponding SDS's to verify label information. If the label is determined to be deficient when referring to the SDS, the chemical manufacturer or supplier should be contacted immediately for corrective action. The labeling system of chemicals delivered to the school will rely on information provided by the manufacturer or supplier. Teachers and students shall not remove or deface existing labels from incoming containers of chemicals. Where possible the teacher should limit in-classroom labeling. The teacher will ensure that labels remain intact by conducting frequent spot checks throughout the classroom/laboratory.

When solutions are made in the classroom and will be saved for future use, GHS labels must be developed for the storage containers. The new labels must contain the following information, at a minimum, according to GHS standards:

- CHEMICAL NAME / IDENTITY   Full clearly recognized name; no acronyms.
- SIGNAL WORD
- PRECAUTIONARY STATEMENTS
- PICTOGRAMS
- NAME & ADDRESS OF MANUFACTURER
- HAZARD STATEMENTS

Teachers must maintain and communicate safety in the classroom. Per regulatory standards, if chemicals are transferred from a manufacturer-labeled container by a teacher or student to a portable/secondary container that will be utilized immediately and is then depleted by that teacher or student during that classroom session, then a temporary label is not required on that container. However, Ward's Science recommends that all containers be labeled before chemical transfer to maintain as high a level of safety as possible. When chemicals are transferred to a portable container not intended for a single classroom session, the container shall be labeled with the appropriate GHS information as identified above. A secondary GHS-compliant labeling system is available through Ward's Science.

Proper labeling is a simple and powerful way to reduce many of the hazards associated with chemicals used in the laboratory. Mixing unknown or improperly identified chemicals can produce dangerous reactions. In addition, many times these chemicals turn into hazardous wastes. When turned over to waste management services, the chemical and hazard information relating to these wastes must be clearly understood and must be treated properly. There have been cases where people have been injured or killed at waste treatment facilities because wastes were poorly identified and packaged.

Clear labeling is essential in order to understand what you have in stock in the classroom and laboratory. You can incur significant costs due to mislabeled or unidentified chemicals on your shelf when you need to analyze an unknown chemical in order to dispose of it. Analyses costs would be many times the original cost of the chemical.

VI. Chemical Storage

Storage related injuries are one of the major sources of accidents in the science classroom and laboratory. Storage related accidents are not only health hazards, they can also be costly. This section concentrates on effective ways of maintaining a safe working environment regarding proper storage of your chemicals.

Fundamental Needs in Chemical Storage

- **Safe access and use by individuals**
- **Minimize chemical interactions**
- **Regulatory compliance**
- **Practical inventory**

Proper storage of chemicals will assist in providing a safe and efficient teaching atmosphere in the laboratory and classroom. It is essential to take and maintain an inventory of your chemicals. Inventory the chemicals in your laboratory every month. Replace worn and damaged labels.

During this inventory, inspect each chemical for deterioration. Deterioration in storage of a specific chemical cannot be specified completely as there are many factors that affect a chemical's life. However many chemicals will show indications of a change in quality. If the chemical shows any signs of the following it should be safely disposed of. If there are any questions regarding how a chemical looks, call Ward's Science for assistance.

Slightly cloudy liquids
Darkening or change in color
Spotting on solids
Caking of anhydrous materials
Existence of solids in liquids
Existence of liquids in solids
Pressure building up in containers
Evidence of reaction with water
Corrosion or damage to the container

There is a good chance that there are chemicals in storage that will never be used. Excess storage of chemicals is never a prudent practice. Dispose of unneeded chemicals, including those that tend to form peroxides, become more reactive with time, and/or are approaching the end of their shelf lives. Follow the chemical disposal applicable regulatory agencies laws for disposal and as defined in *Section XIV – Chemical Disposal* of this manual.

Determining which chemicals to keep is influenced by what demonstrations you will be performing, the chemical shelf life, and the hazardous nature of the chemical. Whether you are setting up a chemical storage area anew or analyzing an existing storage space, the storage principles described in this section should be considered in the final design. Employing these recommendations is essential in creating and maintaining safe storage. This section defines storage as it relates to safe handling and placement of chemicals in the storage room. For information on the design of a chemical storage room please reference *Section VIII – Planning Your Learning Space.*

Storage Guidelines

1. Store minimum quantities needed

Smaller package sizes mean less risk. See *Section II – Purchasing* for further details. Smaller packages also mean fresher chemicals and better experiments.

Ward's Science recommends purchasing the smallest size bottle that meets your needs for the upcoming school year, particularly for hazardous chemicals, anhydrous salts, and any chemical with an 18-month or less shelf life. In addition, new packaging techniques such as pre-measured concentrated solutions and 25 g or less packages should be investigated, both to minimize storage requirements and to minimize disposal requirements.

Adopting microscale techniques will also dramatically decrease your chemical needs.

2. Storing chemicals by compatibility

One of the main problems in chemical storage, and in which is a regular method used, is storing chemicals randomly or alphabetically.

By far the worst storage system involves no system at all or random storage. With this system, there are no restrictions to where chemicals are stored and no limit to the number of adverse reactions that may arise due to incompatible contacts. This is a laboratory waiting for a disaster to happen.

While storing chemicals alphabetically is better than randomly, there is still a great potential of incompatible substances coming in physical contact, particularly during an emergency situation. There are numerous examples that illustrate the problems associated with storing chemicals alphabetically. Many chemicals which may be stored next to one another alphabetically would severely react if they came in contact with one another. The following is a list of but a few of these possibilities:

- **Acetic acid and acetaldehyde** – Acetic acid will cause the acetaldehyde to polymerize, releasing large amounts of heat.
- **Aluminum metal and ammonium nitrate** – This combination will result in a potential explosion.
- **Ammonium nitrate and acetic acid** - This mixture will ignite.
- **Lead perchlorate and methanol** – This is an explosive mixture if agitated.
- **Nitric acid and nitrobenzene** - This mixture may detonate.
- **Silver oxide and sulfur** – This is a potentially explosive mixture.

See Brethericks' *Handbook of Reactive Chemical Hazards, 1999*, or NFPA 491M: *Manual of Hazardous Chemical Reactions for additional information.*

Ward's Science recommends that storage of chemicals be completed based on compatibility. The ten most commonly used compatibility groups are flammables, oxidants, reducers, concentrated acids, concentrated bases, water reactives, extreme toxics, peroxide formers, pyrophorics and gas cylinders. The first five groups are separated / segregated to avoid accidental contact with an incompatible material that could result in a violent or explosive reaction. Water reactives are isolated to lessen the probability of their involvement in a fire situation. Extreme toxics and regulated materials (carcinogens) are segregated to provide some degree of control over their distribution. Peroxide formers should be stored in a cool, dark environment, whereas pyrophorics need only contact with air to burst into flames and must be isolated. Gas cylinders possessing high kinetic energy due to the compressed nature of the gas should also be isolated.

How the chemical groups are divided and assigned depends largely upon the amount of space available. The risk associated with incompatible chemicals coming into contact must be avoided wherever chemicals are handled or stored.

2.1 Chemical Storage Based on Hazard Color Coding

Ward's Science recommends establishing storage space and separating chemicals according to similar hazards, such as flammability, corrosivity, sensitivity to water or air, and toxicity. The following major categories of chemicals and color codings are strongly recommended as a starting point for determining storage:

- **Area 1: LOW HAZARD- Green**
  - Suitable for general storage area
- **Area 2: FLAMMABLES- Red**
  - Store in corrosion-proof area
  - Separate
    - Water compatible flammables
    - Water incompatible flammables
- **Area 3: CORROSIVES**
  - Separating:
    - Acids (except nitric)
    - Nitric acid (isolate)
    - Strong bases
- **Area 4: OXIDIZERS-Yellow**
  - Store away from flammables and combustibles
- **Area 5: POISONS- Blue**
  - Secure in poisons area

The color-coding system used on all Ward's Science chemical containers is one most commonly used in industrial operations and research institutions. It is also the system most commonly used by chemical suppliers throughout the world. The colors indicate generally compatible chemicals. Segregating chemicals by color code allows basic classification by hazard type.

In addition, some items need separate storage. Examples of item that need separate storage are nitric acid and sodium metal. Nitric acid should be stored in an isolation compartment within an acid storage cabinet. Sodium and potassium metals are supplied under oil in a bottle that is in turn enclosed in a sealable can. The can provides isolation for the chemical.

In all cases classification is done based upon the potential interactions of the chemical.

Where large amounts of organic and inorganic chemicals are present, it may be easier to classify chemicals whether they are organic or inorganic first, and then classify by color code. This can provide an extra level of safety with materials that could interact.

2.2 Storage by Compatible Groups (An Alternative Storage Method)

The following chart was taken from the United States Coast Guard's *CHRIS Hazardous Chemical Data*. The chart shows chemicals broken into 24 segregated reactivity groups. Also included are examples of each *r*eactivity group. This is an example of a very complex storage system, a system that can be difficult to administer if all personnel using the storage system are not totally committed to making the system work.

This system is useful when a very large number of chemicals are stored, as in a central chemical storage area in a large research institution.

Group 1 : Inorganic Acids	
Chlorosulfonic acid	Hydrochloric acid
Hydrofluoric acid	Hydrogen chloride
Hydrogen fluoride	Nitric acid
Sulfuric acid	Phosphoric acid
Group 2 : Organic acids	
Acetic acid	Butyric acid
Formic acid	Propionic acid
Group 3 : Caustics (basic)	
Sodium hydroxide	Ammonium hydroxide solution
Group 4 : Amines and Alkanolamines	
Aminoethylethanolamine	Aniline
Diethanolamine	Diethylamine
Dimethylamine	Ethylenediamine
2-Methyl-5-ethylpyridine	Monoethanolamine
Pyridine	Triethanolamine
Triethylamine	Triethylenetetramine
Group 5 : Halogenated Compounds	
Allyl chloride	Carbon tetrachloride
Chlorobenzene	Chloroform
Methylene chloride	Monochlorodifluoromethane
1,2,4-Trichlorobenzene	1,1,1-Trichloroethane
Trichloroethylene	Trichlorofluoromethane
Group 6 : Alcohols, Glycols and Glycol Ether	
1,4-Butanediol	Butanol (iso, n, sec, tert)
Diacetone alcohol	Diethylene glycol
Ethyl alcohol	Ethyl butanol
Ethylene glycol	Furfuryl alcohol
Isoamyl alcohol	Isooctyl alcohol
Methyl alcohol	Methylamyl alcohol
Nonanol	Octanol
Propyl alcohol (n-, iso-)	Propylene glycol

Group 7 : Aldehydes	
Acetaldehyde	Acrolein
Butyraldehyde	Crotonaldehyde
Formaldehyde	Furfural
Paraformaldehyde	Propionaldehyde
Group 8 : Ketones	
Acetone	Acetophenone
Diisobutyl ketone	Isophorone
Mesityl oxide	Methyl ethyl ketone
Group 9 : Saturated Hydrocarbons	
Butane	Cyclohexane
Ethane	Heptane
Hexane	Isobutane
Methane	Nonane
Paraffins	Paraffin wax
Pentane	Petroleum ether
Group 10 : Aromatic Hydrocarbons	
Benzene	Cumene
Dodecyl benzene	Ethyl benzene
Naphtha	Naphthalene
Toluene	Xylene
Group 11 : Olefins	
Butylene	1-Decene
1-Dodecene	Ethylene
1-Heptene	1-Hexene
1-Tridecene	Turpentine
Group 12 : Petroleum Oils	
Asphalt	Gasolines
Jet fuels	Kerosene
Oils	Mineral Oil
Group 13 : Esters	
Amyl acetate	Butyl acetates
Castor oil	Cottonseed oil
Dimethyl sulfate	Dioctyl adipate
Ethyl acetate	Methyl acetate
Group 14 : Monomers and Polymerizable Esters	
Acrylic acid	Acrylonitrile
Butadiene	Butyl acrylate
Ethyl acrylate	Isodecyl acrylate
Isoprene	Methyl acrylate
Group 15 : Phenols	
Carbolic acid	Cresote
Cresols	Phenol

Group 16 : Alkylene Oxides	
Ethylene oxide	Propylene oxide
Group 17 : Cyanohydrins	
Acetone cyanohydrin	Ethylene cyanohydrin
Group 18 : Nitriles	
Acetonitrile	Adiponitrile
Group 19 : Ammonia/ Ammonium Hydroxide	
Group 20 : Halogens	
Group 21 : Ethers (including THF)	
Group 22 : Phosphorus, Elemental	
Group 23 : Sulfur, Molten	
Group 24 : Acid Anhydride	
Acetic anhydride	Propionic anhydride

2.3 Assigning a Storage Classification to a New Chemical

To assign chemicals to a specific storage area based on chemical hazards use the Ward's Science Safety Data Sheet (SDS) to determine this information. The chemical SDS and label shall be used in determining whether the material is a fire hazard, health hazard or reactivity hazard. See *Section IV* for further information.

Many chemicals have multiple hazards and a decision must be made as to which storage area would be most appropriate for each specific chemical. Use the following to prioritize your determination. (Note: Definitions of the characteristics and associated hazards can be found in *Sections IV and IX.)*

1. Flammability characteristics of the material. If the material is flammable, it should be stored in a flammables cabinet.
2. If the material will contribute significantly to a fire (i.e., oxidizers), it should be isolated from the flammables. Always isolate water reactive material away from potential contact with water.
3. Corrosiveness of the material. Store accordingly.
4. Toxicity of the material. In some cases, certain chemicals should be isolated within a storage area. For instance, a material that is an extreme poison but is also flammable, should be locked away in the flammable storage area to also protect it against accidental release.

There will always be some chemicals that will not fit into only one category or another, but with careful consideration of the hazards involved, most of these cases can be handled in a reasonable fashion. Be consistent!

These storage schemes are provided for use and reference. Selection of how the chemicals will be stored must take the issues identified into account. Based on the particular chemicals being stored, select segregate storage to establish as safe a learning environment as possible.

Ward's Science chemical's are labeled with the 5 color-coded areas in mind. If you have older chemicals in your inventory that are still suitable for use, Ward's Science can provide you or your Chemical Hygiene Officer with materials to color code these chemicals and streamline your chemical organization. . A Ward's Science Color-Coded Storage of Chemicals poster is presented at the end of *Section V – Chemical Labeling*.

Figure 1 Ward's Science Color-Coded Chemical Storage

Suggested Practices of Chemical Storage

- Store chemicals according to manufacturers' recommendations.
- Chemicals should be dated when received and when opened. Date and store new chemicals in a manner that enables the older chemicals to be used first. If the chemical is one that degrades in quality or becomes unsafe after prolonged storage, the shelf-life expiration date should also be noted.
- If possible, keep certain items in the original shipping package, e.g., acids and bases in special and expensive foam cubes if they are supplied that way.
- Post an index on the door of each storage area showing the location and storage pattern for all chemicals. Also post emergency telephone numbers in the chemical stores area.
- Shelving should be no deeper than 12-14" and should be secured to walls or floor to prevent tipping. Shelves should be equipped with lips to prevent products from rolling off. Consider using Plasteel instead of wood for shelf construction.
- Do not store flammable materials outside of an approved flammables storage cabinet. Flammables kept outside a cabinet should only be in an approved safety can.
- The storage area and cabinets should be labeled to identify the hazardous nature of the products stored within.
- Chemicals must be stored at an appropriate temperature and humidity level. Chemicals should not be stored near heat sources, such as steam piping or laboratory ovens. Chemicals should *never* be stored in direct sunlight.
- Do not store hazardous chemicals above eye level. Store large bottles on bottom shelves
- Chemicals should not be stored on the floor except in approved shipping containers.
- Acids more than a 6 M concentration should be stored in an acid cabinet
- Water-reactive products (sodium metal, potassium metal, etc.) should be stored under dry oil and further isolated using a strong, sealable outer container such as a can.
- Glass containers should not touch each other on the shelves.
- Secondary containers or trays should be used for chemical storage whenever possible to minimize the flow of material should a spill occur.
- Chemicals should not be stored on benchtops. Only the amounts for immediate use should be kept on benchtops.
- Keep sources of ignition away from the chemical stores area.
- Do not store chemicals in a fume hood.
- Neutralizing chemicals, such as a spill kit, dry sand, vermiculite, and other spill control materials, should be readily available.
- Tri-Class ABC fire extinguishers should be in the chemical stores area.
- Only authorized personnel shall have access to the chemical storage area.
- Complete an annual safety review procedure for your chemical stores area.

Refrigerated Storage

Flammable materials must *never* be stored in ordinary domestic-type refrigerators. Only explosion-proof or flammable material refrigerators should be used for storage of chemicals. Ignition sources available inside a domestic refrigerator storage compartment and the compressor and its circuits are typically located at the bottom of the unit, where chemical vapors can easily accumulate.

A prep room "explosion-proof" or "flammables rated" refrigerator used for storage for flammable liquids can be purchased from Ward's Science distributors. Under no circumstances should you attempt to perform modification on a domestic refrigerator yourself.

Only store chemicals with flashpoints higher than the temperature of the refrigerator.

- Do not store peroxide formers (i.e., ether) in a refrigerator.
- All containers stored within the refrigerator should be tightly capped to keep vapors from interacting with each other.
- Flasks with cork, rubber or glass stoppers should be avoided because of the potential for leaking.
- Food shall not be stored in a refrigerator used for chemical storage. The refrigerator shall be labeled "Food Must Not Be Stored in This Refrigerator" or equivalent.
- Inventory the materials in your refrigerator frequently.
- Defrost your refrigerator/freezer on a regular basis.

Secondary Containment

Secondary containment is used to provide protection in case a spill occurs to contain the spill in a secondary area. Secondary containment will reduce the risk of the hazards involved including chemical exposure, fire, explosion, etc.

Secondary containment is recommended at all times when chemicals are being transported from room to room.
Secondary containers:

- For a single container, must be sized to contain 110% of the single container's capacity.
- For multiple containers stored in the same secondary container: the secondary container must be able to contain 150% of the largest container or 10% of the aggregate quantity stored, whichever is greater .
- Must be capable of holding any spilled material until the spill can be cleaned up.
- The secondary container must be compatible with the hazardous material.

Chemical Waste Storage

The following is provided to assist in defining safe practices for the temporary storage of hazardous wastes. For detailed information on waste disposal please refer to *Section XIV – Chemical Disposal* .

- Hazardous waste should be stored away from the general non-hazardous waste.
- Different types of waste should be stored separately.
- Do not store non-compatible wastes next to one another.
- Hazardous waste should be stored in sealed containers and kept away from direct sunlight.
- Properly label storage waste containers
- Ensure the compatibility of waste containers with their intended contents. For example metal drums should not be used for acid wastes.
- Leave enough space in liquid waste drums to allow for expansion of the contents.
- Keep storage of wastes to a minimum. Dispose of waste on a regular basis to prevent waste build-up.

VII. Laboratory Safety

As defined throughout this manual, when establishing, maintaining and operating a science laboratory the school and science teacher have a responsibility to the school and its students to provide a safe operating environment. Establishing this safe environment is regulated by governmental and association regulations. This section is designed to define these regulations as related to the science laboratory and to assist in establishing a safe and compliant laboratory. Regardless of any regulatory reference made within this section, the information presented by Ward's Science should be considered minimum safety practices and should be followed by all science teachers in the United States and Canada.

What is a Science Laboratory?

As defined by the Occupational Safety and Health Administration (OSHA) under 29CFR 1910.1450, regulations are imposed in the use of chemicals in a science laboratory when handling or use of such chemicals in which all of the following conditions are met:

- Chemical manipulations are carried out on a "laboratory scale";

  "Laboratory scale" means work with substances in which the containers used for reactions, transfers, and other handling of substances is designed to be easily and safely manipulated by one person. "Laboratory scale" excludes those workplaces whose function is to produce commercial quantities of materials.

- Multiple chemical procedures or chemicals are used;
- The procedures involved are not part of a production process, nor in any way simulate a production process; and
- "Protective laboratory practices and equipment" are available and in common use to minimize the potential for employee exposure to hazardous chemicals.

  "Protective laboratory practices and equipment" means those laboratory procedures, practices and equipment accepted by laboratory health and safety experts as effective, or that the employer can show to be effective, in minimizing the potential for employee exposure to hazardous chemicals.

General Safety Practices in the Laboratory

The following is a quick reference list of important safety practices to be aware of and instill in the laboratory. This list is not all-inclusive. Refer to the various sections of this handbook for specific details.

- Science laboratory and classroom safety starts with awareness.
- Be proactive. Know your chemicals. Read and understand the Safety Data Sheet (SDS) for all chemicals being used.
- Be alert to unsafe conditions and actions.
- Chemicals must be stored in a systematic and a neat manner. Flammables should be stored in the smallest container possible. Store flammable/combustible liquids and acids in appropriate safety cabinets and/or safety cans.
- Equipment and chemicals taken from a preparation room or storage area must be immediately returned after use.
- All storage areas, refrigerators, cabinets, etc., should be appropriately labeled.
- All chemicals must be clearly labeled.
- Use appropriate personal protective equipment (PPE).

- Teaching and storage rooms should remain uncluttered. Ensure that all bench tops and work areas remain clean and that all spills are cleaned up immediately.
- Make sure that sinks are clean and are not blocked with wastes.
- Ensure all water outlets, gas turrets on the benches, power outlets and electrical switches are in good working order.
- Don't eat, drink, or chew gum in the science laboratory and classroom.
- Know where fire extinguishers are located, as well as emergency exits, eye wash/emergency shower stations, fire alarm boxes and other safety equipment.
- When conducting experiments be mindful of your body movements and surroundings to avoid bumping into someone or have someone bumping into you.
- Always inspect equipment before using. Keep equipment in a good working order.
- Have appropriate emergency supplies on hand for spills and personal response.
- Wash hands before leaving the lab.
- Be aware of all sources of ignition, i.e., open flames, heat, electrical equipment.
- Be appropriately trained in chemical use, handling, storage, emergency response, safety and health matters.

Laboratory Responsibilities

In the educational science environment with respect to the use of chemicals, certain responsibilities are inherited and undertaken to sustain safety and compliance. Regulations require certain roles be assigned and policies be established to clearly set how chemicals can be used and how students can safely be educated in the laboratory.

