SAFETY GUIDE IN THE HIGH SCHOOL
CHEMISTRY LABORATORY

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CHEMISTRY LABORATORY

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CHAPTER I

INTRODUCTION

Few places in the high school are as potentially dangerous as the chemistry laboratory. That more students have not been injured is a tribute to the teachers. For it is the neglect of observed facts about chemical handling, use and storing that makes many high school chemistry laboratories hazardous. It is the purpose of this report to review a number of the observed facts so the inference will be beneficial to high school chemistry teachers.

It is imperative that chemical safety be built upon two solid foundations; an understanding of the laws of chemistry and physics that govern the elements and their compounds, and a well organized plan for all the situations that may result from the chemical behavior or misbehavior of elements and compounds.

To the teacher, the safety education of the students is as much his responsibility as the chemical education of students. For this the teacher needs to implant in the students a frame of mind which dictates "safety" at all times. One science teacher in a private high school wrote: "For the past 12 years I have watched with great concern the action of my beginning class in chemistry. Would there be amoung this group one who would suffer irreparable damage to his body, through some needless and preventable accident? How tragic, if when time is short, I failed to point out some hazard and an accident occurred which would deprive one of our youngsters of an equal chance in life."[1] Not only this, but the need is pointed out by the fact of the death of a 42-year old junior high school teacher or the burning of another teacher, let alone the students involved. The careless handling or use of chemical substances does produce serious consequences.

To the manufacturers, money lost because of accidents includes not only that due to liability for compensation and disability payments under existing workmen's compensation laws, but also the losses from diminished production as a result of the worker's absences. The general increase in the number of personal damage suits based on accidents in other than industrial locations is noted and it is the opinion of the manufacturers that educational institutions will soon feel this trend. In the case of state institutions such damage suits might be directed against the individual instructor, since a state organization could not be sued without consent.[2]

An example of this is the decision of the Superior Courts of the state of California indicating very clearly that school districts, under the California statutes, are liable for accidents in laboratories and shops where negligence on the part of employees can be shown. In one

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1. John S. Shaw, "Is the School Laboratory a Frankenstein," _Journal of Chemical Education_, Vol. 21 (1944) pp 539-542

2. William B. Cook, and Alfred J. Perkins, "Safety in Chemical Laboratories," _Journal of Chemical Education_, Vol. 31 (1954), pp 95, 96 and 144

case, Counsel for the plaintiff in his closing arguments, (in a verdict of fifteen thousand dollars, with two thousand to his father for medical expenses) stated that school districts are liable for any injury to a student caused by the negligence of a school employee. The attorney presented with telling effect (on the jury) the seriousness of the injury to the boy in the loss of his eye and the consequent effect on his whole life, and argued that it is the duty of school authorities to have in mind the inexperience and lack of skill on the part of young boys, and eliminate from the course of study all things which constitute a hazard, saying that "it is better to leave a boy uneducated rather than to blind him."[3]

We cannot deny the force of this argument from a moral and social standpoint at least, and also must admit that the same argument made by able counsel is likely to result in a verdict against the school district in similar cases when the injury is as serious as the loss of an eye. If a state institution can not be sued then the suit can be directed against the teacher for failing to protect the student against his own carelessness. It has been particularly noticeable in reports of cases of accidents as passed upon by the Appellate or Supreme Court that in practically every case the injured student has denied having received any instruction or cautions leading to decisions against the school districts. It is apparent (from these court decisions) that the instructor's

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3. Park Lovejoy Turrill, "Public Liability and Chemical Education," Journal of Chemical Education, Vol. 10, (1933)

word alone is not sufficient to establish the fact that warnings to each pupil at the beginning of each year were given. The student should be required to pass a satisfactory written examination with his answers signed and preserved on file, in case of necessity, to prove that he had been warned. For even though we attempt to make certain that students are prevented from performing unauthorized experiments we cannot be everywhere at the same time.

CHAPTER II

FOR STUDENT SAFETY

For student safety a thorough presentation on laboratory safety at the beginning of laboratory work is time well spent. This presentation might come under the three headings: 1. Observe rules of safety 2. Familiarize the student with the surroundings and 3. Use plain old-fashioned common-sense.

A laboratory teacher has a great responsibility for the safety of his students. In observing regulations for safety, a rule such as: "No 'horse-play' can be tolerated" should head the list. Chemicals and apparatus must be treated at all times with care and respect. Laboratory accidents are usually the result of carelessness or ignorance, or both. The student that is permitted to do so can cause serious burns, injury-cuts, blindness, poisoning, suffocation not only to himself, but also to his classmates as well. Therefore, it is of utmost importance that teachers refuse to tolerate students who do not resist jostling or who move carelessly in respect to others.

The instruction in the use of tools and special equipment can be illustrated and introduced as the need for the equipment is presented in the different experiments. This more properly is laboratory technique and in the continual teaching of proper techniques, students gain safety habits. It takes continual vigilance.

In becoming familiar with the surroundings, teach the students to check glassware for chips, to locate exits, safety showers, fire extinguishers and the safety chart as well as the proper use of each.

The use of plain old-fashioned common-sense is difficult to teach, but by illustrating the right way and the wrong way of laboratory techniques, this can be done. In contrasting the right way with the wrong way, Fredric Walker gives the following:

The Right Way

1. Make sure that the bore of the stopper is of the proper size for the glass tubing to be used.

2. Fire polish the end of the glass tubing to be used.

3. Use glycerin or soap and water on the glass tubing as an aid in inserting it into the stopper.

4. Grasp the rubber stopper between the thumb and index finger in such a manner that the glass tubing will not come in contact with the hand when it passes through the stopper.