The Science Teacher

This handbook is designed as a useful reference resource for the science teacher to learn from and establish safe procedures and practices in the laboratory. As a science teacher you have the responsibility to:

- Maintain awareness of regulations and health and safety hazards through training programs and consulting reference materials.
- Plan and conduct laboratory exercises using the least toxic alternatives.
- Use good laboratory chemical management practices and teach proper chemical management to students.
- Conduct a monthly inspection of stored chemicals for signs of leakage, improper storage, improper labeling, or any other problems.
- Conduct an annual inventory of laboratory chemicals, and include an inventory each month of all stored wastes.
- Ensure that all materials and wastes are labeled, used and disposed of as required.
- Maintain chemical spill clean-up materials in chemical storage areas.
- Understand and follow all elements of the Laboratory Chemical Hygiene Plan.

The Chemical Hygiene Officer

The school shall designate a Chemical Hygiene Officer who is defined by OSHA as an employee who is designated by the employer (school), and who is qualified by training or experience, to provide technical guidance in the development and implementation of the provisions to the School's Chemical Hygiene Plan. This definition is not intended to place limitations on the position, description or job classification that the designated individual shall hold within the employer's organizational structure.

The Chemical Hygiene Officer also has the responsibility to:

- Work with school administrators, teachers and faculty to develop an appropriate chemical hygiene plan.
- Monitor the procurement, use and disposal of chemicals used in the laboratory.
- Maintain all appropriate audits for chemical hygiene.
- Assist in the development of adequate precautions and facilities.
- Know the current legal requirements concerning associated regulations.
- Continuously seek ways to improve the chemical hygiene program.

The Students

Before students are presented with chemical experiments and particularly before being allowed any hands-on work, they must be informed of the general safety precautions to be taken in a science laboratory. The students should know all of the safety procedures before entering the laboratory. In order to implant a safe way of thinking in the student, the science teacher should establish specific laboratory rules. These rules should be reviewed and prominently displayed. A few rules of note:

- Students must not enter any laboratory or storeroom unless a teacher is present.
- Students must not taste chemicals.
- Students must behave appropriately. No horseplay is allowed in the laboratory and classroom.
- Appropriate dress is mandatory. Depending on the chemical used, students should be given previous notice in order to plan to dress for lab. Student footwear must completely cover the feet and protect them from spilt corrosive or hot liquids.
- Students should be safely seated and not crowded.
- Students should be provided with appropriate personal protective equipment (PPE) including safety goggles for eye protection and a lab apron to protect clothes.

At the very start of the year, and for special tasks in advance of a particular experiment, the science teacher should teach the necessary skills to the student for the safe use of chemicals and associated equipment. This instruction should be accomplished by demonstration. These skills include the following at a minimum:

- Lighting and use of a Bunsen burner
- Heating of liquids or solids in test tubes
- Heating large volumes of liquids
- Handling glassware containing hot liquids
- Carrying glassware
- Handling of chemical bottles
- Diluting concentrated acids
- Inserting glass tubing in rubber stoppers

Chemical Hygiene Plan

The OSHA Laboratory Standard (*29CFR1910.1450)* regulates operations in a laboratory where hazardous chemicals are used. Under this regulation the school must develop and carry out the provisions of a written Chemical Hygiene Plan (CHP). The CHP must include the necessary work practices, procedures and policies to ensure that teachers, students and faculty are protected from all potentially hazardous chemicals in use in the laboratory and classroom area.

As defined by OSHA, the Chemical Hygiene Plan is a written program developed and implemented by the employee (school) which sets forth procedures, equipment, personal protective equipment and work practices that (i) are capable of protecting employees from the health hazards presented by hazardous chemicals used in that particular workplace (laboratory / classroom) and (ii) meets the requirements of paragraph (e) (Guidance plan) of this section.

The purpose of the Chemical Hygiene Plan is to provide guidelines for prudent practices and procedures for the laboratory use of chemicals. The Laboratory Standard specifies that the Chemical Hygiene Plan set forth procedures, equipment, personal protective equipment and work practices capable of protecting teachers, students and faculty from the health hazards presented by the hazardous chemicals used in the laboratory and classroom.

The designated Chemical Hygiene Officer and/or the science teacher are usually the one(s) responsible for developing the Chemical Hygiene Plan (CHP) for the school. Since care and supervision of the science room are primarily the responsibilities of the science teacher, the CHP will serve as a guide to safe science instruction. This Ward's Science Teacher's Comprehensive Lab Manual can be used to help science teachers develop a CHP. A model plan is defined below. An editable Ward's Science Chemical Hygiene Plan is also available upon request.

The following information must be included in a science Chemical Hygiene Plan:

Standard Operating Procedures (SOP)- *1910.1450(e)(3)(i)*

CHP must define prudent laboratory practices to be followed when working with chemicals in a laboratory. These include general and laboratory-specific procedures for work with several categories of chemicals, emergency procedures, and laboratory waste procedures.

Chemical Exposure Control- *1910.1450(e)(3)(ii)*

CHP must define criteria regarding when chemical exposure monitoring will be conducted to determine whether exposure limits are exceeded. It also outlines what control measures (e.g., engineering controls, personal protective equipment) will be used to assure exposure does not exceed exposure limits.

Function of Engineering Controls- *1910.1450(e)(3)(iii)*

CHP must describe a program to ensure laboratory fume hoods and other engineering controls function properly.

Information and Training- *1910.1450(e)(3)(iv)*

CHP must outline general and specific training required and what information must be available and communicated to faculty and students. Records must be kept of attendance at general training, exposure monitoring, medical consultation, and examinations. Such records must be transferred to an individual's physician or made available to the laboratory worker upon request.

Criteria for Prior Approval of Laboratory Procedures- ***1910.1450(e)(3)(v)***

CHP must define written approval procedures that must be obtained from the Chemical Hygiene Officer before beginning work with particularly hazardous substances, including select carcinogens, reproductive toxins, embryotoxins, materials exhibiting a high degree of acute toxicity and materials of unknown toxicity.

Medical Consultations and Examinations- *1910.1450(e)(3)(vi)*

CHP must define how an individual who has actually or potentially been exposed to a chemical or substance will receive needed treatment

Chemical Hygiene Officer Designation- *1910.1450(e)(3)(vii)*

CHP must define the Chemical Hygiene Officer and outline his or her role and responsibilities.

Particularly Hazardous Substances- *1910.1450(e)(3)(viii)*

CHP must define provisions for additional protection for work with particularly hazardous substances. These include "select carcinogens," reproductive toxins and substances which have a high degree of acute toxicity. Specific consideration shall be given to the following provisions, which shall be included where appropriate:

- Establishment of a designated area;
- Use of containment devices such as fume hoods or glove boxes;
- Procedures for safe removal of contaminated waste; and
- Decontamination procedures.

Means of Annual Review of Chemical Hygiene Plan - *1910.1450(e)(4)*

CHP must define how it will be reviewed and evaluated on the effectiveness of the Plan. Review and evaluation must be completed at least annually and updated as necessary.

Sample Chemical Hygiene Plan Outline

The following is a starting point for the possible contents for your Chemical Hygiene Plan. Determine what items are appropriate to you and design a plan that is objectified for your school science laboratory.

- **Introduction**
    - Scope
- **Responsibilities**
    - School
    - Science Teacher
    - Chemical Hygiene Officer
    - Student
- **Chemical Exposure Control**
    - General
    - Procedures
    - Hazardous Chemicals
        - General
        - Irritants
        - Simple Asphyxiants
        - Anesthetics
        - Hepatotoxic Agents
        - Nephrotoxic Agents
        - Neurotoxic Agents
        - Hematopoietic Agents
        - Reproductive Hazards
        - Acutely Toxic Chemicals
        - Extremely Toxic Chemicals
        - Other
    - Labels
        - General
        - Special Labeling Requirements
    - Monitoring
        - Procedures

- **Handling of Chemicals**
- **Chemical Purchases**
    - Approval Process
    - Purchasing
    - Receiving
- **Function of Engineering Controls**
    - Laboratory Fume Hoods
    - Ventilation
    - Other
- **Personal Protective Equipment**
    - General
        - Eye Protection
        - Lab Coats
        - Glove Selection
        - Use of Respirators
        - Other
- **Designated Areas**
    - Laboratory
    - Classroom
    - Chemical Storage
        - General
        - Segregation
        - Chemical Storage Outside the Lab
        - Flammable and Combustible Liquid Storage
        - Chemical Stability
        - Shock Sensitive Chemicals
        - Designated Areas
        - Compressed Gases
- **Room Signs**
- **Safety Data Sheets**
- **Medical Consultation**
- **Chemical Waste Disposal Guidelines**
- **Emergencies Response**
    - Response Materials
    - Fire and Fire Related
    - Chemical Spill
    - Personal Contamination
        - Chemicals Spilled Over a Large Area of the Body
        - Chemicals in the Eyes
        - Ingestion of Hazardous Chemicals
- **Standard Operating Procedures**
    - Acutely Toxic Chemicals
    - Acutely Toxic Gases
    - Carcinogens
    - Compressed Gases
    - Corrosive Liquids
    - Flammable Liquids
    - Oxidizing Chemicals
    - Pyrophoric Chemicals
    - Reactive Liquids

- Reactive Solids
    - Reproductive Hazards
    - Water Sensitive Chemicals
    - Other
- **Training**
    - Chemical Hygiene Officer
    - Science Teacher
    - Student
- **Recordkeeping**
    - Training Records
- **Appendices**
    - Chemical Inventory List

Information and Training

The science teachers and students in the laboratory need to be trained and provided with information to become knowledgeable of the hazards present in their laboratory. This must be completed previous to using chemicals.

Training must include at least the following:

- Methods and observations that may be used to detect the presence or release of a hazardous chemical. This may include monitoring devices, as appropriate, and familiarity with the appearance and odor of the chemicals.
- The physical and health hazards of chemicals in the laboratory.
- The measures that workers can take to protect themselves from these hazards, including protective equipment, appropriate work practices, and emergency procedures

The following information should be available to all persons in the laboratory:

- Full text of the OSHA Laboratory Standard
- Location and availability of the Chemical Hygiene Plan.
- Permissible exposure limits for OSHA Regulated Substances. Refer to chemical Safety Data Sheets (SDS's).
- Signs and symptoms associated with exposure to hazardous chemicals in the laboratory. Refer to SDS's.
- The location and availability of reference materials on the hazards, safe handling, storage and disposal of hazardous chemicals in the laboratory.

Ward's Science understands that safety must be a top priority in science classrooms and laboratories. Ward's Science is available to assist schools in performing safety trainings, preparing a Chemical Hygiene Plan or updating chemical storage and inventory. Valuable resources can be found on our website, and our team of experts is available to address any questions or concerns you may have. For more information, please reach out to us at sciencehelp@vwr. (1-866-260-0501)

VIII. Planning Your Learning Space

A well thought out and organized science classroom and laboratory helps provide a safe and effective educational experience. Whether you have a hand in the room's original design or the ability to rearrange it, this section of the Ward's Science Laboratory Manual will help you provide a safe and successful science lab. The ideal situation would be to incorporate all of the following recommendations, in addition to the requirements. As this is rarely the case, however, science teachers should develop a good chemistry safety-sense. Consider this information, incorporate the required features, and include the recommended features where possible. A Ward's Science *Room Inventory Checklist* is included at the end of this section to assist you in determining what you have and what you need in your learning space.

"Due to the basic nature of science, science classrooms and laboratories are among the most hazardous instructional areas in the school environment, so safety for those who will be using the facilities should be a prominent concern for facility planners." [2]

Before the school year begins, science teachers should review their surroundings and assess the space available for science classroom/laboratory utilization. As part of any school design, provisions for a science lab are generally included. If your building was built without a lab, you will have to do some planning. Science can be taught in a wide range of settings, from a regular classroom to a state-of-the-art facility. Labs with inadequate resources, however, will be more limited as to the number of students that can function in them safely. Differences aside, there are some common features all learning environments must maintain to facilitate quality science instruction.

Due to concerns regarding student supervision, quality of education, and safety, the National Science Teachers Association (NSTA) recommends a maximum class size of 24.[3] This limitation can be increased if the number of science teachers available for the class increases. Ward's Science defines the requirements and recommendations found in this section based on this recommended class size. The following information was compiled from the Occupational Safety and Health Administration (OSHA), Health Canada, National Fire Protection Agency (NFPA), and recommendations of The National Science Teachers Association (NSTA).

The Prep Room

An analysis of the layout of your classroom/laboratory should include chemical preparation and storage areas separate from the instructional area. Where possible, a separate room should be dedicated for each purpose. According to the National Science Education Leadership Association (NSELA), "*A lab prep room should be next to the science lab/classroom. If this is not possible, the prep room should be no more than 760 feet from the science lab/classroom and chemistry teachers should never be assigned a room that does not have a prep room adjoining it.*

The prep room should have a window through which to supervise the classroom/laboratory. NSTA recommends approximately 9–10 square feet of prep/equipment storage area per student in the class.

The prep room should have:

- Utilities including electricity and gas outlets, and hot and cold running water in an acid-resistant sink.
- Appliances including a phone, a refrigerator, and a dishwasher.
- Cabinets for prep room material storage. (The prep room should not be used for general equipment storage.)

[2] The Science Teacher, *Science Facilities by Design*, Sandra S. West, Lamoine L. Motz, and James T. Biehle

[3] National Science Teachers Association (NSTA). 2007. NSTA Position Statement: Liability of Science Educators for Laboratory Safety.

- Fume hood, which can be shared between the prep room and lab if necessary. (Refer to the Fume Hood segment of this section for specific information.)
- Accommodations for fixtures such as an autoclave, demineralizer, etc.

The space should be designed for safe, effective use. If a storage area is integral to the prep area, the room should be designed to limit chemical movement, and should have immediate access to emergency response items including fire extinguishers and neutralizing agents.

The prep room should have designated signage and should not be a teacher's office. The prep room requires separation due to the hazards involved in chemical handling and storage. Science teachers should have their own workspace, apart from the preparation space.

The Prep Storage Room

The preparation area should also include a storage room/area used solely for the storage of chemicals and materials. The room should be approximately 50 to 200 square feet depending on the number of classrooms and students it is serving. The rule of thumb is approximately 1 square foot of storage space per student served. The room should only be accessible from the preparation room (see **Figure 1)** or a room between two classrooms/laboratories **(See Figure 2**).

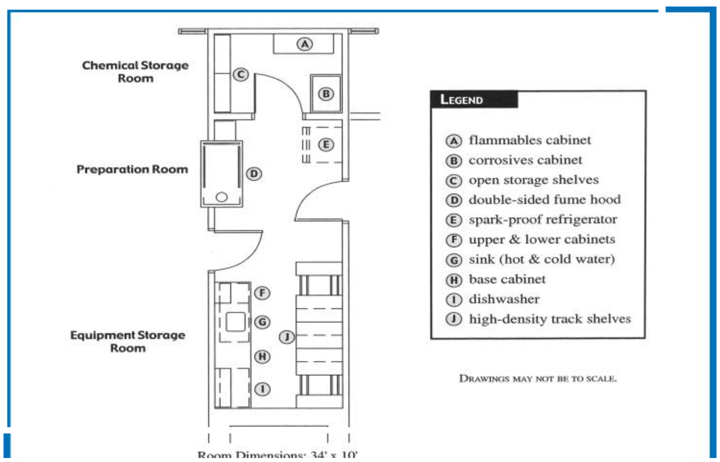


Figure 1 – Prep / Storage Room Layout for Single Laboratory[4]

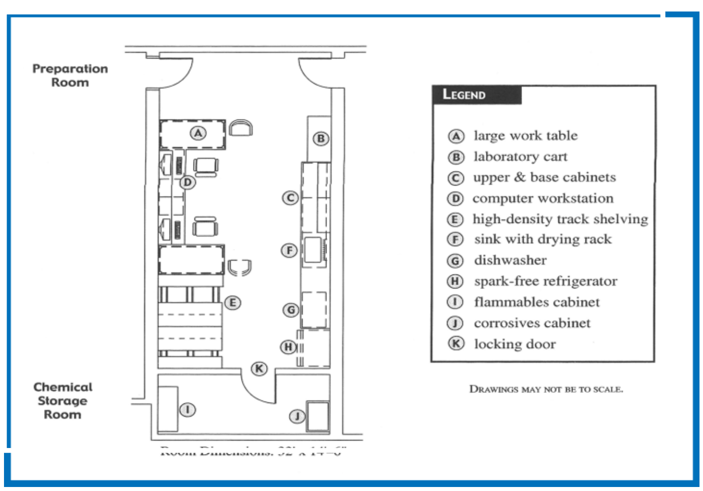


Figure 2 – Prep / Storage Room Layout for Dual Classrooms[3]

[4] *Figures 1 and 2 are reprinted from "Science Facilities Standards" by the University of Texas Dana Center.*

(Refer to *Section VI - Chemical* Storage for additional information).

- Chemicals should be stored in a lockable room that is inaccessible to students, sealed and inaccessible from the ceiling or ductwork, and has a self-closing, outward opening door (that is never propped open).
- Walls and door of the storage room should be fire rated in compliance with federal and local building codes. Due to flammable hazards there should be no electrical outlets used for personal use in this room. Linked fire and smoke detectors should be installed in the chemical storage area and in a nearby main hallway, and both should alarm when either is tripped.
- The storage room should have storage space (wall-mounted adjustable shelving and base cabinets) sufficient for the expected number of chemicals, vented NFPA/OSHA compliant cabinets for acid and flammable chemicals, and storage below eye level for all hazardous materials.
- Per the OSHA Laboratory Standard 1910 - 4 to 12 room air changes (bring in fresh air) per hour is adequate general ventilation, depending on the chemicals used. Fresh air must be brought into the storage area from outside and exhausted to the outside, away from building fresh air intakes. Check your local building codes for specific venting requirements.
- An ABC rated fire extinguisher must be located within the room, along with a bucket of dry, organics-free sand (for alkali fires). If teachers are expected to respond to a fire, they should be properly trained.
- Use the following *Ward's Science Prep Room Equipment Checklist* as the minimum requirements when setting up your Prep Room.

Ward's Science

Prep Room Equipment Checklist

Furniture

- ☐ Epoxy Countertops
- ☐ Large Sink with Overflow
- ☐ Tote Tray Cabinet
- ☐ Rolling Carts
- ☐ Benches for Kit Assembly

Chemical Storage / Solution Preparation

- ☐ Fume Hood
- ☐ Acid Cabinet
- ☐ Flammables Cabinet
- ☐ Poison Cabinet (Optional)
- ☐ Open Chemical Shelving with Shelf Lip

Appliances

- ☐ Water Deionizer/Distiller
- ☐ Flammable Storage Refrigerator
- ☐ Incubator

Safety

- ☐ Safety Shower
- ☐ Eye Wash
- ☐ (2) ABC Type Fire Extinguishers
- ☐ Buckets of Sand and Vermiculite for Spill Control
- ☐ Chemical Transport Containers
- ☐ Acid and Base Neutralizers
- ☐ Spill Control Products
- ☐ Broken Glassware Box
- ☐ Hazard Signs (NFPA Diamond)

Personal Protective Equipment

- ☐ Full Coverage Indirect-vent Chemical Splash Goggles
- ☐ Face Shield
- ☐ Gloves (various kinds applicable to chemicals used)
- ☐ Rubber Apron

The Classroom and Laboratory

To best serve students, design a chemistry classroom/laboratory that is as flexible as possible. The NSTA recommended configuration has movable tables, and can serve as a classroom (for instruction) as well as a laboratory space (with utilities, sinks, and benches around the perimeter of the room). See **Figure 3**, on the following page. When arranging the space available to you, consider the pluses and minuses of each layout scheme. Some points of concern are overcrowding, tight spaces, and dead ends.

Remember that the classroom/laboratory should not be overcrowded. NSTA recommends 55 to 60 square feet of working space per student, depending upon the type of activities to be performed. The lab should be designed for no more than 24 students per teacher. Therefore, a classroom/laboratory combination should be a minimum of 1,320 square feet to provide adequate space for laboratory work.

The following should be used as reference in planning and laying out your chemistry classroom/laboratory:

- The room should have two exits, both opening outward and at least 5 feet wide (1.5 meters) to accommodate handicapped students and serving as emergency exits. Doors should have reinforced glass windows.
- The student workstations should be located so they can all be observed from the teacher workstation. Emergency/master shut-off controls for water, gas, and electricity should be located at or near the teacher's station.
- Typically a student lab workstation or working area should provide nine square feet of horizontal surface, a 15-inch by 15-inch sink with running water, and a duplex electrical outlet (at a minimum). If a permanent eyewash and shower hose is not in place in the laboratory, sinks should have goose-necked faucets to allow the attachment of portable ones. Chemistry laboratories should be provided with natural gas, and each workstation should have safety gas connections.
- A separate HVAC system should be dedicated to the science classroom/laboratory. Per the OSHA Laboratory Standard, four to 12 room air changes (bringing in fresh air) per hour is adequate general ventilation. The system should be adjustable for up to 12 air changes per hour depending on the chemicals used. This is needed in case of a chemical spill or if particular experiments or demonstrations generate hazardous vapor or strong odor. When increasing ventilation and the amount of air changes, open doors and windows to allow for a maximum flow of fresh air. The polluted air should be exhausted outside of the building away from any fresh air intakes.
- In order to meet Americans with Disabilities Act (ADA) requirements for handicapped and disabled students, there should be at least 20 square feet (1.9 square meters) of additional working space per student to the space allowance defined above. One student workstation must be accessible to disabled students. In order to provide accessibility, the workstation should have a lower counter and sink height, gooseneck controls that do not require twisting, and enough space around the workstation to maneuver a wheelchair.
- ADA requirements also require aisle space between tables and space at the perimeter of the room to accommodate wheelchair passage (a minimum of 32 inches of clearance). Add additional space if equipment and material will be transported through the aisles. The floor should be tiled and covered with non-skid wax.
- Lab table and counter surfaces should be made of material that are resistant to acid, alkali, solvent, and temperate heat.
- There should be electrical outlets located at six to eight foot intervals (1.8–2.4 meters), which should be covered when not in use. Electrical outlets within 5 feet (1.5 meters) of water/sinks should be equipped with ground-fault interrupters (GFIs).
- The laboratory/classroom should have a variety of cabinets and drawers above and below lab workstations for student material and equipment storage.
- The room should have adequate natural lighting for experiments. The general lighting level should be between 538.2–1076.4 lumens per square meter.

- There should be a telephone or an intercom available for notifying building staff and/or authorities of an emergency.
- The classroom/laboratory should have a hands-free emergency safety shower/eyewash station with a flow rate of 1.5 gallons per minute (5.7 liters per minute) at a pressure below 25 psi, with a drain to accommodate the water flow. The unit should be located near the door, accessible from both sides, and unobstructed at all times. The station should be handicapped accessible. The emergency safety shower/eyewash station should be maintained in accordance with ANSI standard, Z-358.1-1998. Test eyewash weekly for 3-5 min. Typically, if an individual is splashed in the eyes with a chemical, they should flush the eyes with water for at least 15 minutes.
- If audiovisual equipment or computers are to be used in the lab, add the following additional space to the total classroom/laboratory area:
  - Computer Station: Add approximately 15 square feet (1.4 square meters).
  - Television w/ VCR or Laser Disc Player: Add approximately 10 square feet (.9 square meters).
  - Projector: Add approximately 12 square feet (1.1 square meters).
- A fire blanket, an ABC rated fire extinguisher, and a bucket of dry, organics-free sand should be located within 50 feet of any point in the room. If teachers are expected to respond to a fire, they should be properly trained. A first-aid kit should be immediately available, stocked appropriately to contend with the potential injuries associated with a science lab.

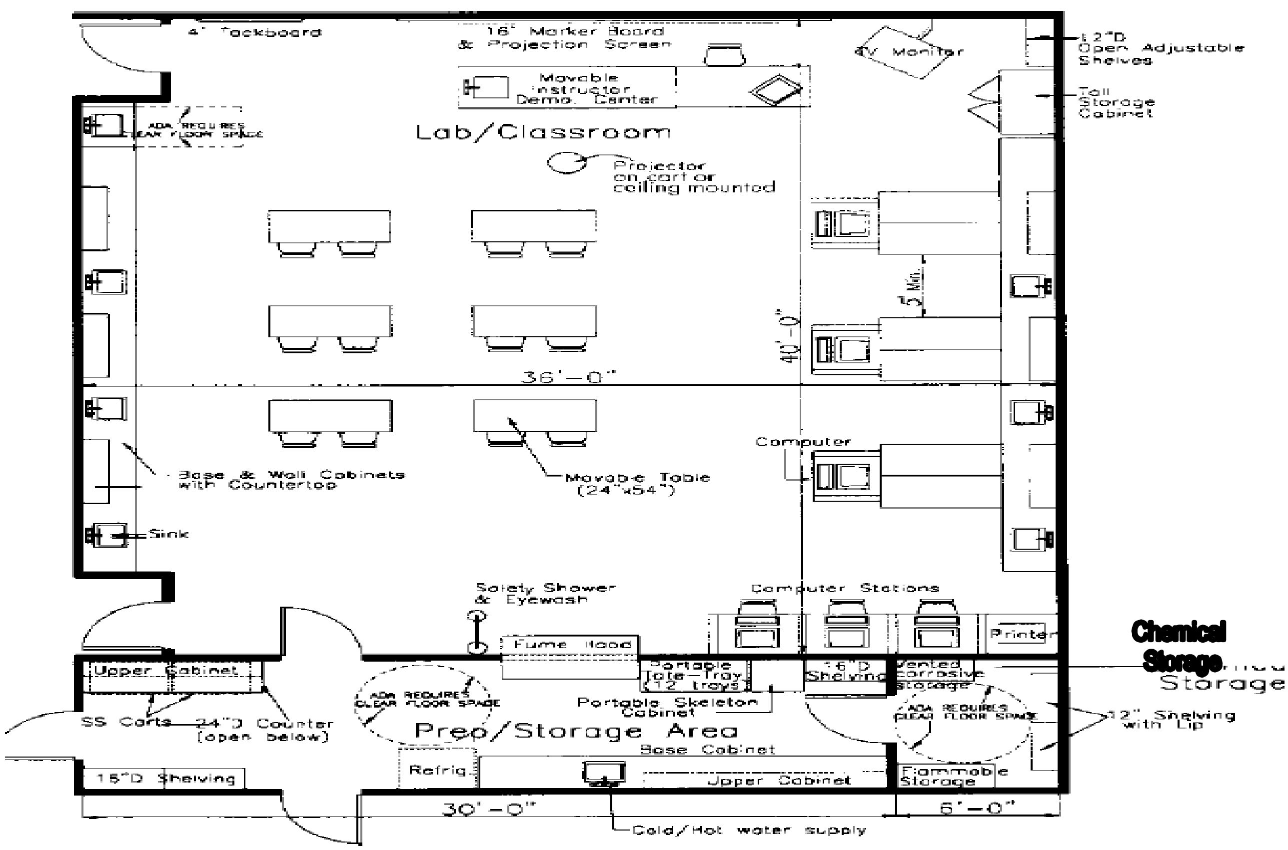


Figure 3 – Science Classroom / Laboratory / Prep Room Layout
Reprinted *from The Science Teacher, Science Facilities by Design,*

by Sandra S. West, Lamoine I. Motz and James T. Biehle.

The Fume Hood

A laboratory fume hood protects against inhalation exposure and keeps hazardous atmospheres, resulting from chemical preparations and demonstrations, from spreading to other areas.

There are several types of fume hoods including laboratory fume hoods, exhausted laminar flow hoods, and biological safety cabinets. The laboratory fume hood is the most common local exhaust ventilation system and is the one typically used in a school chemistry classroom/laboratory/prep room, and will be the only type of hood discussed in this section. When operated correctly, a laboratory fume hood can control gases, dusts, mists, and vapors released by hazardous chemicals.

For high school laboratories, where chemicals of low to moderate toxicity are used, at least one functioning portable or permanent exhaust hood that meets American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) 110 testing standards, should be used.

- The fume hood must provide a face velocity of approximately 80–120 linear feet per minute (24.4–36.6 meters/minute).
- A fume hood is not considered part of the room's ventilation. The exhaust from a chemical fume hood is separate, and comes under separate requirements than the room ventilation system. It should meet the American National Standards Institute (ANSI) Z9.5 Standard.
- Exhaust should be vented to the outside through the roof or outside wall. A common through-the-wall hood may serve the laboratory and preparation room.
- Exhaust hood(s) should be located at least 10 feet (3.1 meters) away from entrances and exits, windows, intake ducts, and high traffic areas.
- Do not store equipment under the hood unless it was designed for such use. Items in the hood will prevent proper airflow while it is in use, decreasing the efficiency of hood and creating a potential safety risk.

Check the fume hood and ductwork regularly to make sure it is operational. An annual test with a small smoke generator, or velometer, can ensure that the hood is venting properly.

You Have a Legal Responsibility to Provide a Safe Science Classroom and Laboratory

As a teacher you and your school have a responsibility to provide a safe learning environment. This task starts with the design and layout of your classroom, lab, and prep room. This design responsibility is not optional or based on convenience, but is a legal responsibility to your students. The following are excerpts from *The Science Teacher, Science Facilities by Design*, by Sandra S. West, Lamoine l. Motz, and James T. Biehle.

The Potential for Litigation

"The link between science facilities and the legal arena has a long and unfortunate history. In one Texas science classroom, students were working quietly when one student bumped the elbow of an adjacent student who was holding a compass, and the point penetrated the student's eyelid. The accident happened because students simply did not have sufficient "elbow room" to work safely. Because the science class was held in an existing science room, the only viable safety accommodation was to decrease the maximum class size for any one class assigned to that room. Although no litigation resulted from the accident, the potential for a court finding of negligence by the school was significant."

You must attain an assurance that you and the school are providing the safest and best classroom environments to the best of your ability. Lawsuits are a regular occurrence and many times are based on ignorance and negligence of the school and/or teacher. The following excerpts from *The Science Teacher, Science Facilities by Design* cite examples of negligence for which lawsuits have been brought:

Malfeasance, *or forcing employees or students to assume unnecessary risk, such as asking students to move chemicals from room to room or requiring teachers to work in unventilated spaces that violate federal, state, or local standards. Litigation focuses on working environments made unsafe by inadequate space, poor ventilation, insufficient supervision of students, a lack of personal protection equipment such as eyewashes and showers, or lack of separate and secure chemical storage.*

Nonfeasance*, or failure on the part of school authorities to do what should be done, such as provide adequate facilities or alter the curriculum when facilities are inadequate. In one case, a 14-year-old girl was badly burned while carrying alcohol to light burners in a classroom that was not equipped for laboratory work. The court found against the teacher for inappropriate supervision and against the principal for scheduling the science class in a room with improper and inappropriate facilities*

(Bush v. Oscoda Area Schools, 1981).

In another case, a Texas chemistry teacher was working alone after school preparing chemicals for the next day's class. She was seriously injured when she dropped a bottle of concentrated sulfuric acid, slipped in the acid, and fell backwards onto a large piece of glass. In addition to the acid burns, she suffered a long and deep cut in her back. She called for help and a colleague carried her to the nearest shower in the girl's gym. The lack of a safety shower in the chemistry laboratory was a clear violation of all safety recommendations. The court found that the school had not made a reasonable effort to provide a safe working environment for the science teacher or students (Lubbuck Avalanche Journal,1989).

School districts need to analyze and update science classrooms and laboratories on a regular basis. You can never design a science classroom and laboratory that is completely accident-proof, but you need to make a recognized concerted effort. The next section is designed to assist you and your school in recognizing deficiencies in your science classroom and laboratory, and tell you how to correct them. School districts, planners, and teachers should use and learn from this manual in concert with recommendations of associated recognized professionals and accepted standards.

Science Room Inventory Checklist

GENERAL LABORATORY LOCATION

- ❑ Room Number ______________________
- ❑ Phone Number ______________________
- ❑ Building Interior w/ windows
- ❑ Building Interior w/o windows
- ❑ Floor Location
- ❑ Separate Science Building

TYPE OF LABORATORY

- ❑ Biology
- ❑ Chemistry
- ❑ Physics / Physical Science
- ❑ Prep Room
- ❑ Other ______________________

SAFETY SUPPLY CHECKLIST

- ❑ Eyewash
- ❑ Safety Shower
- ❑ Safety Glasses / Goggles
- ❑ Lab Aprons
- ❑ Fire Blanket
- ❑ Fire Extinguisher
  Quantity ? ____________________
- ❑ First Aid Kit
- ❑ Safety Signage
  - ❑ Exits
  - ❑ NFPA
  - ❑ Other ____________________
- ❑ Safety Goggles Cabinet / Sanitizer
- ❑ Smoke / Heat Sensor
- ❑ Secondary Containment
- ❑ Spill Control Materials
- ❑ Waste Containers
- ❑ Other ______________________

GENERAL SERVICE HOOD

- ❑ Electric
- ❑ Gas
- ❑ Vacuum
- ❑ Water
- ❑ Other ______________________

FUME HOOD CHECKLIST

- ❑ Is there a fume hood in the lab?
- ❑ CFM* at Full Sash Raised Position
- ❑ CFM* at ½ Sash Raised Position
- ❑ CFM* at Full Sash Closed Position
- ❑ Airflow Sensor
- ❑ Other ______________________

  * *cubic feet per minute*

LAB SUPPLY CHECKLIST

- ❑ Autoclave
- ❑ Beakers , flasks, etc.
- ❑ Broken Glass Container
- ❑ Central Air Supply Cutoff
- ❑ Central Gas Cutoff
- ❑ Central Power Cutoff
- ❑ Central Vacuum Cutoff
- ❑ Central Water Cutoff
- ❑ Recycling Bin
  - ❑ Glass
  - ❑ Biohazard

CHEMICAL STORAGE

- ❑ Segregation
- ❑ What Method?
- ❑ Acid Storage Cabinet
- ❑ Chemicals Labeled
- ❑ Chemical Storage Shelf lips
- ❑ Corrosive Storage Cabinet
- ❑ Flammable Storage Cabinet
- ❑ Flammable Waste Container
- ❑ Gas Cylinder Support
- ❑ Storage Ventilation
- ❑ Explosion Safe Refrigerator
- ❑ Other ______________________

____
Inventory Taken By

____
Signature

____
Date

Ward's Science
Tel: (866) 260-0501

General Lab Layout Comments ____

____

____

General Lab Storage Comments ____

____

____

Condition of Lab ____

____

____

Casework ____

____

____

Countertops / Benchtops ____

____

____

Fixtures ____

____

____

Sinks and Traps ____

____

____

IX. Know Your Chemicals

To safely purchase, handle, store and use chemicals, a science teacher must know what the hazards are associated with the chemicals. Ward's Science cannot put too much emphasis on the importance of "knowing your chemicals". This manual provides the science teacher with the necessary information to gain the proper knowledge for safe use of chemicals. This knowledge should be obtained even before the chemicals are received and put to use. This section should be used in conjunction with information presented on the applicable chemical Safety Data Sheets (SDS's) in defining hazardous chemical properties. Chemical hazardous properties must be understood before many of the safety measures found within this handbook can be initiated. Detailed information on reading and understanding an SDS can be found in *Section IV - Where To Find Information on the Chemicals You Just Purchased.*

Ward's Science has included the following information, taken from the *"Chemical Safety for Teachers and Their Supervisors", American Chemical Society, 2001*, regarding chemical hazards.

Chemical Hazards

"The hazards presented by any chemical depend upon the properties of that chemical. Each chemical is different from all others because it has properties that are different. So, it follows that each chemical presents different hazards. But to use a chemical properly, first we must know the hazards of that chemical; second, we must know and apply the appropriate precautionary measures that will reduce the probability of harm from those hazards; and third, we must know and be prepared to carry out the necessary emergency measures (should our precautions fail) that will minimize the harm, just in case. It would seem that these requirements are formidable. How can I know that much about each of the many chemicals my students and I will use in the lab—to say nothing of teaching all this to the students? Fortunately, there is a practical answer: classification. Chemicals present only four classes of chemical hazards:

Flammability
Corrosivity
Toxicity
Reactivity

The following sections describe each of these hazards separately. Keep in mind that any single chemical may simultaneously present more than one hazard. A few chemicals also possess physical hazards, which are discussed later."

Flammability

The first chemical hazard to be discussed is flammability. Although one chemical may indeed be more flammable, say, than another[5], the precautions and emergency treatment depend principally upon flammability itself, not the degree of flammability.

A flammable chemical (obviously) will burn. Other terms that convey the same hazard potential information include "extremely flammable" and "combustible". Keep in mind that the vapors of flammables, if ignited when

5 The degree of flammability of liquids or solids is numerically expressed by "flash point" (also, and more accurately, called "lower flash point"). The smaller the flash point number (expressed in degrees Fahrenheit or Celsius) the greater the degree of flammability. For example, the flash point of unleaded 87 octane gasoline is –40 ºF, compared with the less flammable kerosene, which has a flash point of +63 ºF.

mixed with air in suitable proportions (ranging from 1% to more than 50% [by volume] in some cases) can explode. Flammable solids sublime; hence, their vapors are just as hazardous as the vapors from a flammable liquid. For example, glacial acetic acid (solid or liquid, depending on the temperature) is a flammable chemical as defined here. Keep in mind also that the vapors of most flammables are denser than air and can travel 10, 20, or 30 feet, or even further. The traveling vapors mix with air as they move. Consequently, a source of ignition can be several tens of feet away from the flammable liquid and still cause a fire or explosion by igniting the vapor trail that has traveled from the flammable liquid to the ignition source.

Precautionary measures include the enforced absence of ignition sources, such as lighted burners, hot plates, other hot surfaces (a lighted incandescent light bulb), and sources of sparks (electrical sparks, static charge sparks, and friction sparks). Keep containers closed when not actually in use. Ensure that the air movement in the laboratory is sufficient to keep the concentration of the flammable vapor in the air well below 1%. Minimize the quantities available—usually 100 mL is more than ample for lab use. If more is necessary, provide it in separate containers, 100 mL maximum in each container. Store flammables in an approved flammable liquid storage cabinet, preferably in safety cans. Use fabric, not plastic, tape to tape glass vessels (test tubes, flasks, beakers) beforehand if they are to contain flammable gases or vapors. Otherwise, when handled by students or used by teachers in demonstrations of an exploding gas or vapor, there can be flying glass shards from the ignition of the air–gas mixture. Even with the necessary taping, conduct such demonstrations only behind a sturdy shield that will confine flying fragments.

Corrosivity

A corrosive chemical either destroys living tissue or causes permanent change in such tissue through chemical action. (A chemical that corrodes iron, for example, wet salt [sodium chloride], is not corrosive under this definition—which pertains to chemical safety. Sulfuric acid will corrode iron but is also a corrosive in this safety context.) Corrosives can destroy both skin and tissues underneath the skin; corrosives destroy eyes, the respiratory system, and any other living tissue. Corrosive effects include impaired sight or permanent blindness, severe disfigurement, permanent severe breathing difficulties, even death.

Promptly flush splashes of corrosives off the skin with copious flowing water for at least 15 minutes. If splashed on clothing, the clothing must be removed while under a safety shower. Do not remove the clothing and then get under the shower. While under the shower, remove all clothing, including shoes, socks, wristwatch and strap, and other jewelry if they are splashed with corrosives (this is no time for modesty). Stay under the shower for at least 15 minutes while someone else calls a doctor. (It helps if the water is tepid, not cold.) Make certain in advance that the safety shower is working and that students know how to use it.

A splash of a corrosive chemical in the eye is a very serious matter. Get the victim to an eyewash fountain within 10 seconds. The eyewash fountain must be capable of delivering a gentle but copious flow of fresh water (preferably tepid) for at least 15 minutes to both eyes. (Most portable eyewash devices cannot meet this requirement.) Ensure in advance that safety showers and eyewash fountains are working and that students know how to use them.

While the victim is flushing the eyes for at least 15 minutes, someone else should call the doctor for further instructions. (The doctor's phone number should already be posted by the telephone.) The victim should hold both eyelids open with thumb and forefinger and roll the eyeballs up, down, left and right, continuously, so as to work the flushing water around to the back of the eyeball and wash any chemical away from the optic nerve. If the chemical destroys a portion of the optic nerve, permanent blindness ensues. If instead the chemical destroys a portion of the front of the eye, the prognosis may be less dire.

In all cases of contact with corrosives, take the victim to a physician for further evaluation and treatment.

Irritants are chemicals similar to corrosives except that they do not destroy tissue by chemical action. Irritants cause inflammation, itching, and so on. The effects are usually reversible but may or may not be severe or long lasting; victims should be referred to a physician.

Finally, some chemicals are sensitizers. The first exposure does not usually cause any notable symptoms. The second, or perhaps the third or fourth or more, exposure does cause symptoms because the victim has been sensitized by prior exposure(s). Poison ivy is an example of this kind of effect; some victims can be exposed several dozens of times before that next, and then often quite serious, exposure incident.

From the above discussion, it would seem that the use of corrosive chemicals in grades 7–12 should be severely limited or perhaps not used at all. Corrosive chemicals are potentially seriously harmful. There is no need for their use in pre-high school laboratory work. At that level, purchase and use diluted solutions of the strong acids and bases. Other corrosives such as elemental bromine are not needed at all.

On the other hand, high school students can use corrosives if the precautions described above are followed. After all, as adults in training, older students can profit from supervised instruction in matters that would be inappropriate for less mature students.

Toxicity

Broadly speaking, there are two different toxic effects, chronic and acute. A chronic toxic effect is noted only after repeated exposures or after a single, long exposure. Commonly known chronic toxic effects include cancer and reproductive malfunctions. Acute toxic effects occur promptly upon exposure, or within a short time—a few hours at most. Ingestion of methyl and ethyl alcohol are examples. Both exhibit the same acute toxic effect: inebriation. Ethyl alcohol exhibits a chronic effect: cirrhosis of the liver.

Methyl alcohol exhibits two additional acute toxic effects: blindness and death. To understand this, consider the "dose–response" phenomenon, a characteristic of all toxins, both acute and chronic: the greater the dose, the more severe the response to the toxin. Thus, *a very small* amount of methyl alcohol inebriates, a bit more causes blindness, yet a bit more is fatal. All toxic substances share this characteristic; exposure to a larger amount of the toxin is worse than exposure to a smaller amount; an exposure of longer duration has a greater toxic effect than exposure of a shorter duration.

One precautionary measure for toxins is now obvious: Minimize the exposure. Use the smallest amount of a toxin that is suitable for the purposes of an experiment. Minimize the time an experimenter will work with a toxin. Work with toxins only in a fume hood that is known to be operating properly.

In addition to minimizing the exposure by using the least amount necessary for the shortest possible period of time, precautionary measures for toxins include **barriers**, **cleanliness**, and **avoidance**. Thus, one avoidance precaution is, simply, good ventilation throughout the laboratory as well as the use of fume hoods. Wearing impervious gloves is an example of a barrier precaution.

Cleanliness includes good housekeeping practices, such as minimizing dust from solid toxins, mist from liquid toxins, prompt spill cleanup, and probably most important of all, **thorough washing** of hands and arms and scrubbing under fingernails as a habitual practice before leaving the laboratory.

Further precautions involve your awareness of the most likely symptoms of toxic overexposure: headache, nausea, and dizziness. Whenever you experience any of these three while you or someone else nearby is working with a toxic chemical, get to fresh air immediately and do not return until the symptom has disappeared. If on your return the symptom recurs, leave immediately and call a physician; it is likely that you have been overexposed.

However, the absence of these or other symptoms does not necessarily indicate no exposure. In advance, read the SDS's for the chemicals you and your students will be handling. Consult with a local physician in advance, advising him or her of the toxic chemicals used in the lab, and ensure that the physician will be prepared in advance to treat victims of toxic exposures.

For each toxic chemical, after reading the SDS:

1. Evaluate the toxic risk posed to your students in their use, with precautions, of the chemical;
2. Evaluate the educational benefit to be gained if the chemical is used, with precautions, by your students; and
3. Based on the balance between risks and benefit, decide whether or not to use the chemical.

If you decide to use a particular chemical, be sure that you know:

- whether or not, in case of ingestion, vomiting should or should not be induced,
- the symptoms of exposure to that chemical, and
- if applicable, the recommended procedure in case of unconsciousness.

Reactivity

Container labels do not always describe the fact that a chemical is self-reactive, for example, that it will spontaneously explode, or that if mechanically disturbed it could explode. Nor do labels always state that a chemical, if mixed with certain other chemicals, will react rapidly and release a large amount of energy. For reactivity information, refer to the SDS for a chemical; if applicable, that information should be described in the SDS.

Precautionary measures for self-reactive chemicals include, of course, not providing students with any such chemicals. These include picric acid, wet or dry (when dry—as it may become in students' use—picric acid can detonate when mechanically disturbed). Peroxide formers are similarly hazardous. They include metallic potassium, diethyl ether, and other ethers such as dioxane and tetrahy-drofuran; their peroxides are explosively unstable when mechanically disturbed.

The other reactive hazard is reactive incompatibility. Even dilute acid is reactively incompatible with dilute base. Other combinations include oxidizing agents and reducing agents—chlorates and powdered metal, to cite one example. There are other kinds of incompatible pairs. For this, the SDS is the usual information source.

Precautionary measures include providing reactively incompatible pairs to students only when that provision is deliberately determined by the teacher—and even then providing very small quantities, and only under direct supervision.

Physical Hazards

We come now to our last hazard category, physical hazards. Some physical hazards are associated with chemicals, some with objects, and some with people. A physical hazard that once was quite common among teachers of chemistry was their tendency to accept donations of chemicals from well-meaning donors. An example of a physical hazard that is associated with some chemicals is slipperiness. Concentrated sulfuric acid is very slippery. It is reported to be impossible to remain standing in the middle of a spill of this acid.

Radiation from radioactive species is a physical hazard. Dry ice can cause freeze burns and is another example of a chemical with a physical hazard. Various nonchemical physical hazards include loose clothing (sleeves, blouses, neck ties), loose long hair, bulky jewelry, horseplay, hot surfaces, and unattended but still-lit Bunsen burners. For all of these, the precautionary measures are obvious.

Incompatible Chemicals

Various chemicals will react dangerously when mixed with certain other materials. Some of the chemicals regularly used by science teachers, along with the chemicals that they are incompatible with, are listed below. This list should not be considered all-inclusive. The absence of a chemical from this list should not be taken to indicate that it is safe to mix with any other chemical! Understand and double-check your data before starting your demonstrations.

Chemical	Incompatible with
Acetic acid	Chromic acid, nitric acid, hydroxyl compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetic anhydride	Hydroxyl-containing compounds such as ethylene glycol, perchloric acid
Acetone	Concentrated nitric and sulfuric acid mixtures, hydrogen peroxide
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkali and alkaline earth metals, such as sodium, potassium, lithium, magnesium, calcium, powdered aluminum	Carbon dioxide, carbon tetrachloride, other chlorinated hydrocarbons (also prohibit the use of water, foam, and dry chemical extinguishers on fires)
Ammonia (anhydrous)	Mercury (in manometers, for example), chlorine, calcium hypochlorite, iodine, bromine, hydrogen fluoride
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulfur, finely divided organics, combustible
Aniline	Nitric acid, hydrogen peroxide
Arsenates and arsenites	Any reducing agents
Azides	Acids, heavy metals and their salts, oxidizing agents
Bromine	Ammonia, acetylene, butadiene, butane, other petroleum gases, sodium carbide, turpentine, benzene, finely divided metals
Calcium oxide	Water
Carbon (activated)	Calcium hypochlorite, other oxidants
Carbon tetrachloride	Sodium
Chlorates	Ammonium salts, acids, metal powders, sulfur, finely divided organics, combustibles
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, benzene, finely divided metals, turpentine
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulfide
Chromic acid and chromium trioxide	Acetic acid, naphthalene, camphor, glycerol, turpentine, alcohol, other flammable liquids
Copper	Acetylene, hydrogen peroxide
Cumene hydroperoxide	Acids (organic or inorganic)
Cyanides	Acids
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
Fluorine	Isolate from everything
Hydrides	Water
Hydrocarbons (benzene, butane, propane, gasoline, turpentine, etc.)	Fluorine, chlorine, bromine, chromic acid, peroxides
Hydrocyanic acid	Nitric acid, alkalis

Chemical	Incompatible with
Hydrofluoric acid (anhydrous); Hydrogen fluoride	Ammonia (aqueous or anhydrous)
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, any flammable liquid, combustible materials, aniline, nitromethane
Hydrogen sulfide	Fuming nitric acid, oxidizing gases
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous)
Nitrates	Acids, reducing agents
Nitric acid (concentrated)	Acetic acid, acetone, alcohol, aniline, chromic acid, hydrocyanic acid, hydrogen sulfide, flammable liquids, flammable gases, nitratable substances
Nitrites	Acids, oxidizing agents
Nitroparaffins	Inorganic bases, amines
Oxalic acid	Silver, mercury, and their salts
Oxygen	Oils, grease, hydrogen, flammable materials (liquids, solids, or gases)
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease, oils (all organics)
Peroxides, organic	Acids (organic or mineral); avoid friction, store cold
Phosphorus (white)	Air, oxygen, alkalis, reducing agents
Phosphorus pentoxide	Alcohol, strong bases, water
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium chlorate (see also chlorates)	Acids
Potassium perchlorate (see also perchloric acid)	Acids
Potassium permanganate	Glycerol, ethylene glycol, benzaldehyde, sulfuric acid
Selenides	Reducing agents
Silver and silver salts	Acetylene, oxalic acid, tartaric acid, ammonium compounds, fulminic acid (produced in nitric acid-ethanol mixtures)
Sodium (see also alkali metals)	Carbon tetrachloride, carbon dioxide, water
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium peroxide	Any oxidizable substance, such as ethanol, methanol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerol, ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulfides	Acids
Sulfuric acid	Chlorates, perchlorates, permanganates
Tellurides	Reducing agents

Excessive Risk Chemicals – Risk Exceeds Educational Utility

Chemical	Hazards
Acetic anhydride	Explosive potential, corrosive
Acetyl chloride	Corrosive, dangerous fire risk, reacts violently with water and alcohol
Acrylamide	Toxic by absorption, suspected carcinogen
Acrylonitrile	Flammable, poison
Adipoyl chloride	Corrosive; absorbs through skin, lachrymator
Aluminum chloride, anhydrous	Water reactive, corrosive
Ammonia, gas	Corrosive lachrymator
Ammonium bifluoride	Reacts with water, forms hydrofluoric acid
Ammonium bichromate	May explode on contact with organics, suspected carcinogen
Ammonium chromate	Oxidizer, poison; may explode when heated
Ammonium dichromate	Reactive, may cause fire and explosion
Ammonium perchlorate	Explosive; highly reactive
Ammonium sulfide	Poison, corrosive, reacts with water and acids
Aniline	Carcinogen, toxic, absorbs through skin
Aniline hydrochloride	Poison
Antimony oxide	Heath and contact hazard
Antimony powder	Flammable as dust, heath hazard
Antimony trichloride	Corrosive; emits hydrogen chloride gas if moistened
Arsenic compounds	Poison, carcinogen
Asbestos, friable	Inhalation health hazard, carcinogen
Azide compounds	Explosive in contact with metals, extremely reactive, highly toxic
Barium chromate	Poison
Benzene	Flammable, carcinogen
Benzoyl peroxide	Organic peroxide, flammable, oxidizer
Beryllium and its compounds	Poison, Dust is P-Listed & highly toxic, carcinogen
Bromine	Corrosive, oxidizer, volatile liquid
Cadmium compounds	Toxic heavy metal, carcinogen
Calcium fluoride (fluorspar)	Teratogen, emits toxic fumes when heated
Carbon disulfide	Flammable, toxic, P-listed, extremely hazardous
Carbon tetrachloride	Toxic, carcinogen
Chloral hydrate	Hypnotic drug, controlled substance
Chlorine	Poison gas, corrosive
Chlorobenzene	Explosive limits 1.8% to 9.6%, toxic inhalation and contact hazard
Chloroform	Carcinogen; if old, forms deadly phosgene gas
Chlorosulfonic acid	Toxic, aka sulfuric chlorohydrins
Chromic acid	Strong oxidizer, poison
Collodion	Flammable, explosive when dry; nitrocellulose compound
Cuprous cyanide	Toxic
Cyanogen bromide	Poison, strong irritant to skin and eyes
Cyclohexene	Flammable, peroxide former
Dichlorobenzene	Toxic
Dichloroethane	Flammable, toxic
Dinitro phenol	Explosive, "Bomb Squad"
Ethyleneimine	Flammable; toxic; P-listed
Ferrous sulfide	Spontaneously ignites with air if wet
Formaldehyde (formalin)	Toxic, carcinogen, sensitizer
Gunpowder	Explosive
Hydrazine	Flammable; absorbs through skin; carcinogen, corrosive

Chemical	Hazards
Hydriodic acid	Corrosive, toxic
Hydrobromic acid	Corrosive, poison
Hydrofluoric acid	Corrosive, poisonous
Hydrogen	Flammable
Hydrogen sulfide, gas	Poison; stench
Immersion oil (old)	May contain 10-30% PCBs such as arochlor 1260
Isopropyl ether	Flammable, highest risk peroxide former
Lithium aluminum hydride	Flammable; reacts with air, water and organics
Lithium metal	Reacts with water, nitrogen in air
Mercaptoethanol	Flammable; corrosive; intense stench
Mercury compounds	Poisonous heavy metal
Mercury, liquid	Toxic heavy metal; carcinogen
Methylene chloride	Toxic, carcinogen, narcotic
Methyl ethyl ketone	Flammable, dangerous fire risk, toxic
Methyl iodide (Iodomethane)	May be a narcotic; carcinogen; lachrymator
Methyl isocyanate	Flammable, dangerous fire risk, toxic
Methyl isopropyl ketone	Toxic
Methyl methacrylate	Flammable; vapor causes explosive mix with air
Naphthylamine, a-	Combustible, toxic; carcinogen
Nickel oxide	Flammable as dust; toxic, carcinogen
Nicotine	Poison, P-listed; extremely hazardous
Nitrilotriacetic acid	Corrosive
Nitrobenzene	Highly toxic
Nitrocellulose	Flammable, explosive; call ETSI
Nitrogen triiodide	Explosive; “Bomb Squad”
Nitroglycerin	Explosive; “Bomb Squad”
Osmium tetraoxide (osmic acid)	Highly toxic; P-listed; Extremely hazardous
Pentachlorophenol	Extremely toxic
Perchloric acid	Powerful oxidizer, reactive
Phosphorus pentasulfide	Water reactive; toxic; incompatible with air and moisture
Phosphorus pentoxide	Oxidizer, toxic
Phosphorus, red	Flammable solid
Phosphorus, yellow or white	Air reactive, poison
Picric Acid, trinitrophenol	Explosive when dry
Potassium cyanide	Poison, P-listed; extremely hazardous
Potassium perchlorate	Powerful oxidizer; reactively hazard
Potassium sulfide	Flammable; May ignite spontaneously
Potassium, metal	Water reactive; peroxide former (orange fog/crystals)
Pyridine	Flammable, toxic; Vapor forms explosive mix with air
Selenium	Toxic
Silver oxide	Poison
Silver cyanide	Extremely toxic
Sodium metal lump	Water reactive; ignites spontaneously in dry hot air, corrosive
Sodium arsenate	Toxic; carcinogen
Sodium arsenite	Toxic; carcinogen
Sodium azide	Poison; explosive reaction with metals. P-Listed; extremely hazardous
Sodium borohydide	Flammable solid; water reactive
Sodium cyanide	Poison; P-Listed; Extremely hazardous
Sodium fluoride (bifluoride)	Highly toxic by ingestion or inhalation; strong skin irritation
Sodium fluoroacetate	Tox-X Deadly poison

Chemical	Hazards
Sodium peroxide	Water reactive; may cause fire and explosion
Strontium	Flammable. Store under naphtha; reacts with water
Testosterone HCl	Controlled substance
Tetrahydrofuran	Flammable, peroxide former
Thioacetamide	Toxic; carcinogen; combustible
Thionyl chloride	Corrosive
Thiourea	Carcinogen
Titanium trichloride	Flammable; fire risk
Triethylamine	Flammable; toxic; irritant
Trinitrobenzene	Explosive; "Bomb Squad"
Trinitrophenol	Explosive; "Bomb Squad"
Trinitrotoluene	Explosive; "Bomb Squad"
Uranium/Uranyl compounds	Radioactive

High Risk Chemicals – Only Allow Very Limited Amounts in Storage

Only Appropriate for Advanced-Level High-School Science Classes

Chemical	Hazards
Acetamide	Carcinogen; P-Listed, Extremely Hazardous
Ammonium nitrate	Powerful oxidizer, reactive
Barium peroxide	Fire and explosion risk with organic materials, oxidizer, toxic
Butyric acid	Corrosive; intensive stench
Cadmium sulfide	Highly toxic; carcinogen
Calcium carbide	Flammable; reactive with water
Chromium trioxide	Oxidizer, poison
Ethidium bromide	Potent mutagen
Hexamethylenediamine	Corrosive; absorbs through skin, lachrymator
Hexanediamine, 1-6	Corrosive; absorbs through skin, lachrymator
Hydrogen peroxide, >29%	Powerful oxidizer, corrosive to skin
Lead compounds	Highly toxic
Lead nitrate	Toxic heavy metal; oxidizer
Magnesium, power	Flammable
Mercury thermometers	Toxic heavy metal; corrosive
Phenol	Poison
Potassium chlroate	Powerful oxidizer, reactive
Potassium chromate	Oxidizer; toxic
Potassium dichromate	Powerful oxidizer, carcinogen
Radioactive materials	Radioactive
Sebacoyl chloride	Corrosive fumes; lachrymator
Silver compounds	Toxic
Sodium chlorate	Powerful oxidizer
Sodium chromate	Oxidizer
Sodium dichromate	Reactive; may cause fire or explosion
Sodium, metal, small chips	Water reactive; corrosive
Strontium nitrate	Oxidizer; may explode when heated or shocked
Thermite	Flammable solid
Toluene	Flammable, dangerous fire risk, toxic
Wood's Metal	Poison
Xylene	Flammable, toxic

X. Preparing and Handling Chemicals for Use

Personal Protective Equipment

The Occupational Safety and Health Administration (OSHA) and Health Canada require that in setting up safety and health applications in the laboratory and classroom, whenever feasible engineering controls such as erecting splashguards and installing mechanical ventilation should be used. In addition, sound application practices should be employed to protect the laboratory personnel from exposure to hazardous chemicals. Often, however, these practices do not provide the full protection required to protect individuals from the potential hazards in a laboratory and classroom. Therefore, additional protection must be provided in the form of personal protection. This Personal Protective Equipment or PPE must be defined and used to protect against possible contact with hazardous chemicals. Depending upon the associated hazards, PPE will need to be selected to protect the body parts that could be harmed by the exposure from spills, splashes, chemical reactions, etc.

In selecting PPE, all wearers of PPE must be properly trained in the purpose, limitations, correct use and care of the PPE before being worn, as regulated by OSHA and Health Canada.

Per these regulations:

- Protective equipment must be provided by the school, used and maintained in sanitary and reliable condition, as necessary to protect the wearer from hazards, and;
- All personal protective equipment shall be of safe design and construction for the work to be performed.

In this section, Ward's Science will help define when, where and what personal protective equipment should be used. To protect an individual in the laboratory from direct exposure to hazardous chemicals and to minimize any potential harm done from contact, a variety of PPE is available and should be worn when required.

How to Choose the Correct Personal Protective Equipment

Personal Protective Equipment must be selected based on the protection it provides against specific chemicals or classes of chemicals when used under certain conditions. Keep in mind that no one type of PPE provides protection from all chemicals or all concentrations of chemicals.

Ward's Science provides a Safety Data Sheet (SDS) for every chemical we sell. Based on the information contained within the SDS, work environment and the specific application of the chemical, PPE can be selected. See *Section IV* for detailed information on SDS's.

In addition to the information on the SDS, other factors must be accounted for. These include: concentration of the chemical to which the individual(s) may be exposed, the length of exposure, temperature of the chemical, worker comfort, and proximity to the chemical. Analyze the experiments, demonstrations and exposures presented in the laboratory and classroom and select appropriately.

Eye Protection

Safety Glasses

The most common need for personal protective equipment in the laboratory and classroom is for eye protection. Safety glasses are provided for use in laboratories and must be worn at all times in all laboratories where chemicals are being used. Safety glasses should be required by all persons who enter a chemical work area or storage, even if the individual is not directly handling or using chemicals.

Safety glasses can look very much like normal glasses but have lenses that are impact resistant and frames that are far stronger than standard glasses. In the science room, environment safety glasses must have side shields and should be worn whenever there is the possibility of objects (such as chemicals substances, particles and glass) striking the eye. Safety glasses must have an American National Standards Institute (ANSI) Z87 designation on the eyewear to be compliant and provide the adequate protection. Safety glasses come in a variety of styles to provide the best fit and comfort, including some designed to fit over prescription glasses.

Safety glasses will not provide adequate protection from significant chemical splashes. They do not seal to the face, resulting in gaps at the top, bottom and sides, where chemicals may seep through. Safety glasses are also not appropriate for dusts and powders, which can get by the glasses. Safety goggles are best used for this type of potential exposure.

Chemical Splash Goggles

Goggles that seal to the face provide much more eye protection than safety glasses against contact with solid and liquid chemicals. Chemical splash goggles should be worn when there is potential for splash from a hazardous material. Like safety glasses, goggles are impact resistant. Chemical splash goggles should have indirect ventilation so hazardous substances cannot drain into the eye area. They can also be worn over prescription glasses. As with safety glasses, goggles must have an American National Standards Institute (ANSI) Z87 designation on the eyewear to be compliant and provide the adequate protection.

Face Shields

Face shields should be used when using or handling large volumes of hazardous materials, when handling hot materials or strong corrosives, toxics that can be absorbed through the eyes or skin, and reactives when carrying out reactions under a vacuum. Face shields must always be used in conjunction with safety glasses or goggles.

Hand Protection

Teachers and students who handle chemicals that are hazardous and/or may come in contact with the skin must wear appropriate gloves that will prevent contact of the hands with the chemicals.

Gloves should resist penetration and permeation by the chemicals being used. *Figure 1 – Gloves Chemical Resistance Chart* is provided as a brief reference regarding glove selection. This color-coded chart makes determining which glove material is best suited for the chemicals you are working with easy to recognize.

- Green – excellent. Material in question is the best option. Some chemicals may have more than one material rated as “excellent”.
- Yellow – good. Material in question will withstand chemical, although prolonged exposure may not be recommended. There may or may not be a better material option.
- White – acceptable. Material in question can be used safely with chemical, although prolonged exposure may not be recommended. There may or may not be a better material option.
- Red – not recommended. Material in question is not compatible with chemical and should be avoided when using that chemical. There will be a safer alternative listed.

This chart should be used as a starting point but cannot account for all possible conditions. Contact your Ward's Science representative for final selection.

	Glove Material		
Chemical	**Latex**	**Neoprene**	**Nitrile**
2,3-dichloro-1-propene	not recommended	not recommended	Acceptable
Acetelaldehyde	excellent	excellent	Acceptable
Acetic acid 50%	excellent	excellent	Excellent
Acetic acid, glacial	excellent	excellent	Good
Acetone	excellent	good	not recommended
Alcoholic beverages	excellent	excellent	Excellent
Ammonia conc.	excellent	excellent	Excellent
Ammonium acetate	excellent	excellent	Excellent
Ammonium carbonate	excellent	excellent	Excellent
Ammonium chloride	excellent	excellent	Excellent
Ammonium nitrate	excellent	excellent	Excellent
Amyl acetate	not recommended	acceptable	Acceptable
Amyl alcohol	excellent	excellent	Excellent
Aniline	good	good	Acceptable
Animal greases	acceptable	excellent	Excellent
Asphalt	not recommended	acceptable	Excellent
Bacon fat	not recommended	excellent	Excellent
Beets	excellent	excellent	Excellent
Benzaldehyde	not recommended	not recommended	Acceptable
Benzene	not recommended	not recommended	Acceptable
Benzyl alcohol	acceptable	good	Good
Birds	acceptable	excellent	Excellent
Bleach	excellent	excellent	Excellent
Borax	excellent	excellent	Excellent
Boric acid conc	excellent	excellent	Excellent
Brake oils	good	excellent	Excellent
Bromides	good	good	Good
Butanol	excellent	excellent	Excellent
Butter	not recommended	excellent	Excellent
Butyl acetate	not recommended	acceptable	Acceptable
Calcium acetate	excellent	excellent	excellent
Calcium chloride	excellent	excellent	Excellent
Calcium fluorophosphate	excellent	excellent	Excellent
Calcium hydroxide	excellent	excellent	Excellent

Chemical	Latex	Neoprene	Nitrile
Calcium hypochloride	excellent	excellent	Excellent
Calcium nitrate	excellent	excellent	Excellent
Calcium phosphate	excellent	excellent	Excellent
Carbon tetrachloride	not recommended	acceptable	Good
Castor oil	not recommended	excellent	Excellent
Chlorine	not recommended	excellent	Excellent
Chloroacetone	excellent	excellent	not recommended
Chlorobenzene	not recommended	acceptable	Acceptable
Chloroform	not recommended	acceptable	Good
Chromic acid	not recommended	not recommended	Acceptable
Citric acid	excellent	excellent	Excellent
Creosote	acceptable	excellent	Excellent
Cresol	not recommended	excellent	Excellent
Cutting oil	not recommended	excellent	Excellent
Cyclohexane	not recommended	acceptable	Good
Cyclohexanol	excellent	excellent	Excellent
Cyclohexanone	good	good	not recommended
di-Butyl ether	not recommended	acceptable	Excellent
di-Butyl phlalate	good	acceptable	Excellent
Dichloroethane	not recommended	not recommended	Acceptable
Diesel	not recommended	acceptable	Excellent
Diethanolamine	excellent	excellent	Excellent
Dioctyl phlalate	good	excellent	Excellent
Domestic detergents	excellent	excellent	Good
Ethanol	excellent	excellent	Excellent
Ethanolamine	excellent	excellent	Excellent
Ethyl acetate	not recommended	acceptable	Acceptable
Ethylamine	acceptable	acceptable	Excellent
Ethylaniline	acceptable	excellent	Excellent
Ethylene glycol	excellent	excellent	excellent
Fish and shellfish	acceptable	excellent	Excellent
Fixers	excellent	excellent	Excellent
Fluorides	excellent	excellent	Excellent
Formaldehyde up to 30%	excellent	excellent	Excellent

Chemical	Latex	Neoprene	Nitrile
Formic acid methyl ester	acceptable	excellent	Acceptable
Formic acid up to 90%	not recommended	good	Excellent
Formol (or Formaldehyde)	excellent	excellent	Excellent
Fuel oil	not recommended	acceptable	Excellent
Fuels	not recommended	acceptable	not recommended
Furol (furfural or furaldehyde)	excellent	good	Acceptable
Gas oil	not recommended	acceptable	Excellent
Glyercine	excellent	excellent	Excellent
Glycols	excellent	excellent	Excellent
Groundnut oil	not recommended	excellent	Excellent
Hair bleach products	excellent	excellent	Excellent
Hair dye	excellent	excellent	Excellent
Hexanes	not recommended	acceptable	Excellent
Hydroxy-4-methyl-4-pentanone-2	excellent	excellent	not recommended
Hydraulic fluids (esters)	excellent	excellent	Excellent
Hydraulic oils (petroleum)	not recommended	acceptable	Excellent
Hydrochloric acid up to 30%	excellent	excellent	Excellent
Hydrofluoric acid up to 30%	good	excellent	Excellent
Hydrogen bromide	excellent	acceptable	Acceptable
Hydrogen peroxide solution	acceptable	excellent	Excellent
Isobutanol	excellent	excellent	Excellent
Isobutyl ketone	excellent	excellent	Excellent
Kerosene	not recommended	excellent	Acceptable
Lactic acid up to 85%	acceptable	excellent	Excellent
Linseed oil	not recommended	excellent	Excellent
Lubricating oils	not recommended	acceptable	Excellent
Magnesia (MgO)	excellent	excellent	Excellent
Manure	excellent	excellent	excellent
Methanol	excellent	excellent	Excellent
Methyl acetate	acceptable	excellent	Acceptable
Methyl ethyl ketone	excellent	good	not recommended
Methyl isobutyl ketone	good	acceptable	not recommended
Methylamine	excellent	good	Excellent
Methylaniline	acceptable	good	Excellent

Chemical	Latex	Neoprene	Nitrile
Methcyclopentane	not recommended	acceptable	Excellent
Methylene chloride	not recommended	acceptable	Acceptable
Milk and milk products	acceptable	excellent	Excellent
Mineral greases	not recommended	acceptable	Excellent
Naphtha	not recommended	acceptable	Excellent
Naphthalene	not recommended	acceptable	Good
n-Butylamine	excellent	excellent	Excellent
Nickel chlorine	excellent	excellent	Excellent
Nitric acid up to 20%	good	good	Acceptable
Nitrobenzene	acceptable	acceptable	Acceptable
Nitrohydrochloric acid	acceptable	good	Acceptable
Nitropropane	excellent	good	Acceptable
Non-alcoholic beverages	excellent	excellent	Excellent
Octanol	acceptable	excellent	Excellent
Oil-based paint	not recommended	acceptable	Excellent
Oils for turbines	not recommended	acceptable	Excellent
Oleic acid	acceptable	excellent	Excellent
Olive oil	not recommended	excellent	Excellent
Oxalic acid	excellent	excellent	Excellent
Paraffin oil	not recommended	acceptable	Excellent
Perchloroethylene	not recommended	acceptable	Good
Perfumes and essences	excellent	excellent	Good
Petrol (for cars)	not recommended	good	Excellent
Petroleum products	not recommended	acceptable	Good
Petroleum spirits	not recommended	good	Excellent
Phenol	acceptable	good	Good
Phosphoric acid	excellent	excellent	excellent
Pine oil	not recommended	acceptable	Excellent
Polyester resins	not recommended	acceptable	Good
Potash conc	excellent	excellent	Excellent
Potash pellets	excellent	excellent	Excellent
Potassium acetate	excellent	excellent	Excellent
Potassium carbonate	excellent	excellent	Excellent
Potassium chloride	excellent	excellent	Excellent

Chemical	Latex	Neoprene	Nitrile
Potassium cyanide	excellent	excellent	Excellent
Potassium dichromate	acceptable	excellent	Excellent
Potassium nitrate	excellent	excellent	Excellent
Potassium permanganate	excellent	excellent	Excellent
Potassium phosphate	excellent	excellent	Excellent
Potassium sulfate	excellent	excellent	Excellent
Powder detergent	excellent	excellent	Excellent
Products for setting hair	excellent	excellent	Excellent
Quick lime	excellent	excellent	Excellent
Salicylic acid methyl ester	excellent	excellent	Excellent
Shampoos	excellent	excellent	Excellent
Shuttle oil	not recommended	acceptable	Acceptable
Silicates	excellent	excellent	Excellent
Slaked lime	excellent	excellent	Excellent
Sodium bisulfite	excellent	excellent	Acceptable
Sodium carbonate	excellent	excellent	Acceptable
Sodium chloride	excellent	excellent	Excellent
Sodium hypochloride	excellent	excellent	Excellent
Sodium nitrate	excellent	excellent	Excellent
Sodium phosphate	excellent	excellent	Excellent
Sodium sulfate	excellent	excellent	Excellent
Soya oil	not recommended	excellent	Excellent
Stearic acid	good	excellent	Good
Styrene	not recommended	acceptable	Acceptable
Sulfites, bisulfites, hyposulfites	excellent	excellent	Excellent
Sulfuric acid conc	not recommended	acceptable	not recommended
Sulfuric acid diluted (battery)	excellent	excellent	Excellent
Sulfuric ether (pharmacy)	acceptable	excellent	Excellent
Tartaric acid	excellent	excellent	Excellent
Turpentine	not recommended	acceptable	Excellent
Tetrahydrofuran (THF)	good	acceptable	not recommended
Tin chloride	acceptable	excellent	Excellent
Toluene	acceptable	acceptable	Good
Tributyl phosphate	acceptable	good	Good
Trichloroethylene	not recommended	acceptable	Acceptable
Tricresyl phosphate	excellent	good	Excellent
Triethanolamine up to 85%	excellent	excellent	Excellent
Trinitrobenzene	not recommended	acceptable	Good

Chemical	Latex	Neoprene	Nitrile
Trinitrotoluene	not recommended	acceptable	Good
Triphenyl phosphate	acceptable	excellent	Excellent
Vinegar and condiments	excellent	excellent	Excellent
Water paints	excellent	excellent	Excellent
Weed killer	excellent	good	not recommended
White spirit	not recommended	good	Excellent
Xylene	not recommended	acceptable	Good
Xylophene	not recommended	acceptable	Excellent
Zinc sulfate	excellent	excellent	Excellent

Foot Protection

Covered shoes that fully encase the foot should be worn at all times in the laboratories and where chemicals are stored or used. Perforated shoes, sandals or cloth sneakers should never be worn in laboratories or where mechanical work is conducted. Keep in mind that leather shoes tend to absorb chemicals and may have to be discarded if contaminated with a hazardous material. Chemical resistant overshoes or boots may be used to avoid possible exposure to corrosive chemical or large quantities of solvents or water that might penetrate normal footwear (e.g., during spill cleanup).

Protective Clothing

When the possibility of chemical contamination exists, protective clothing that resists physical and chemical hazards should be worn over street clothes. Lab coats are appropriate for minor chemical splashes and spills, while plastic or rubber aprons are best for protection from corrosive or irritating liquids. When working with chemicals that are highly corrosive, highly toxic or could cause thermal burns, arm guards or gloves with extra long wrists should be worn to protect the forearms from chemical contact. Close and tie the open end of the glove off or tuck it into the individual's sleeves to prevent contact with the chemical.

When highly corrosive chemicals are used, individual should wear chemically resistant aprons and coats to prevent contact with the body. If an accident does occur, these garments are not designed for long-term protection and should be removed immediately and properly disposed of as hazardous waste if contaminated. If a garment is designed to be reusable, it must be decontaminated following the accepted measures as defined by the appropriate SDS or manufacturer. Disposable outer garments, similar to a Tyvek suit, should be used when cleaning or when decontamination of reusable protective clothing is difficult.

Protective clothing and lab coats should be regarded not as means of preventing exposure, but as means of lessening or delaying exposure. The effectiveness of clothing as a protective barrier for the skin depends upon its prompt removal in the event that it becomes contaminated.

Respirators

The implementation of appropriate engineering and procedural controls should always be the preferred method for ensuring that any airborne levels of chemicals within the laboratory are below regulatory limits. However, in rare circumstances where these controls measures are not sufficient, laboratory personnel may need to utilize respirators for a particular operation. If this is the case, personnel must participate fully in a respiratory protection program, which requires a medical exam, respirator fit-testing, and training prior to respirator use and as defined by OSHA and Health Canada. Respirators in the school science environment should only be available for emergency purposes and only if personnel are trained in how to use them. Typically any chemical usage by the science teacher for student demonstrations that require respirator use should not be completed and will not be addressed in this handbook.

Internal Transportation of Chemicals

Spills and chemical exposure can occur if chemicals are transported incorrectly, even when moving chemicals from one part of the laboratory to another. To avoid this type of incident, consider the following:

- Use a bottle carrier, cart or other secondary container when transporting chemicals in breakable containers.
- When moving in the laboratory, anticipate sudden backing up or changes in direction by others. If you should stumble while carrying glassware or chemicals, try to propel them away from yourself and others.
- When transporting compressed gas cylinders, the cylinder should always be strapped in a cylinder cart and the valve protected with a cover cap. Do not attempt to carry or roll cylinders from one area to another.

Glassware Use

The following procedures must be adopted when using glassware:

- Containers should be labeled before substances are put in them.
- When moving chemicals, care must be taken to prevent breakage and spillage.
- When you are finished using glassware, all glassware must be cleaned, dried and put away, before the end of the day if possible.
- Chipped or cracked items should be properly discarded. Hand protection should be used when picking up broken glass.
- Hand protection should also be used when inserting glass tubing into rubber stoppers or placing plastic rubber tubing on glass hose connections.
- Tubing should be fire polished or rounded and lubricated.
- With any graduated cylinders, avoid parallax errors by taking level readings at the level of the meniscus (curved surface of the liquid). Whether the meniscus curves upward (as in H_2O) or downward (as in Hg), the reading should be taken from the point of the curve on the central axis of the cylinder.

Burettes

Burettes are useful where an accurate volume of liquid must be delivered. Burettes are stamped TD for "to deliver". As with other glassware, rinse the inside at least once with the solutions with which you will be working. Drops of liquid clinging to the inside indicate that the burette is not clean. Liquids should always be dispensed using proper hand positions and never by mouth. This is necessary not only to protect the individual from mouth contamination, but also to deliver the proper amount of liquid and to ensure support of the stopcock.

Erlenmeyer Flasks

The shape of the Erlenmeyer flask is designed to facilitate swirling or mixing of reactants. The Erlenmeyer flask is not a piece of precision glassware, as a 250 mL flask typically holds 270 mL or so. Do not make volume measurements with an Erlenmeyer flask unless you only need an approximate amount.

Glass Stirring Rods

A glass stirring rod is a useful tool to mix reactants. It is also placed in liquids that are being boiled to stir and helps to spread the heat evenly. The stirring rod also facilitates the transfer of a liquid being poured into a cylinder or other device, as it provides a path for the liquid to follow.

Pipettes

Whether they are equipped with a bulb or a pump, graduated pipettes are used to accurately transfer a small volume of liquid. As with a burette, a pipette is marked TD for "To Deliver". As with all laboratory glassware, the same cautions apply for avoiding parallax. Before making an accurate transfer, the user should pump the desired liquid into the pipette, roll the pipette horizontally to coat the entire interior surface, and then allow the liquid to drain through the tip. When attempting an accurate delivery of liquid, wipe off the tip of the pipette with an appropriate material before releasing the liquid. After transferring the liquid, remove any hanging drops by touching the tip of the pipette against the container.

Volumetric Flasks

Volumetric flasks are used to prepare solutions of exact concentrations. Their volume must be precisely known. Therefore volumetric flasks should never be heated, and solutions with a high heat of solution should not be prepared directly in them. The purpose of a volumetric flask is usually stamped directly on its neck with the letters TC for "to contain". Generally, the procedure for preparing a solution in a volumetric flask is to first rinse the inside of the flask with the solvent, then transfer a small amount of solvent followed by the required amount of solute, and swirl. The flask is then further filled with solvent to just below the mark etched in the glass. The last few drops are added with a medicine dropper or pipette for added accuracy. To mix, the stopper and the base should be supported and the flask should be inverted about ten times to ensure homogeneity.

Summary

There are many different pieces of laboratory equipment. Each has its own procedure to safely complete the assigned task. The aforementioned items were but a few of these. Regardless of whether a specific task or laboratory device was addressed in this section and/or within this handbook, the intent of every laboratory procedures is to handle, maintain control and complete the chemistry procedure in as safe a manner as possible.

XI. Solutions – How To Make Them and Shake Them

This chapter is excerpted from the book *Shake It - Make It* by Mike McMillan. The complete book has much more detail, and includes a 40-page unit on solutions, both theory and practice. **Safety note: Making solutions can be hazardous if appropriate precautions are not taken.**

General precautions include:

- Always use eye protection. The recommended eyewear is a pair of chemical splash goggles with full-face coverage, which comply with the ANSI-Z87.1 specifications.

- A pair of appropriate gloves is recommended. This handbook includes a glove selection guide.

- Some solutions should be prepared under a fume hood, which has been tested for appropriate face velocity.

- A volumetric flask is calibrated to contain at 25 °C. When making a solution, the final concentration is attained by adding distilled water until the bottom of the meniscus is at the fill line of the flask. If the initial solution was prepared in warm water, the solution must be allowed to cool before doing the final volume adjustment.

- When diluting a solution, always add the more concentrated solution to distilled water. In some cases a cooling water bath may be required.

- Always prepare a solution by first measuring 40-50% of the solvent into the bottle or flask that will hold the final product. Add the solute slowly, stirring if necessary. Once all the solute has been added and has dissolved, dilute the solution to final volume and mix well.

- If a magnetic stirrer is used to mix the solution, do not fill the volumetric flask to the fill line until the magnetic stir bar has been removed from the flask. A better procedure is to mix 400-500 milliliter (mL) of solution in beaker, transfer the beaker contents to a volumetric flask, rinse the beaker thoroughly with distilled water (add the rinse water to the volumetric flask), and then fill the volumetric flask to the mark.

Solution Definitions

Accounting for solutes with a specified purity

Sometimes a solute has an assay of less than 100% and an exact concentration is desired. If, for example, the solute has a formula weight of 120 and a purity of 85%, the amount of solute for a 0.1 M solution would normally be 12.0g. To account for the purity, divide the solute amount by the purity. 12.0g/0.85=14.12g required.

<u>[Actual Amount of Solute Required] = [Original Amount of Solute]/[Purity(%)/100]</u>

Molarity (M) - Molarity is the number of moles of the solute in a fixed volume of solution. A 1 M solution of sodium chloride is made by dissolving 58.44g of NaCl in 1L of distilled water. Smaller volumes require proportionately smaller amounts of the solute and solvent. A 0.5 M solution of NaCl in 1L would require 29.72g of NaCl.

Normality (N) - The number of equivalents of the ion desired in 1L of solvent. In acid-base chemistry, the equivalent is defined as the mass of solute that accepts or donates 1 mole of protons. Phosphoric acid is a triprotic acid, and each mole can donate 3 equivalents (3 moles of protons). A 1 M solution of phosphoric acid is also a 3N solution. Hydrochloric acid is a monoprotic acid, so the molarity and normality of hydrochloric acid are the same. If redox chemistry is being used, a 1N solution is one that accepts or donates 1 mole of electrons. Copper $^{(+2)}$ donates 2 electrons as a part of the reduction of the ion to copper metal. A 1 M Cu $^{(2+)}$ solution is also a 2N solution. The molarity and normality of a Copper$^{(+1)}$ solution are equal.

Percent (%) - When a solid is dissolved in a liquid on a weight/volume basis, this is a solution whose concentration is expressed as *x* %. Ten grams (10 g) of sodium chloride dissolved in 1L of water is a 1% weight-to-volume solution. Volume-to-volume solutions (a solution composed of two liquids with both the components measured on a volume basis) are also possible. Percent solutions are most used for biological stains, for pH indicators, and for special purposes.

Serial Dilutions - Dilute solutions are prepared most exactly using this technique. If a 0.001 M HCl solution is desired, it can be prepared by measuring 0.8 mL of concentrated acid and diluting to 1 L. The potential error of measurement in the 0.8 mL is fairly high. To minimize errors of measurement, a serial dilution is done. The usual method is to prepare a 0.1 M or 1.0 M solution first. Once that is made, a portion of that solution is diluted to the final concentration. If the first solution is 1 M in 1 L, and a final concentration of 0.001 M is desired, that can be made by diluting 10 mL of the 1 M solution to 1 L final volume. The potential measurement error is much lower, because 10X the amount of concentrated material was measured to start with.

Solute - The chemical being dissolved *into* solution. Also, defined as the chemical in lower concentration in the mixture.

Solvent - The chemical that is in higher concentration in the mixture. Typical solvents include distilled water, ethyl alcohol, and isopropyl alcohol

Standard Solutions - Whenever quantitative results are needed, a standard solution must be used to determine the exact molarity or normality of the solution being prepared. Hydrochloric acid (concentrated) is supplied with the approximate molarity of 12.1 M. If the exact concentration of the HCl solution is required, the HCl solution must be standardized against a known standard solution, one whose exact concentration is known.

Solution Recipes

To prepare a 0.1 M solution of the following, dissolve the amount shown in the table in about 500 mL of distilled water inside a volumetric flask. After all the solute has been dissolved, dilute to final volume of 1 L.

Chemical Name	Formula	f.w.	g/L (0.1 M)
Aluminum chloride 6-hydrate	$AlCl_3 \bullet 6H_2O$	241.43	24.143
Aluminum potassium sulfate 12-hydrate	$AlK(SO_4)2 \bullet 12H_2O$	474.40	47.440
Ammonium chloride	NH_4Cl	53.49	5.349
Ammonium dichromate	$(NH_4)_2Cr_2O_7$	252.06	25.206
Ammonium nitrate	NH_4NO_3	80.04	8.004
Barium chloride dihydrate	$BaCl_2 \bullet 2H_2O$	244.28	24.428
Barium hydroxide 8-hydrate	$Ba(OH)_2 \bullet 8H_2O$	315.48	31.550
Calcium carbonate	$CaCO_3$	100.09	10.009
Calcium chloride dihydrate	$CaCl_2 \bullet 2H_2O$	147.02	14.702

Chemical Name	Formula	f.w.	g/L (0.1 M)
Calcium hydroxide	$Ca(OH)_2$	78.08	7.808
Calcium nitrate 4-hydrate	$Ca(NO_3)_2 \bullet 4H_2O$	236.15	23.615
Calcium oxide	CaO	56.08	5.608
Calcium sulfate dihydrate	$CaSO_4 \bullet 2H_2O$	172.17	17.217
Citric acid monohydrate	$C_6H_7O_8 \bullet H_2O$	210.14	21.014
Cobalt chloride 6-hydrate	$CoCl_2 \bullet 6H_2O$	237.95	23.795
Copper(II) chloride dihydrate	$CuCl_2 \bullet 2H_2O$	170.48	17.048
Copper(II) nitrate 3-hydrate	$CuNO_3 \bullet 3H_2O$	241.6	24.160
Copper(II) sulfate 5-hydrate	$CuSO_4$ $5H_2O$	249.69	24.969
Dextrose monohydrate (glucose)	$C_6H_{12}O_6 \bullet H_2O$	180.16	18.016
d-Fructose	$C_6H_{12}O_6$	180.16	18.016
Iron(II) ammonium sulfate 6-hydrate	$Fe(NH_4)_2(SO_4)_2 \bullet 6H_2O$	392.13	39.213
Iron(II) sulfate 7-hydrate	$FeSO_4 \bullet 7H_2O$	278.02	27.802
Iron(III) chloride 6-hydrate	$FeCl_3 \bullet 6H_2O$	270.32	27.032
Iron(III) nitrate 9-hydrate	$Fe(NO_3)_3 \bullet 9H_2O$	404.00	40.400
Lead nitrate	$Pb(NO_3)_2$	331.23	33.120
Lithium chloride	LiCl	42.400	42.400
Magnesium chloride 6-hydrate	$MgCl_2 \bullet 6H_2O$	203.33	20.333
Magnesium nitrate 6-hydrate	$Mg(NO_3)_2 \bullet 6H_2O$	256.41	25.643
Magnesium sulfate 7-hydrate	$MgSO_4 \bullet 7H_2O$	246.48	24.648
Manganese dioxide	MnO_2	86.94	8.694
Nickel chloride 6-Hydrate	$NiCl_2 \bullet 6H_2O$	237.72	23.772
Nickel nitrate 6-hydrate	$Ni(NO_3)_2 \bullet 6H_2O$	290.82	29.082
Nickel sulfate 6-hydrate	$NiSO_4 \bullet 6H_2O$	262.87	26.287
Potassium bromide	KBr	119.02	11.902
Potassium chlorate	$KClO_3$	122.56	12.256
Potassium chloride	KCl	74.56	7.456
Potassium dichromate	$K_2Cr_2O_7$	294.19	29.419
Potassium hydroxide	KOH	56.11	5.611
Potassium iodate	$KClO_3$	214.00	21.400
Potassium iodide	KCl	166.01	16.601
Potassium nitrate	KNO_3	101.11	10.111
Potassium permanganate	$KMnO_4$	158.04	15.804
Potassium sodium tartrate 4-hydrate	$KNaC_4H_4O_6 \bullet 4H_2O$	282.23	28.223
Potassium thiocyanate	KSCN	97.18	9.718
Silver nitrate	$AgNO_3$	169.87	16.987
Sodium acetate	CH_3COONa	82.03	8.203
Sodium bicarbonate anhydrous	$NaHCO_3$	84.01	8.401
Sodium bisulfate anhydrous	$NaHSO_4$	120.07	12.007
Sodium borate 10-hydrate	$NaB_4O_7 \bullet 10H_2O$	381.33	38.133
Sodium carbonate anhydrous	$NaCO_3$	105.99	10.599
Sodium chlorate	$NaClO_3$	106.44	10.644
Sodium chloride	NaCl	58.45	5.845
Sodium hydroxide	NaOH	40.00	4.000
Sodium iodide	NaI	149.84	14.984

Chemical Name	Formula	f.w.	g/L (0.1 M)
Sodium lauryl sulfate	$C_{12}N_{25}O_4SNa$	288.38	18.838
Sodium nitrate	$NaNO_3$	84.99	8.499
Sodium oxalate	$Na_2C_2O_4$	134.00	13.400
Sodium phosphate dibasic anhydrous	Na_2HPO_4	141.90	14.190
Sodium phosphate tribasic 12-hydrate	$Na_3PO_4 \bullet 12H_2O$	380.12	38.012
Sodium sulfate 10-hydrate	$Na_2SO_4 \bullet 10H_2O$	322.19	32.219
Sodium thiosulfate 5-hydrate	$Na_2S_2O_3 \bullet 5H_2O$	248.18	24.818
Strontium chloride 6-hydrate	$SrCl_2 \bullet 6H_2O$	266.62	26.662
Strontium nitrate	$Sr(NO_3)_2$	211.63	21.163
Tin(II) chloride dihydrate	$SnCl_2 \bullet 2H_2O$	225.36	22.536
Tin(IV) chloride 5-hydrate	$SnCl_4 \bullet 5H_2O$	350.61	35.061
Zinc nitrate 6-hydrate	$Zn(NO_3)_2 \bullet 6H_2O$	297.48	29.748
Zinc sulfate 7-hydrate	$ZnSO_4 \bullet 7H_2O$	287.54	28.754

Acid/Base Solutions (Dilutions)

Chemical Name	Formula	f.w.	mL/L (1.0 M)	mL/L (0.1 M)
Acetic acid (~17.4 M)	CH_3COOH	60.05	57.5	100.0
Hydrochloric acid (~12.1 M)	HCl	36.46	82.7	100.0
Nitric acid (~15.8 M)	HNO_3	63.01	63.3	100.0
Phosphoric acid (~14.8 M)	H_3PO_4	98.0	67.6	100.0
Sulfuric acid (~18 M)	H_2SO_4	98.08	55.6	100.0
Ammonium hydroxide	NH_4OH	35.05	67.6	100.0

Biological Stains and Indicators

Chemical Name	Formula	g/100 mL
Phenolphthalein (1% in alcohol)	$C_{20}H_{14}O_4$	1.000
Methylene Blue (1% in water)	$C_{16}H_{18}ClN_3SCl$	1.000
Congo Red (0.1% in alcohol)	$C_{32}N_{17}O_5SNa$	0.100
Methyl Orange (0.1% in water)	$4\text{-}(CH_3)_2NC_6H_4N{:}NC_6H_4\text{-}4\text{-}SO_3Na$	0.100

Serial Dilutions

Chemical Name	Formula	mL/L Original Solution/ Concentration	Final Concentration (1 L dilution)
Hydrochloric acid (~12.1 M)	HCl	495.9 mL (12.1 M)	6 M
		82.7 mL (15.8 M)	1 M
		100 mL (1 M)	0.1 M
		500 mL (1 M)	0.05 M
Nitric acid (~15.8 M)	HNO_3	189.9 mL (15.8 M)	6 M
		63.3 mL (15.8 M)	1 M
		100 mL (1 M)	0.1 M
Sulfuric acid (~18.0 M)	H_2SO_4	333.33 mL (18.0 M)	6.0 M
		55.6 mL (18.0 M)	1.0 M
		27.8 mL (18.0 M)	0.5 M
		500 mL (1.0 M)	0.5 M

Standard Solution

Chemical Name	Formula	f.w.	g/L (0.1 M)
Potassium acid phthalate (Potassium hydrogen phthalate)	$KHC_8H_4O_4$	204.23	20.423

XII. Spill Prevention, Response, and Control

Being a conscientious science teacher means being proactive in taking steps to prevent spills. However, no matter how careful you are, or what precautions you take, a spill is always possible. Proper response procedures and safety equipment must always be available to contain and control a spill.

Spill Prevention

The first step in safety is prevention. Laboratories and experiments should be designed to minimize the possibility of chemical spills. A clean, organized, clutter-free laboratory can be maintained by putting away chemicals, equipment, and related materials when you are done with them.

Chemicals should be stored and dispensed in unbreakable containers, such as plastic or PVC coated glass bottles. Store highly toxic materials in secondary containment devices, such as heavy-duty plastic bags or airtight containers. If a container is dropped, secondary containment will help safely contain a spill.

Note: Review the SDS for any chemicals you will be using BEFORE starting any experiment, as a proactive measure for quicker response in case of an emergency.

Chemical Dispensing

Many spills occur when a chemical is dispensed. Awareness and an understanding of prevention procedures will minimize the possibility of a spill. Heed the following safe-handling recommendations when dispensing chemicals:

1. Establish a safe location in the laboratory to dispense chemicals. The laboratory fume hood should always be used.
2. Dispense chemicals over a spill containment tray or an absorbent pad. Plastic cafeteria trays are usually chemical resistant and make good containment devices. Do not return the trays to the cafeteria.
3. Use a spatula and weighing boat to weigh out chemicals.
4. Read the label carefully before removing a chemical from its container. Using the wrong material can lead to accidents. Review the SDS before using any chemical.
5. Do not use more material than directed. Once you remove the appropriate amount of the chemical, re-seal the container immediately.
6. Choose experiments that use the least amount of chemicals whenever possible.
7. Never return any quantity of a chemical to its original container; this practice can lead to contamination and possibly to a dangerous situation. Deposit unused chemicals in the appropriate, labeled waste container. Follow all regulatory hazardous waste procedures for final disposal.
8. Try to avoid raising chemical "dust" into the air when using solids during an experiment.
9. Use a stirring rod when pouring liquids to help direct the flow. (See *Section X - Preparing and Handling Chemicals For Use* for further information.)
10. Pour slowly when mixing concentrated solutions into other liquids.

11. Add chemicals to a reaction mixture slowly. Chemicals should never be quickly dumped together, unless that is the experiment's specific procedure. Observe the initial reaction when a small amount is mixed, and wait before adding more.
12. Review the experiment's procedures if a chemical reaction fails to initiate as expected. Make sure that the proper chemicals were used, in the proper amounts, before proceeding.

Spill Kit Materials

Chemistry laboratories should have spill control materials, or, at a minimum, kits that contain sand (for absorption) and neutralizers. These materials should be available in a volume capable of handling a spill from the largest container used in the laboratory. Contact Ward's Science to order your spill control materials. Neutralizers and absorbents should be used as directed by the SDS for the specific chemical to be contained, absorbed or neutralized. Chemical spill response materials should also be kept in the chemical storage area.

Sand

Sand is used to contain a spill. Ward's Science recommends that 30 pounds of clean, dry sand be immediately available in the laboratory Sandbox sand will suit the purpose and can be purchased from a local discount or hardware store.

Chemical Absorbent

The chemical absorbent contains and absorbs chemical liquid spills for easier control and clean up. Ward's Science recommends that 20 pounds of odorless kitty litter, vermiculite, or oil absorbent be immediately available in the laboratory.

Neutralizers

An acid neutralizer is a base such as sodium carbonate or calcium hydroxide and is used to neutralize inorganic acid spills. If acids are used, Ward's Science recommends that 30 pounds of sodium bicarbonate (baking soda) be immediately available in the laboratory. If strong bases are used in the laboratory, a supply of vinegar or citric acid should be on hand to neutralize the base. A 2.5-kg bottle of vinegar or citric acid should be large enough to neutralize the contents of any amount of base material used in a laboratory. Sodium bicarbonate, vinegar, and citric acid can be purchased from Ward's Science as well as from an industrial chemical, building supply, or swimming pool supply distributors.

The sand, absorbent, and neutralizers should be stored in sealed, labeled containers that can be quickly opened and used. A plastic broom, plastic dustpan, and large heavy-duty plastic garbage bags should be included with the response materials. You can also obtain spill control pillows, blankets and specialized neutralizers and absorbents if desired. Convenient spill control kits are available from Ward's Science.

Spill Response and Control Procedures

As the chemistry teacher, you (and your school) are required to define and establish a written contingency plan, specifying your school's procedure to handle chemical spills. This should be part of your Chemical Hygiene Plan, (See *Section VII* for more information on Chemical Hygiene Plans.) Responsibilities and specific applications and procedures will need to be defined in your contingency. This is a standard chemical response plan for chemicals that are not highly toxic or highly hazardous. Response procedures rely on the proper spill response, containment, and clean up training for response individuals. At a minimum, your contingency plan should consist of the following:

1. Quickly assess the spill, its hazards, and the danger to you and your students. Notify other laboratory personnel of the accident, and if necessary, evacuate the area. If the spilled chemicals are unknown, assume the worse. Always evacuate.
2. Contact internal spill response personnel (such as your safety coordinator or trained spill response team) immediately.
3. Call **911** (fire department, ambulance) if your students' safety is at risk.
4. Review the SDS for the spilled chemical, including its hazards, spill response procedures, and first aid measures.
5. Tend to injured or contaminated persons as directed by the SDS. If you are splashed by a chemical you know is innocuous, you may have time contain the spill before cleaning yourself. **Note:** If you use a safety shower near a chemical spill, the water may expand spill area.
6. Avoid breathing vapors from the spill. Ventilate the room and wait before cleaning up if the material is producing heat or giving off vapors.
7. Wear appropriate protective equipment as directed by the SDS when cleaning the spill.
8. Contain the spill as follows when it is safe to approach the area without exposing yourself to the risk:
    a. Gently pour sand around and over the spill. The sand will contain the spill, prevent it from spreading, and provide traction if you need to walk over it.
    b. Gently sprinkle the absorbent (kitty litter, vermiculite, oil absorbent) around and over the entire spill to avoid further spreading. This will absorb the liquid and help contain vapors.
    c. Apply the appropriate neutralizer around and over the entire spill, if it is an inorganic acid or base. Using a plastic broom, mix the spilled chemical, sand and neutralizer to make sure the neutralizer contacts all of the spilled chemical.
9. Clean up the spill using standard procedures described in the chemical's SDS.
10. Use a plastic dustpan and plastic broom to sweep up the residue and place it into a heavy-duty garbage bag, plastic container, or other appropriate container, and dispose of it as chemical waste. Follow federal and local regulations for disposal. See *Section XIV - Chemical Disposal* for further information.
11. Clean spill area with water and a suitable cleanser.
12. Decontaminate clothes, personal protective equipment, and tools.
13. Evacuate the area and get help if you feel uncomfortable at any time.

For a highly hazardous or toxic chemical spill, the following procedure should be used:

1. Attend to injured or contaminated persons and remove them from the hazard area.
2. Turn off ignition and heat sources if the spilled material is flammable.
3. Close all doors to area where the spill is. Notify other personnel of the accident evacuate the area. Call 911 to notify emergency personnel.

Emergency Procedures

In the event of an accident or emergency, teachers should act promptly and decisively. A pre-existing emergency plan should be established, practiced, and followed. If you are expected to respond to chemical related accidents or spills, you should be trained to do so. In the event of injury to personnel or students, the following steps should be taken:

- Assess the situation and take immediate action to remove any hazards. This will help reduce student exposure and the potential for injury. Assess the severity of any injuries to guide your course of action.

- Call **911** and notify school nurse, principal and other emergency personnel, if an injury requires medical attention. Follow emergency procedures defined in the appropriate SDS, and make the form available to emergency personnel.
- Flush any chemicals from a victim's eyes immediately. The eyewash should consist of potable, aerated water, from 60° F - 90° F (15.5 °C – 32.2 °C), at a rate of 3-5 gallons/minute (11.4-18.9 liters/minute). Hold the victim's eyelids open as wide as possible and flush for at least 15 minutes (or until emergency personnel arrive). DO NOT flush with anything other than water. Flushing should wash out contact lenses. If the lens chemically adheres to the eye DO NOT remove the contact. Allow emergency personnel to remove it.
- Immediately place a burning victim under an emergency shower. If a shower is not nearby, the individual should drop and roll. Smother the flames with a fire blanket or with the spray from a fire extinguisher. DO NOT wrap an upright student in a fire blanket. This could create a "chimney effect" and increase the severity of fire.
- Spray burning chemicals with an ABC fire extinguisher. All personnel who might need to use a fire extinguisher should be properly trained to do so. Stand within 6 feet (1.8 meters) of the fire and make sure there is an exit in case the fire cannot be controlled. Administer the PASS method to use the extinguisher.

  P – Pull the pin.
  A – Aim low or at the base of the fire.
  S – Squeeze trigger.
  S – Sweep from side to side of the fire.

  The average fire extinguisher operates at maximum efficiency for 8-10 seconds. Take care not to blow and scatter the material on fire. Some fires, such as alkali metals, cannot be extinguished with ABC extinguishers and must be extinguished with dry sand or specialty extinguishers. If these chemicals are used in your lab, keep a covered bucket of sand available for extinguishing purposes.
- Obtain medical attention for any victims. Contact the victim's parent, guardian, or designated person.
- Complete an accident investigation, using school reporting forms, including eyewitness testimonies. Assess the procedures that led up to the accident and adjust them to eliminate or reduce the possibility of a reoccurrence.

Spill Prevention and Response Training

As a chemistry teacher, you provide your students with a number of chemicals, most of which have hazardous properties of varying degrees. You are responsible for keeping this potentially dangerous environment a safe one. Providing a safe environment includes instituting methods that help prevent accidents. All chemistry teachers need to be trained in prevention methods, and must understand how to incorporate them into their daily chemistry activities. This training should include hazard communication (as defined by OSHA and Health Canada); the use of a Safety Data Sheet (SDS); experiments planning; laboratory layout; procedures and equipment usage; dispensing techniques; and ways to utilize small quantity chemical experiments. In addition, teachers should complete refresher safety training annually, and when new chemicals and hazards are introduced into the environment.

Since every second counts when handling a spill, knowing what you are working with and how to respond is essential in protecting you and your students. Chemical safety is most successful when you are proactive in your preparedness, so using the information in this section will greatly reduce the potential for spills, and help you handle them in the safest manner possible in the event that a spill occurs.

XIII. Chemical Disposal

Federal, state/provincial, and local regulations govern the disposal of hazardous waste generated by school laboratories. In order to control this hazardous waste, schools must develop and implement waste minimization procedures. As defined in *Section II - Purchasing Your Chemicals*, effective waste minimization begins with smart and efficient purchasing. Make sure to buy only the amount of chemicals you need.

School chemistry classroom/laboratory experiments and demonstrations result in chemical hazardous waste. Initial disposal information is found on the chemical Safety Data Sheets (SDS's) for when it comes time to dispose of this waste. Since specific disposal requirements are government mandated and regulated, be sure to research specific requirements before any chemicals are even brought into your school. If you are not absolutely clear on these hazardous waste disposal requirements, call your local, provincial, or state government.

This section provides some useful guidelines on how to handle chemical and hazardous waste, and provides examples on how generate less waste in your laboratory. Waste minimization is not only good for the environment, but also reduces costs associated with chemical waste disposal.

All chemical waste should be disposed of through a central channel of responsibility. For example, a school with multiple chemistry laboratories and science teachers should set up a central waste disposal process, designating one individual to track, label, and handle all waste.

Chemical wastes include but are not limited to:

- Used or unneeded laboratory chemicals.
- Glassware and laboratory supplies contaminated with chemical residue.
- Contaminated materials resulting from chemical spill response.
- Paints, oils, pesticides, cleaners, etc.

Guidelines for Reducing Chemical Waste

<u>During Purchasing</u>

- Purchase chemicals in smaller container sizes. The contents of smaller containers are more likely to be utilized and would result in a less significant loss if subjected to degradation or contamination.
- Do not purchase chemicals in quantities that result in a long period if storage before depletion. This can jeopardize the chemical properties over time and create hazardous storage conditions.
- See *Section II – Purchasing Your Chemicals* for detailed information.

<u>Storage Concerns</u>

- Store chemicals according to manufacturers' recommendations. Following the manufacturers' special storage requirements will maximize the shelf life of the chemical.
- Date and store new chemicals in a manner that enables the older chemicals to be used first.
- Label all containers that contain or will contain chemicals. Use the complete common chemical name to identify each container's contents.
- Replace damaged caps and lids, and make sure they are on securely at all times. This will limit air and moisture contamination to the contents.

- Inventory the chemicals in your laboratory every month. Replace worn and damaged labels. Be sure chemicals are stored by compatibility rather than alphabetically. Dispose of chemicals that are no longer needed.
- Dispose of chemicals that tend to form peroxides, become more reactive with time, or are approaching the end of their shelf lives.
- See *Section VI – Storing Your Chemicals* for detailed information on chemical storage.

Unused Chemicals and Hazardous Waste Disposal

1. All leftover materials and washings from an experiment should be considered hazardous waste unless clearly identified otherwise.
2. Only non-contaminated paper towels should be placed in the regular trash. Paper towels that were used to wipe up solid chemical waste are considered hazardous solid waste and should be disposed of accordingly. Used filter paper is also hazardous waste unless clearly proven otherwise.
3. It is the responsibility of the teacher to instruct his or her students on the handling of chemical waste.
4. Teachers should provide each student with a beaker for all liquid waste, which includes aqueous solutions, reaction products, and washings.
5. Students should inform the teacher when the beaker becomes full, and never dispose of any hazardous waste themselves.
6. If the object being disposed of has precipitated solids, decant the solvent into a liquid waste flask so only the solids remain. Dispose of the hazardous solid separately from the solution.
7. Poisonous and reactive compounds, such as concentrated organic peroxides, should be disposed of in individual containers.
8. Label containers specifically for solid waste.
9. Provide containers for recyclable and used paper products when needed.
10. Provide a separate container for glass trash.

Getting Rid of Your Hazardous Waste and Residual Chemicals

Waste chemicals can be disposed of in a number of ways, depending on the specific substance. These include disposal in sanitary landfills; hazardous waste landfills; sewer systems; or by incineration, recycling, or reuse. Chemicals can also be treated by chemical, physical, or biological processes, including neutralization, oxidation, precipitation, and solidification. The process for disposal must be in compliance with requirements as regulated by the Environmental Protection Agency (EPA), Environment Canada, local/provincial regulations, and as recommended by the American Chemical Society (ACS).

There are a number of options to relieve your school of unneeded and waste chemicals. Residual waste resulting from experiments and demonstration can be handled using one of the listed disposal methods. This information is also valid for surplus chemicals that are still usable.

Before using a method, clearly identify your disposal options, and if needed, consult the various available resources. Some of these include:

- Local, or provincial/state department of education, or an officer of your province/state's science teacher's professional association. Many areas have resources to supply information on successful existing programs.
- The chemistry department of a nearby college or university. They can inform you about the disposal processes they use, and may even be able to use your surplus chemicals.
- Contact other local chemistry teachers for advice on the correct compliance methods for disposal

in your area and double-check sources of their information.
- Contact the American Chemical Society (ACS) for information.
- Information on the Internet is plentiful. Start with federal requirements and work your way down to local and municipal requirements. All the information identified above can be found using the Internet. Using it wisely can answer most of your questions very effectively.

Based on your chemical and waste, select an option for handling these residual chemicals.

- Always check the local regulations before determining which of the disposal methods is best for you. If you are unsure if a method is permitted, positively verify it before proceeding.
- Consider the cost of your options, but never determine a disposal method for cost or convenience at the price of safety.
- Pay a certified, approved hazardous waste disposal firm to remove these materials. There is a cost associated with this, but its safety benefits to you and the school cannot be overstated.
- Find out if there are any other schools in your district, or organizations in your area, that need to dispose of laboratory chemicals and suggest a partnership with them to share the expenses.

Taking Care of Disposal Yourself

If you decide to dispose of the chemicals yourself, use the following information to do so safely. Ward's Science is providing this information for your convenience. These options are viable ONLY if they fall within the guidelines defined by the regulatory agencies in your area. If you decide to handle disposal yourself, it is important to do it safely. Provisions for the safely disposing of your hazardous chemicals include:

- Wearing personal safety gear including gloves, safety glasses/goggles, etc.
- Working under a fume hood.
- Making sure a fire extinguisher and response materials are present at all times.
- Working with an assistant at all times. Never dispose of chemicals by yourself!
- Gaining a full knowledge of the disposal process procedures, from beginning to end, before you start. (If you are completing chemical elimination through chemical methods, such as neutralization, first practice the procedure with small amounts to verify knowledge of the process, to ensure reactions (i.e., heat generation) and final results. Once knowledge of process is verified and can be completed without any surprises, the balance of the waste product can be processed.)

Disposing of Non-Hazardous Waste Chemicals as Trash

The following guide was prepared by Cornell University Environmental Health and Safety (EH&S) and adapted for the school chemistry teacher. Keep in mind that these references were approved by the NY DEC and regulatory authorities for Cornell University, and are provided in this manual as alternatives for your school. The guide lists solid chemicals that are not considered hazardous and that can disposed with regular trash. You should securely package waste for disposal, and personally transport it to the dumpster. Always check with your local municipality for rules and regulations in your area.

<u>Not Considered Hazardous and can be properly disposed in the trash.</u>

A. *Organic Chemicals*

Enzymes
Sugars and sugar alcohols
Starch
Naturally occurring amino acids and salts

Citric acid and its Na, K, Mg, Ca, NH_4 salts
Lactic acid and its Na, K, Mg, Ca, NH_4 salts

B. *Inorganic Chemicals*

Silica
Sulfates: Na, K, Mg, Ca, Sr, NH_4
Phosphates: Na, K, Mg, Ca, Sr, NH_4
Carbonates: Na, K, Mg, Ca, Sr, NH_4
Oxides: B, Mg, Ca, Sr, Al, Si, Ti, Mn, Fe, Co, Cu
Chlorides: Ca, Na, K, Mg, NH_4
Borates: Na, K, Mg, Ca

C. *Laboratory Materials Not Contaminated with Hazardous Chemicals*

Chromatographic adsorbent
Glassware
Filter papers
Filter aids
Rubber and plastic protective clothing

Other examples of non-hazardous biochemicals include polysaccharides, nucleic acids and naturally occurring precursors, and dry biological media.

Packaging Instructions:

1. **Package securely for the dumpster** by using at least two layers of packaging so that material cannot spill during collection.
2. Leave label on innermost container.
3. Label outer container "Non-hazardous" waste.
4. **Place containers in the dumpster yourself**. Custodians should not handle even non-hazardous laboratory chemicals.

Sanitary Drain Disposal of Laboratory Waste Chemicals

The following guide was also prepared by Cornell University Environmental Health and Safety (EH&S) and adapted for the school chemistry teacher. Keep in mind that these references were approved by the DEC and regulatory authorities for Cornell University, and are provided in this manual as alternatives for your school. Verify compliance with your local regulations and wastewater treatment facility before initiating disposal of any amounts of identified chemicals.

It is the responsibility of the school chemistry teachers to make sure that chemical waste generated from their activities is disposed of properly. Some materials can be safely discharged into the sanitary sewer, while others can cause significant health problems for people or have adverse effects on the environment. If the amount of discharge is considerable, it could affect the functioning of the servicing wastewater facility. Such chemicals can form sludge to the point that it has to be reclassified as a hazardous waste where otherwise it might have been recycled.

Chemistry teachers should reference the following information before undertaking drain disposal of any lab chemicals.

- Only the materials found on the safe list can be discharged down the SANITARY drain.
- Drain disposal must only be used when the drain flows to a sanitary sewer system that eventually goes to the wastewater treatment plant. Storm drain systems flow directly into surface water and should ***NEVER*** be used for chemical disposal. *Floor drains may flow to storm sewers and should never be used for disposal.* Only use laboratory sinks for disposal of chemicals on the safe list as discussed below.
- Quantities of chemical waste for drain disposal should be limited generally to a few hundred grams or milliliters or less per day. Larger amounts should have prior approval from your local authorities and waste water treatment facility. Only materials listed in this document as safe for drain disposal are approved for drain disposal in quantities up to 100 grams or 100 milliliter per discharge. Disposal should be followed by flushing with at least 100-fold excess of water.
- **Note:** Sulfuric, hydrochloric, acetic, and phosphoric acids may be discharged in larger quantities only if they are neutralized to a pH of between 5.5 and 9.5 before they can be drained to the sanitary sewer.
- Understand the hazards and toxicity of the materials you work with by consulting Safety Data Sheets. Work slowly to avoid splashes and wear the proper protective equipment (lab coat, goggles, face shield, gloves) during drain disposal.

<u>Safe for Drain Disposal</u>

The following materials are examples of chemicals that are safe for laboratory sink drain disposal as long as they do not contain any materials that are prohibited from drain disposal.

- Aqueous solutions with 5.5 > pH <9.5
- Neutralized acids and bases with 5.5 > pH < 9.5
- Enzymes
- Proteins
- Sugars
- Citric acid
- Lactic acid
- Sodium, potassium, magnesium, calcium or ammonium salts
- Autoclaved or disinfected biological liquids
- Starches
- Naturally occurring amino acids

Check with your local municipality for a list of materials that may be safe for drain disposal in your area.

Inorganics

Dilute solutions of inorganic salts, where both cation and anion are listed below, are suitable for drain disposal. Materials listed are considered to be relatively low in toxicity. Compounds of any of these ions that are strongly acidic or basic should be neutralized before drain disposal.

Cations	**Anions**
Al^{+3}	BO_3^{-3}
Bi^{+3}	$B_4O_7^{-2}$
Ca^{+2}	Br^-
$Cu^{+,+3}$	CO_3^{-2}
$Fe^{+2,+3}$	Cl^-
H^+	HS^-
K^+	HSO^{-3}
Li^+	I^-
Mg^{+2}	OCN^-
Na^+	OH^-
NH_4^+	NO_3^-
Sn^{+2}	PO_4^{-3}
Sr^{+2}	SCN^-
$Ti^{+3,+4}$	SO_3^{-2}
Zn^{+2}	SO_4^{-2}
Zr^{+2}	

- Mineral acids and bases should be neutralized to a pH level in the 5.5-9 range before disposal.
- Copper and zinc have specific discharge limits set by sewage treatment plants. Contact your local wastewater facility prior to discharging any copper or zinc.

<u>Materials *Prohibited* From Drain Disposal</u>

- Ashes, cinders, sand, mud, straw, shavings, metal, glass, rags, plastics, wood, paint residues, and solid or viscous substances capable of causing obstruction to the flow of sewers.

- Some chemicals that are ***not safe*** for drain disposal include:
  - Halogenated hydrocarbons
  - Mercury and mercury compounds
  - Nitrocompounds
  - Mercaptans
  - Flammables (immiscible in water)
  - Explosives such as azides and peroxides
  - Water soluble polymers (potential to form gels that block sewers)
  - Water reactive materials
  - Malodorous materials
  - Toxic chemicals such as carcinogens, mutagens, and teratogens
  - Radioactive materials
  - Materials with pH < 5.5 or pH > 9.5 (Neutralized acids and bases may be eligible for drain disposable if there are no other restrictions on the material)

- Grease, oil
- Animal products (tissue, blood, hair, bones, etc.)
- Non-aqueous solutions with a flashpoint < 60° Celsius (140° Fahrenheit) such as gasoline, benzene, xylene, bromates, etc.
- Mixtures that have a component not found on the safe list.
- Any other material not found on the safe list.

This list is by no means exhaustive. If you are not certain about drain disposal for a particular material, dispose of it as hazardous waste or contact your local municipality for instructions.

Materials That Are Not Legally Disposable

As a prerequisite to shipping chemical waste, the identity of the material must be established. A potential problem in any laboratory is "orphan" waste. Orphan waste is unidentified material left behind by students and/or a teacher. Contact your local municipality for proper disposal methods in your area. The best method of dealing with such "orphan" waste is to prevent its occurrence by removing as much chemical waste as possible at the time of its creation.

Heavy Metals Disposal

Heavy metals have been banned from land disposal. Alternate methods of treatment and disposal are under investigation; however, none of these have received final federal approval. Disposal should be subcontracted to a certified and approved waste disposal organization. Only the teacher should separate mercury from glassware (such as thermometers and manometers), using proper precautions. All heavy metal compounds should be kept separate from other materials to facilitate proper disposal.

- **Non-Chemical Paraphernalia Disposal**
  Plasticware, disposable gloves, glassware, paper towels, and tools that are contaminated with chemical waste, must be disposed of through a certified and approved waste disposal organization. Such items should be decontaminated and reused if possible. The appropriate method of decontamination is based on the chemical waste and information found on the SDS. When washing these items, *the resulting rinsing solution will be considered chemical waste*. For disposing of empty bottles, regulations require that they be rinsed three times, with a 30-second drain time between rinses, before being discarded or reused.

The Five Most Common Laboratory Waste Handling Errors

It is the science teacher's responsibility to manage laboratory hazardous waste. This task does not need to be overwhelming. Clearly understanding the hazards involved, being persistent in your maintenance, and instituting safe and effective control measures should establish an effective routine. But remember: never become complacent in your handling of chemical wastes. The five most common mistakes in handling hazardous waste in the laboratory are listed below.

1. **Improper Labeling of Waste Containers**
   - Failing to label a waste bottle.
   - Storing waste in a bottle labeled inappropriately or only as "Waste". Per regulatory requirements, waste containers must always be clearly labeled as "Hazardous Waste".

2. **Improper Isolation of Waste**
   - Mixing incompatible chemicals in a single waste container.

3. **Improper Storage of Waste**
   - Storing waste in a fume hood where experiments are being performed.
   - Using metal cans for waste. Depending upon the pH of a substance, the metal container can easily be corroded. Use only glass or polyethylene containers for waste.
   - Storing flammable waste containers on a bench or floor. Store your flammable waste containers in an approved flammable storage cabinet.
   - Storing waste bottles in or near a sink or floor drain. This could allow hazardous waste to enter the sewer.

4. **Failure to Securely Cap Waste Bottles**
   - Leaving the cap off a waste bottle. The only time a cap should be off a waste bottle is when you are putting waste into it.
   - Leaving a funnel in the waste bottle. The funnel can easily be removed and used in another waste bottle, resulting in an accident.

5. **Accumulation of Excessive Waste**
   - You should have no more than ONE bottle of each kind of waste in your laboratory.

XIV. Preparing for Next Year

When the school year comes to an end, you have the opportunity to assess and enhance your lessons. You should break down the progress and events of the year and determine what went right, what went wrong, and what you can improve on. In planning the next school year, adhere to the following path - analyze, prioritize, enhance, plan, purchase, and initiate. Here are some questions you should ask yourself to help in this process.

- Did all the demonstrations and experiments reflect the subject matter being taught?
- Were they as spectacular as they could be?
- Were you uncomfortable using any of the chemicals needed for a particular experiment or demonstration?
- Are there safer chemicals you can use in place of hazardous ones, to get the same results in a particular experiment?
- Are the demonstrations you have been using getting old?
- Did you have enough chemicals and materials to get you through the year?

Once you have answered these fundamental questions you are on your way. This section will help define the areas you need to focus on to effectively plan the upcoming school year.

Define Your Budget

Break down what you spent over the year. Did you have enough money to get you through the year, or did you have to make do? Did you spend wisely, or were there better choices to be made? Was last year's planning successful, or were unplanned costs an issue? This information will help you refine your upcoming budget. Additionally, your Ward's Science representative can always help you determine the most cost effective means of buying chemicals and chemical supplies.

Chemical Purchasing

As detailed in *Section II - Purchasing Your Chemicals*, smart chemical purchasing is an essential element in helping you provide a safe and successful chemistry experience. Buying too much of a chemical for the year creates a potentially dangerous storage condition, waste, and a significant disposal expense. Buying too little may limit students' hands-on experimentation—an important learning experience.

Take inventory of all the chemicals remaining in storage. Determine which can still be used. Properly dispose of those that cannot or will not be used. (See *Section XIV –Chemical Disposal* for further information). Select your intended experiments and demonstrations and estimate the amount of the chemicals you need to use in the laboratory. Try to select a demonstration or experiment that can use up left over chemicals. Also, try to use chemicals with low hazard characteristics. Once you have determined the experiments you will be presenting and you purchase the chemicals, stick with them. Deviations from the planned demonstrations or experiments will likely result in unused chemicals at the end of the year.

Ward's QuickPrep™ chemicals come in pre-measured packaging that saves prep time by eliminating the need to weigh chemicals when you dispense them. Additionally, QuickPrep chemicals do not require a UPS Hazardous Materials Surcharge ($70.00/order at this writing. Ward's also provides selected chemicals in 25 g bottle 4-packs. These packages do not require the Hazard Surcharge either, and remain fresher since you only open what you need.

In *Section XVII – Ward's Demonstrations To Get the Students' Attention,* Ward's Science provides chemistry demonstrations for use in your classroom or laboratory, and the amount of chemical needed for each. This makes it easy to order efficiently.

Personal Protection

Do you have enough safety equipment and supplies to adequately provide protection for the number of students enrolled in your classes next year? Check your personal protection stock – safety glasses, safety goggles, aprons, lab coats, gloves, plastic demonstration shields, etc. If any are broken, incomplete, excessively dirty, excessively worn, or provide inadequate protection, they should be replaced. Remember, these students rely on you to provide a safe learning environment.

Spill Response Materials

Do you have enough safety materials and equipment to respond to a spill? Spill response materials and equipment need to be present in sufficient amounts at all times. Verify that you have adequate amounts of containment materials including sand, blankets, and related materials.

If you use acids or bases, make sure you have absorption and neutralizing materials including kitty litter and vermiculite (or similar materials) to handle possible spills. You also need to keep a broom and dustpan, specifically designated for spill response. All response materials and equipment should be on hand before the school year begins. (See *Section XIII – Spill Prevention, Response and Control* for detailed information).

Safety Data Sheets (SDS's)

Do you have the latest Safety Data Sheet (SDS) for all the chemicals that you have on hand? SDS's have replaced Material Safety Data Sheets (MSDS) and provide more and better organized chemical information. Be sure that you have an SDS for all of the chemicals in your inventory. Double check, since these sheets are can become mangled, unreadable, and even lost throughout the school year. Do this in the summer if you have limited time for SDS maintenance during the school year. All SDS's are available online.

Chemical Labeling

During your chemical inventory, check the labels on the containers. Make sure that they are legible and have all the required information on them. *(See Section V – Labeling)*. If necessary, replace the label with a proper GHS label.

Laboratory Equipment

Is all the laboratory equipment functioning properly? Is the fume hood working and exhausting as designed? Do all the gas, air and water outlets work? Does the emergency shower and eyewash provide the proper volume of water at the correct temperature? Do you have enough beakers, test tubes, vials and glassware? Take an inventory of these items, to find out if something needs to be replaced or repaired. Don't wait until you need the equipment to find out its broken—there may be a lead time on orders for replacements and repairmen may not be immediately available.

Success

If you effectively used this handbook throughout the year, the educational experience you provided to your students was successful and rewarding. The information presented in this section will help you provide the same rewarding educational experience to your incoming students.

XV. Common Problems

Safety should be your number one concern. Not anticipating and preparing for possible emergencies is the main fault in most chemistry programs. Once you have decided which experiments and demonstrations you will present for the upcoming year, you need to break them down to determine necessary safety procedures and physical protection measures. Good planning and constant maintenance of your program is a must throughout the whole year.

One of the many important words found throughout this handbook is “proactive.” In being proactive, you need to plan for contingencies, including possible accidents. As careful as you may be, and as many precautions as you take, the potential of an accident is always there. If an accident occurs, what are you going to do? Do you have the proper procedure in place? Are you going to evacuate? Who do you contact? Are you qualified to clean up a spill? Do you have the proper equipment and materials to clean up a spill? How do you dispose of the residue? Know this information and have the right materials in place to properly react. Many simple accidents in the chemistry classroom or laboratory have turned into major disasters because precautionary measures were not taken—personnel were not proactive.

One way to be proactive is to fully understand any chemicals, and their inherent hazards, before you and your students use them. Safety Data Sheets (SDS’s) provide chemical- or mixture-specific hazards and emergency response information. Read the SDS and teach the students how to read it as well. Do not wait for an exposure or accident to find how to respond. Read, understand, and prepare.

A good teacher is a good communicator. As part of teaching the students about chemicals, you must also teach the importance of hazard awareness and safety. If students do not understand every detail of the information, there could be an accident in the making. When presenting an experiment, review the applicable SDS or SDS’s and completely walk through the experiment, step by step, before students perform the experiment themselves. Many students comprehend a concept more fully if it is shown rather than explained. As some students will not ask clarifying questions, be sure to confirm their comprehension by asking them questions yourself. Ultimately, their safety is your responsibility.

Facilities vary greatly in size and suitability for the purpose of chemistry education. Purchase chemicals appropriate to the safety features of the room, and your available budget. Limit overstock and subsequent waste of chemicals for both safety and economical reasons. Dispose of chemicals you have on-hand but have no foreseeable use for. This helps to keep storage areas clear and safe. In storage areas, shelves are adequate for most chemicals (excluding highly flammables, combustibles, and acids), but safety cabinets are better. For laboratories with limited storage space, safety cabinets are all the more important. Keep chemicals locked up.

Teaching chemistry is an area of expertise. You have got to know your subject matter, what to look for, and what to expect, because common problems in the chemistry laboratory are not necessarily common sense issues. Be diligent, because many problems arise from complacency. With a little work, proactive planning, and safety initiatives, you can provide an accident free educational experience for your students.

XVI. Ward's Science – Demonstrations to Get Students' Attention

Ward's Science demonstrations have been tested and reviewed, and are designed for maximum impact and maximum safety.

Ward's Science recommends that all demonstrations follow the American Chemical Society National Chemistry Week Demonstration Guidelines, on the next page, and that all prudent safety precautions be taken.

Each Ward's Science demonstration includes a materials list, safety requirements, a detailed procedure, follow-up notes, possible topic extensions, and disposal/cleanup recommendations. Always use proper disposal techniques, per local and state regulations.

Ward's Science Demonstrations include:

- Blue Bottle (Redox Reactions)
- Burning Money (Combustion Reactions)
- Colors of Manganese Ions (Oxidation States of an Element)
- Crushing Can (Atmospheric Pressure)
- Crystal Ball (Supersaturated Solutions)
- Density Column (Density of Liquids and Solids)
- Disappearing Ink (pH Indicator Color Changes)
- Disappearing Water (Super-Absorbent Polymers)
- Fear of Water (Hydrophobia)
- Freezer Flask (Endothermic Reactions)
- Glow in the Dark (Chemiluminescence)
- Iodine Clock Reaction (Chemical Kinetics)
- Joke Juice (Polymer Cross-Linking)
- Orange Clock (Electrochemistry)
- Under Pressure (Expansion/Contraction of Gases)
- What's That Smell? (Ester Synthesis)

Chemical Demonstration Guidelines

The American Chemical Society's Division of Chemical Education has published safety guidelines for *National Chemistry Week*, applicable to all demonstrations. The complete text of the Guidelines can be found on the Internet at the ACS website: http://www.chemistry.org
Type "Chemistry Demonstrations" in the Search window to access the document.

Minimum Safety Guidelines for Chemical Demonstrations
ACS Division of Chemical Education

Chemical Demonstrators Must:

1. Know the properties of the chemicals and the chemical reactions involved in all demonstrations presented.
2. Comply with local rules and regulations.
3. Wear appropriate eye protection for all chemical demonstrations.
4. Warn members of the audience to cover their ears whenever a loud noise is anticipated.
5. Plan the demonstration so that harmful quantities of noxious gases (e.g., NO_2, SO_2, H_2S) do not enter the local air supply.
6. Provide safety shield protection wherever there is the slightest possibility that a container, its fragments or its contents could be propelled with sufficient force to cause personal injury.
7. Arrange to have a fire extinguisher at hand whenever the slightest possibility of fire exists.
8. Not taste or encourage spectators to taste any nonfood substance.
9. Not use demonstrations in which parts of the human body are placed in danger (such as placing dry ice in the mouth or dipping hands in liquid nitrogen).
10. Not use open containers of volatile, toxic substances (e.g., benzene, CCl_4, CS_2, formaldehyde) without adequate ventilation as provided by fume hoods.
11. Provide written procedure, hazard, and disposal information for each demonstration whenever the audience is encouraged to repeat the demonstration.
12. Arrange for appropriate waste containers for and subsequent disposal of materials harmful to the environment.

Revised 4/1/95

Blue Bottle

Purpose

To develop a model of a redox reaction where oxygen gas is the oxidizing agent.

Materials

- Sodium hydroxide, NaOH
- Glucose, $C_6H_{12}O_6$
- Methylene blue (1% in isopropyl alcohol)
- 500-mL Erlenmeyer flask with rubber stopper
- Electronic balance

Safety

- Read the SDS sheets for all chemicals before using them.
- Wear safety glasses, gloves, and lab coat.
- Sodium hydroxide is caustic. Handle with care.

Procedure

1. Add 200 mL of water to the 500 mL Erlenmeyer flask.
2. Add 5.0 g of sodium hydroxide. Stir to dissolve.
3. Add 5.0 g of glucose. Stir to dissolve.
4. Add 50 mL of water to the solution in the flask.
5. Add about 10 drops of 1% methylene blue indicator.
6. Firmly seal the flask with the appropriate sized rubber stopper.
7. Let the blue solution sit undisturbed.
8. Shake the container several times after the solution becomes colorless, then leave undisturbed.

Results

- The solution turns colorless upon standing.
- The contents of the flask are clear but turn blue upon shaking.
- When left undisturbed the flask contents turn clear.
- The process can be repeated several times.

Follow-up Teaching Notes

- Make the solutions just prior to use.
- The oxygen that dissolves upon shaking oxidizes the colorless methylene blue, turning it blue.
- The glucose reduces the blue dye, turning it back to its colorless form.
- **Related Lab:** Ward's Science Lab Activity Oscillating Reactions: The Traffic Light (470219-088)
    - Uses 20 drops of indigo carmine solution (1% in water) or 4-5 small crystals instead of methylene blue and a green to red-orange to yellow transition occurs:
    - If yellow solution is shaken gently, it will turn red-orange in color.
    - If yellow solution is shaken more vigorously, the red-orange color solution will turn green in color.

Connections

- Redox reactions, developing a model.
- Photochemical reactions in alternate demo.

Extension

- Photochemical variation:
    - Add 2.0 g of iron(II) sulfate to 100 mL of 0.1 M sulfuric acid solution in a 250 mL Erlenmeyer flask.
    - Add a couple of crystals of methylene blue. Mix.
    - The solution should turn nearly colorless when placed on an overhead projector. (if it remains blue, then dilute the solution).

- Upon removal from the light, source the solution returns to blue color.

Disposal/Clean-up

- Neutralize the solution before washing the products down the drain (add dilute hydrochloric acid, <0.5 M, until the pH is approximately 7. Check local codes before starting any disposal activity.

Burning Money

Purpose

To illustrate a combustion reaction involving a solution with a low combustion temperature.

Materials

- Paper ($20.00 bill or piece of white paper towel)
- Isopropyl alcohol, 99%
- (1) 400-mL beaker
- Crucible tongs
- Container of water (to extinguish the burning paper)

Safety

- Read the SDS sheets for all chemicals before using them.
- Wear safety glasses, gloves, and lab coat.
- Alcohol is highly volatile and flammable. Ensure no open flames are present (candle, Bunsen burner).
- Avoid inhalation of alcohol vapors
- Burning drops of alcohol may fall from the bill so ensure the audience is at least 1 meter away.

Procedure

1. Pour 100 mL of water into a 400-mL beaker.
2. Add 100 mL of isopropyl alcohol to the beaker. Stir.
3. Soak the bill or paper towel in the solution and then remove with crucible tongs.
4. Light the bill.
5. Extinguish the paper by waving it in the air or submerging it into a container of water.

Results

- Soaked paper ignites into a blue flame but the paper does not burn.

Follow-up Teaching Notes

- Soaked paper ignites into a blue flame but the paper does not ignite due to its combustion temperature, 232 ^{0}C.
- Ethanol and water in a 2 to 1 ratio by volume works as well.

Connections

- Combustion, enthalpy of reaction, flammability.

Extension

- Add some salt to the solution to color the flame and make it more visible. (Ex.: Sodium chloride colors the flame yellow instead of blue).

Disposal/Clean-up

- Unused solution can be stored in a sealed and properly labeled container for reuse.
- Alcohol soaked paper should be rinsed thoroughly with water after using it.

Colors of Manganese Ions

Purpose

To illustrate the various oxidation states of an element.

Materials

- Potassium permanganate, $KMnO_4$ (0.1 M)
- Sodium hydroxide, NaOH (2.0 M)
- Sulfuric acid, H_2SO_4 (3.0 M)
- Sodium bisulfite, $NaHSO_3$ (0.1 M)
- EDTA (1.0 M)
- Manganese(II) sulfate, $MnSO_4$ (powder)
- (5) 100-mL beakers
- 50 mL graduated cylinder

Safety

- Read the SDS sheets for all chemicals before using them.
- Wear safety glasses, gloves, and lab coat.
- Concentrated acids and bases are used.
- Permanganate solution will stain.

Procedure

1. Pour 50 mL of 0.1 M potassium permanganate in five 100-mL beakers (labeled 1 to 5).
2. To beaker number 1 add 15 mL of 3.0 M sulfuric acid and then, while stirring slowly, add 0.1 M sodium bisulfite until a color change takes place.
3. To beaker number 2 add 20 mL of 2.0 M sodium hydroxide and then, while stirring slowly, add 0.1 M sodium bisulfite until a color change takes place.
4. To beaker number 3 slowly add 0.1 M sodium bisulfite while stirring until a color change takes place.
5. To beaker number 4 add 5 mL of 1.0 M EDTA and a pinch of solid manganese(II) sulfate; then stir.

Follow-up Teaching Notes

- The chart below outlines color corresponding to the various oxidation states of manganese

Beaker	Oxidation State of Mn	Color
1	+2	colorless
2	+6	green
3	+4	brown
4	+3	violet/rose
5	+7	purple

Concepts

- Oxidation states, balancing redox equations.

Extension

- Students can be asked to write balanced equations for beakers 1, 2, and 3 if they are told the oxidation half-reaction is $HSO_3^{-1} \rightarrow SO_4^{-2}$
- The reduction half-reaction is $MnO_4^{-1} \rightarrow Mn^{?}$ where the ? refers to the oxidation state of manganese in the appropriate beaker.

Disposal/Clean-up

- Remaining contents can be placed in the science department's heavy metal waste container for proper disposal.

Crushing Can

Purpose
To illustrate the presence of atmospheric pressure.

Materials
- Empty pop can (or large metal container with lid)
- Aluminum pie plate
- Hot plate or Bunsen burner
- Wire gauze square held by a support ring and stand
- Beaker tongs
- Water

Safety

- Wear safety glasses when working with the Bunsen burner.

Procedure
1. Add water to an empty pop can until the bottom is covered to a depth of ~1 cm.
2. Using a hot plate, heat the can to a point that steam is visible from the opening. A Bunsen burner can be used to heat the can but do not heat the can directly with the flame. Place the can on a wire gauze square that is held by a support ring and stand.
3. Continue heating for a minute. Then, using beaker tongs, carefully and quickly invert the can in an aluminum pie plate containing water (or a plastic dish tub half filled with water).

Results
- When the can is inserted into the liquid, it is crushed.

Follow-up Teaching Notes
- The generation of steam pushes air out of the can.
- Upon inversion in the cold water, the steam condenses back to liquid water, causing a decrease in pressure relative to its surroundings.
- The atmospheric pressure crushes the can as a result (implosion).

Connections
- Atmospheric pressure, changes of state.

Disposal/Clean-up
- The pop can may be recycled.

Crystal Ball

Purpose
To illustrate the crystallization of a supersaturated solution.

Materials

- Sodium acetate trihydrate, $CH_3COONa \bullet 3H_2O$
- Round bottom flask or Erlenmeyer flask with rubber stopper
- Hot plate or Bunsen burner
- Wash bottle
- Distilled water

Safety

- Read the SDS sheets for all chemicals before using them.
- Wear safety glasses and gloves.

Procedure

1. Fill a very clean flask with sodium acetate trihydrate crystals.
2. Heat the flask on a hot plate (or gently with a Bunsen burner) until the crystals dissolve in their own water of hydration. (A small amount of water can be added if needed).
3. Continue heating the liquid for a couple of minutes but do not let it boil over.
4. Allow the liquid to cool to room temperature, undisturbed.
5. Wash down the sides of the flask with a small amount of distilled water; then gently stopper the flask.
6. When ready, remove the cap and add one small crystal of sodium acetate trihydrate.
7. Have students feel the flask immediately after crystallization has taken place.

Results

- Upon addition of the seed crystal to the supersaturated solution, the crystal starts to grow outwards until the entire flask is solid white.
- The flask should feel warm.

Follow-up Teaching Notes

- The flask feels quite warm to the touch due to the release of heat upon crystallization

$$\text{solute}_{(aq)} \rightarrow \text{solute}_{(s)} + \text{heat}$$

Connections

- Solutions (super saturation), heat of solution.

Extension

- Slowly drip saturated sodium acetate solution on a desk from a buret to produce a crystal column.

Disposal/Clean-up

- The flask can be sealed and reused many times (a small of amount of water may be needed to aid dissolving).

Density Column

Purpose

To illustrate the concept of density by making a density column that can be used to determine the relative densities of several solid objects.

Materials

- Syrup (brown) or light corn syrup
- Dishwashing detergent (green)
- Water (colored red with food coloring)
- Vegetable oil (yellow)
- Ethanol (colored blue with food coloring)
- 250-mL glass graduated cylinder
- Small ice cube
- Small cork
- Small piece of chalk

Safety

- Read the SDS sheet for ethanol.
- Ethanol is highly volatile and flammable. Ensure no open flames are present (candle, Bunsen burner).
- Wear safety glasses and gloves.
- Avoid inhalation of ethanol vapors.

Procedure

1. Pour 50 mL of syrup in a 250-mL glass graduated cylinder and let the liquid settle.
2. Tilt the graduated cylinder and pour 50 mL of dishwashing detergent slowly down the side of the cylinder. Then, let the liquid settle in the upright position. The detergent should form a layer on top of the syrup.
3. Repeat step 2 for the other liquids: red colored water, vegetable oil, and blue colored alcohol.
4. Drop in various items (ice, cork, chalk, …) and observe the level at which the object sinks or floats.
5. Cover the cylinder in plastic wrap and leave undisturbed for several days before re-examining.
6. Shake the graduated cylinder and re-examine after several minutes.

Results

- The colored liquids layer in the column (from bottom to top: brown, green, red, yellow, blue).

Follow-up Teaching Notes

- The liquids, with the exception of the oil, are miscible so care must taken when layering them.

Connections

- Density, separation methods, solubility, diffusion.

Extension

- Students could determine the densities of the liquids to generate order of pouring the liquids.
- The actual densities of the solids can be determined and compared to their position in the density column.

Disposal/Clean-up

- Contents of the cylinder can be safely poured down the drain but ensure that solids are strained out or removed from the sink trap and placed in the garbage.

Disappearing Ink

Purpose
To illustrate the effect of pH change on indicator color.

Materials

- Thymolphthalein
- Ethanol
- Sodium hydroxide solution, NaOH (0.1 M)
- 100-mL beaker or bottle

Safety

- Read the SDS sheets for all chemicals before using them.
- Wear safety glasses and gloves.
- Sodium hydroxide is caustic; handle with care.

Procedure

1. Dissolve a small amount of thymolphthalein in ~10 mL of ethanol.
2. Slowly add 40 mL of water while stirring.
3. Add aqueous sodium hydroxide solution, 0.1 M, dropwise, until solution turns dark blue.
4. The resulting solution can be used as disappearing ink.

Results

- The ink disappears over time.

Follow-up Teaching Notes

- Thymolphthalein is blue above pH 10 and colorless below pH 9.
- The ink solution becomes colorless as it absorbs carbon dioxide from the air

$$2\,NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

Connections

- acid/base indicators, pH.

Extension

- Two common invisible inks are:

  $AgNO_{3\,(aq)}$, which can be developed by light
  $CuSO_{4\,(aq)}$, which can be developed by ammonia

Disposal/Clean-up

- The paper can be disposed of in the garbage.
- Extra ink can be placed in a sealed and properly labeled container for reuse.

Disappearing Water

Purpose
To illustrate the absorbing power of the polymer found in diapers.

Materials
- Acrylic sodium salt polymer (A.S.A.P.), diaper powder, potassium polyacrylate
- Styrofoam cup
- Bottle of water
- Piece of cardboard

Safety

- Read the SDS sheet for acrylic sodium salt polymer.
- Wear safety glasses and gloves.
- Water/powder may fall out of cup.

Procedure
1. Cover the bottom of a white Styrofoam cup with a thin layer of ASAP powder prior to class.
2. Show the class that the cup is empty by tilting it towards them. (The diaper powder is white and as a result cannot be seen.)
3. Pour a small amount of the bottled water (~10 mL) into the cup.
4. Glance in the cup to check if all the powder was wetted by water. If not, add some more water.
5. Place a piece of cardboard over the top of the cup and then invert the cup.
6. Place the cup over a student's head and then remove the cardboard.
7. Allow the student to look up and then reveal the empty cup to the class.
8. The addition of water can be repeated several times, but be careful near the end or someone may get wet.

Results
- The diaper powder turns to a damp white gel, which remains stuck to the bottom of the cup upon addition of water.

Follow-up Teaching Notes
- Diaper powder absorbs ~900 times its own mass of water.

Connections
- Polymers.

Extension
- Have students design a lab to determine the absorbing capacity of the powder and/or what conditions affect absorbance.

Disposal/Clean-up
- The cup and contents can be disposed of in the garbage.

Fear of Water

Purpose
To illustrate the hydrophobic effect.

Materials
- Hydrophobic sand
- Ethanol
- Water
- Filter paper
- Funnel
- (2) 400 mL beakers

Safety
- Read the SDS sheet for ethanol.
- Wear safety glasses and gloves.
- Alcohol is highly volatile and flammable. Ensure no open flames are present (candle, Bunsen burner).
- Avoid inhalation of alcohol vapors

Procedure
1. Pour 200 mL of water into a 400-mL beaker.
2. Sprinkle some hydrophobic sand onto the water.
3. Try to push the sand down with your finger.
4. Sprinkle more sand into the beaker so that some falls to the bottom.
5. Pour 200 mL of ethanol into a second 400-mL beaker.
6. Sprinkle hydrophobic sand into this second beaker and observe.

Results
- The hydrophobic sand remains on the surface of the water when a small amount is sprinkled on the water.
- The sand appears to stick to the finger when submerged.
- When large amounts of sand are added, intestinal shapes form at the bottom of the beaker.

Follow-up Teaching Notes
- The non-polar sand does not mix with the polar water molecules.
- The sand appears to bond together in water, giving rise to the concept of hydrophobic bonding.
- Effect disappears with ethanol, or if regular sand is used in water.

Connections
- Hydrogen bonding, hydrophobic bonding, surface tension.

Extension
- Can explore the effects of detergents on surface tension of water.

Disposal/Clean-up
- Recollect the sand for reuse by filtration.
- The used water can be washed down the drain.
- The used alcohol can be washed down the drain with lots of water.

Freezer Flask

Purpose

To illustrate an endothermic reaction involving reactants in the solid state.

Materials

- Barium hydroxide 8-hydrate, $Ba(OH)_2 \cdot 8H_2O$
- Ammonium thiocyanate, NH_4SCN
- 500-mL Erlenmeyer flask with rubber stopper
- Wood board
- Electronic balance
- Water

Safety

- Read the SDS sheets for all chemicals before using them.
- Ammonia gas is produced. Avoid inhalation. (You may wish to do this demonstration in a fume hood)
- Wear safety glasses, gloves, and lab coat.
- Firmly hold the rubber stopper to prevent it from popping off.

Procedure

1. Pour a small amount of water (enough to ensure good contact with the base of the Erlenmeyer flask) on a square wooden board.
2. Place 50 g of barium hydroxide octahydrate and 25 g ammonium thiocyanate into the Erlenmeyer flask. Place a rubber stopper in the flask. Swirl to mix.
3. Place the flask in the puddle of water on the board.
4. Lift the flask after a few minutes.

Results

- The reaction vessel gets cold enough to freeze the water between the board and the flask.

Follow-up Teaching Notes

- Energy absorbed by the reaction freezes the water so that the board will be attached to the flask.
- Reaction is:

$Ba(OH)_2 \cdot 8H_2O_{(s)} + 2\ NH_4SCN_{(s)} \rightarrow Ba(SCN)_{2(aq)} + 2\ NH_{3\ (g)} + 10\ H_2O_{(l)}$

- Ammonium nitrate can be a substitute for ammonium thiocyanate.

Connections

- Enthalpy and heat of reaction, reaction between two solids.

Extensions

- Demonstration of an endothermic reaction: dissolve ammonium chloride in water.
- Demonstration of an exothermic reaction: dissolve calcium chloride in water.

Disposal/Clean-up

- Open the flask in a fume hood and allow the ammonia to evaporate overnight.
- Remaining contents can be placed in the science department's heavy metal waste container for proper disposal.

Glow in the Dark

Purpose
Illustrate a chemical change involving chemiluminescence.

Materials
- Sodium carbonate 10-hydrate, $Na_2CO_3 \bullet 10H_2O$
- Sodium bicarbonate, $NaHCO_3$
- Luminol (3-aminophthalhydrazide)
- Ammonium carbonate monohydrate, $(NH_4)_2CO_3 \bullet H_2O$
- Copper(II) sulfate 5-hydrate, $CuSO_4 \bullet 5H_2O$
- (2) 1-L Erlenmeyer flasks
- (2) 400-mL glass beakers
- 100-mL graduated cylinder
- Electronic balance
- Deionized water

Safety
- Read the SDS sheets for all chemicals before using them.
- Wear safety glasses, gloves, and lab coat.
- Have an audience member remain by the light switch so no one has to move while the lights are dimmed.

Procedure
1. Add 500 mL of deionized water to a 1-L Erlenmeyer flask labeled "Solution A".
2. Add 10.7 g of sodium carbonate to Solution A. Stir.
3. Add 0.2 g of luminol to Solution A. Stir.
4. Add 24.0 g of sodium bicarbonate to Solution A. Stir.
5. Add 0.5 g of ammonium carbonate to Solution A. Stir.
6. Add 0.4 g of copper sulfate to Solution A. Stir.
7. Add deionized water to Solution a flask to a final volume of 1 L.
8. Add 950 mL of deionized water to a 1-L Erlenmeyer flask labeled "Solution B.
9. Add 50 mL of 3 % hydrogen peroxide to Solution B. Stir.
10. Pour equal volumes (~100 mL) of Solution A and B into separate beakers.
11. Dim the lights and then mix the solutions in the two beakers together.

Results
- Upon mixing, the resulting solution glows for several minutes.

Follow-up Teaching Notes
- The two solutions can be poured simultaneously down a clear spiral plastic tube for a more dramatic effect.

Concept
- Chemiluminescence.

Disposal/Clean-up
- The resulting solution can be placed in the science department's organic waste container for proper disposal by a licensed disposal company.

Iodine Clock Reaction

Purpose
To illustrate a time-delayed reaction, which leads to the exploration of several factors which affect reaction rate.

Materials
- Soluble starch
- Potassium iodate, KIO_3
- Sodium hydrogen sulfite (sodium bisulfite), $NaHSO_3$
- Sulfuric acid, H_2SO_4 (1.0 M)
- (2) 1-L Erlenmeyer flasks
- (2) 400-mL beakers
- 1 ea. 25-mL and 100-mL graduated cylinders
- Distilled water
- Stirring rod
- Electronic balance
- Timer (optional)

Safety
- Read the SDS sheets for all chemicals before using them.
- Wear safety glasses and gloves.

Procedure
1. Prepare Solution A in a 1-L Erlenmeyer flask (Flask A) containing 0.9 L of water.
2. Add 2 g of potassium iodate to Flask A. Stir.
3. Add distilled water to Flask A to make a total volume of 1 L.
4. Prepare Solution B in a 1-L Erlenmeyer flask (Flask B) containing 0.9 L of boiling water.
5. While stirring, slowly add 4.0 g of soluble starch to Flask B.
6. Add 0.8 g of sodium bisulfite to Flask B. Stir.
7. Add 10.0 mL of 1.0 M sulfuric acid to Flask B. Stir.
8. Add distilled water to Flask B to make a total volume of 1 L.
9. Allow Flask B to return to room temperature.
10. Pour 100 mL of Solution A in a 400-mL beaker (Beaker A).
11. Pour 100 mL of Solution B in a second 400-mL beaker (Beaker B).
12. Pour the solution in Beaker B into Beaker A, and mix.
13. Start the timer (optional).

Results
- Upon mixing the two reactants, the resulting solution turns dark blue after a set amount of time.

Follow-up Teaching Notes
- Time the reaction just prior to the demonstration so you can say a "magic word" to activate the reaction.
- Prepare the solution no earlier than the day before you plan to do the demonstration.

Connections
- Rates of reaction.

Extensions

- Allow students to investigate the effect of concentration on rate of reaction by diluting a known amount of Solution B with a known amount of water.
- Allow students to investigate the effect of temperature on rate of reaction by heating and cooling the contents of Beaker A and Beaker B.

Disposal/Clean-up

- The solutions can be disposed of down the drain. Consult local regulations before any disposal activity.

Joke Juice

Purpose
Illustrate the effect of cross-linking on a polymer.

Materials

- Guar gum
- Borax, sodium tetraborate decahydrate, $Na_2B_4O_7 \bullet H_2O$
- Red food coloring
- Glass stirring rod
- Empty glass juice bottle (~300 mL)
- Distilled water
- 100-mL graduated cylinder
- 100-mL beaker
- Electronic balance

Safety

- Read the SDS sheets for all chemicals before using them.
- Wear safety glasses and gloves.
- Remove the original label from the juice bottle and clearly label the container to ensure it is not mistaken as drinkable juice.

Procedure

1. Prepare 25 mL of a saturated solution of sodium borate by mixing borax with water until no more dissolves. (solubility ~1 g / 16 mL H_2O)
2. Add 100 mL of distilled water into the empty glass juice container.
3. Add 3 drops of red food coloring.
4. Add 0.6 g of guar gum and stir until dissolved.
5. While swirling the liquid in the bottle, slowly add 5 mL of the saturated borax solution prepared in step 1.
6. Cap the juice bottle.

Results

- The addition of sodium borate to an aqueous suspension of guar gum produces a cross-linked gel.
- The resulting cross-linked polymer forms a red gel that looks like juice.

Follow-up Teaching Notes

- The juice bottle can be opened and quickly shaken forward and back causing the gel to partially leave the bottle walls and then quickly snap back.

Connections

- Polymers, cross-linking.

Extension

- Borax solution and Elmer's glue is an example of cross-linking where varying the amount of borax solution produces the effect of slime or Silly Putty.
- Nylon demonstration kit (available from Ward's distributors) is another great example of a polymer synthesis.

Disposal/Clean-up

- The natural polymer can be disposed of in the garbage.

Orange Clock

Purpose
To illustrate several principles of batteries by using orange juice to power an electric clock.

Materials

- Magnesium strip or ribbon
- Copper strip
- Orange juice
- Steel wool (not a soap pad)
- Electrical leads (with alligator clips)
- Battery powered clock (variety that requires a single 1.5 V AA battery)
- 250-mL beaker

Safety

- Read the SDS sheets for all chemicals before using them.
- Wear safety glasses and gloves.
- Do not taste the orange juice!

Procedure

1. Clean a strip of magnesium and a strip of copper with steel wool.
2. Pour ~200 mL of orange juice into a 250-mL beaker.
3. Connect an electrical lead to one end of the magnesium strip and submerge the other end in the orange juice. (You could tape it to the side of the beaker).
4. Connect the second electrical lead to one end of the copper strip and submerge the other end in the orange juice on the opposite side of the beaker.
5. Connect the other ends of the electrical leads to the battery compartment of a clock that would normally run on a single AA battery.
6. If the clock does not run, reverse the electrical leads in the battery compartment.

Results

- The second-hand of the clock will begin to move upon connection to the electrical leads.

Follow-up Teaching Notes

- A voltaic (galvanic) cell is created with the magnesium the anode and the copper the cathode.
- The components of the cell can be changed to explore the key components (i.e., change one of the metal electrodes) of a voltaic (galvanic) cell.

Connections

- Electrochemistry, redox reactions, voltaic (galvanic) cells.

Extension

- Connect two or more cells in series to generate a higher voltage.

Disposal/Clean-up

- The orange juice can be disposed of down the drain.
- The metal strips (electrodes) can be cleaned and reused.

Under Pressure

Purpose
To illustrate expansion of gases under reduced pressure.

Materials
- Shaving cream
- Marshmallow
- Soda water
- Doll's head
- Balloon
- Tape
- Vacuum pump with bell jar

Safety
- Wear safety glasses and gloves.
- Ensure there are no cracks in the bell jar.

Procedure
1. Fill an empty doll's head with shaving cream from the neck opening. Ensure openings are present at the eyes and ears.
2. Tape the neck opening closed.
3. Place the doll's head in a bell jar connected to vacuum pump.
4. Evacuate the chamber of air.
5. Other items that can be placed in the bell jar include soda water, small balloon, or a marshmallow.

Results
- As the surrounding pressure decreases, the shaving cream/marshmallow expands.

Follow-up Teaching Notes
- Shaving cream is a foam (type of colloid) that consists of a gas evenly distributed in a liquid.
- As the surrounding pressure is decreased, the gas expands in size.

Connections
- Gas laws, solubility of gases, decompression sickness, colloids

Extension
- Can be related to decompression sickness.

Disposal/Clean-up
- The marshmallow and shaving cream can be disposed of in the garbage.
- The soda water can be washed down the drain.

What's That Smell?

Purpose
Illustrate the variety of odors that are produced from esters.

Materials

- Organic alcohols in dropper bottles (see chart below for suggested alcohols)
- Organic acids in dropper bottles (see chart below for suggested acids)
- Sulfuric acid, H_2SO_4 (18 M)
- Sodium carbonate, Na_2CO_3
- Test tubes
- Test tube holder
- Bunsen burner

Safety

- Read the SDS sheets for all chemicals before using them.
- Wear safety glasses and gloves.
- Waft vapors when detecting odors.
- Concentrated acids are used.

Procedure

1. In a test tube, add 15 drops of ethanol to 20 drops of glacial acetic acid.
2. Add one drop of concentrated sulfuric acid.
3. Mix the reactants by gently tapping the test tube.
4. Gently heat the bottom of the test tube for several minutes. Keeping the test tube on a slight angle helps control vapor loss. If the solution starts to boil, remove it from the heat.
5. Add a small amount of sodium carbonate to neutralize any excess acid.
6. Carefully smell by wafting. Dilute with water if the smell is too strong.
7. See the chart for more combinations. Use 0.5 g of solid acids such as salicylic acid.

Results

- Vary depending on the organic acid and alcohol used (see reference chart below).

Follow-up Teaching Notes:

- Ester reference chart

Acid	**Alcohol**	**Odor**
acetic acid	ethanol	nail polish remover
acetic acid	1-butanol	raspberries
acetic acid	2-butanol	strawberries
acetic acid	1-pentanol	pear
acetic acid	isoamyl alcohol	banana
benzoic acid	ethanol	cherry
salicylic acid	methanol	Wintergreen
anthranilic acid	methanol	Grape
butanoic acid	ethanol	pineapple

- The concentrated sulfuric acid acts a catalyst and as a dehydrating agent for the condensation reaction between the alcohol and the carboxylic acid.

- When using butyric acid, perform the demonstration in a fume hood due to the bad butyric acid odor.

Connections

- Organic synthesis, esters, condensation reactions.

Disposal/Clean-up

- Dispose of the esters down the drain with lots of water. Check local codes before any disposal activity.

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