5. Grasp the tubing with the other hand as near the end to insert it as is convenient.

6. Insert the fire-polished end of the glass tubing into the bored hold of the stopper gently twisting the tubing or the stopper as force is exerted with both hands.[4]

The Wrong Way

1. Do not attempt to force glass tubing into a bored hole in the rubber stopper considerably smaller in diameter than the outside diameter of the glass tubing.

2. Do not insert glass tubing with jagged or rough ends.

3. Do not grasp the rubber stopper in such a manner that the end of the glass tubing will strike the hand holding the rubber stopper as the end of the glass tubing passes through this stopper.

4. Do not hold the glass tubing a considerable distance from the end to be inserted. This puts a lateral strain on the glass, which will cause it to break easily.

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4. Fredric Walker, "Safety in Chemical Laboratories", Journal of Chemical Education, Vol. 11, (1934) pp 506-09

Safety in the laboratory, as with safety in general, is largely a matter of thinking before you act. The following have been selected as aids to the teacher to help guide students in the elimination of many common accidents that occur in the High School Chemistry Laboratory.

When cutting glass tubing, it is always best to protect the hands with a piece of cloth. Hot glass looks the same as cold glass, so be careful.

Set up apparatus away from the edge of the desk to reduce the chances of it being knocked off.

In pouring a liquid, always grasp the bottle so that the label is in the palm of the hand. In this way, the drop that often runs down the side of the bottle will not come in contact with your hand or ruin the label. Hold the stopper between the knuckles of the hand holding the bottle. This avoids contamination of the stopper, or possible damage to you or the desk. All liquid reagents, particularly corrosive reagents, should be poured from the containers with the use of a pouring rod. This will obviate the possibility of small quantities of the reagent contaminating the sides of the container and, consequently, of burns from this source.

Be economical in the use of reagents and avoid obtaining more than is needed. Uncovered reagent bottles are prohibited and never return reagents that you have been using to the reagent bottle unless you are instructed to do so. Otherwise the reagents may become dangerously contaminated.

Keep your face away from any chemical being heated in open apparatus. Use goggles to protect your eyes.

Avoid deep breathing of unfamiliar gases. To avoid over inhalation the best plan is to hold the test tube or bottle of gas some distance away and then by wafting some of the escaping gas toward your nose by waving your cupped hand past the mouth of the tube toward your face.

Perform experiments that liberate poisonous vapors under ventilating hoods. Many chemical vapors are poisonous to breathe. Some deadly vapors cannot even be smelled.

Label accurately all bottles and other containers for chemicals and keep each in its proper place.

Read labels with care. It is best to read them twice, once before you remove something from a container and again as you are returning the container to the place from which you obtained it. Substances that look alike also may have similar names and only close scrutiny of the labels will prevent any possibility of your having serious accidents or making errors.[5]

Follow directions for disposing of waste. Do not throw paper, matches, broken glass, and other refuse that may clog the drains into the sinks or trough. If you wish to dispose of them, place them in the waste crock at the end of your laboratory bench. Also place all solid reagents for which no special receptacle is provided in the waste crocks. Special receptacles are available for the disposal of dangerous or inflammable chemicals.[6]

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5. Howard Nechamkin "Laboratory Problems in General Chemistry", (New York) 1953 Thomas Y. Crowell Co.

6. Ibid

You will wear an apron or laboratory coat at all times. Not even a highly skilled worker can entirely avoid spilling or spattering corrosive substances upon his clothing.

Keep all conversation at a minimum. When you find it necessary to converse with your neighbor, do so quietly. Address any question to your teacher. Do not annoy your neighbor with it. If your neighbor knows the answer, he is losing time while replying to you. If he does not, both of you are losing time.[7]

Familiarize yourself with the location and use of fire-fighting equipment in the laboratory, both hand extinguishers and connected water hose. Water can be used on all but oil and electric fires. Foam extinguishers put out oil fires. Carbon tetrachloride extinguishers are effective against electric fires. Carbon dioxide extinguishers can be used on all fires, but water may also be required for complete quenching.[8]

Obtain first aid immediately for any injury, no matter how slight. The teacher will decide what treatment should be given. He is responsible for your safety during the period and is qualified to assist you in emergencies.

Never neutralize a chemical in the eye with another chemical. Use water freely, gently, and continually until the doctor takes charge. A bubler drinking fountain is a good agency for washing eyes.[9]

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7. Howard Nechamkin "Laboratory Problems in General Chemistry", (New York) 1953 Thomas Y. Crowell Co.

8. John S. Shaw, "Is the School Laboratory a Frankenstein?" Journal of Chemical Education, Vol. 21 (1944) pp 539-542

9. Ibid. John S. Shaw

If strong acids, bases, or other corrosive chemicals are spilled on your skin, wash immediately with large volumes of water and then report to the teacher for first-aid treatment. Chemicals sometimes get in the eye but seldom in the mouth. However, washing with plenty of water is the first treatment in either case.

Good housekeeping and neatness are essential. Clean all spills immediately and be sure that all apparatus is absolutely clean before using and before putting it back.

In heating tubes, hold tube at an angle and keep it moving while heating. When heating a container or pouring liquids into it, do not point its mouth like a gun toward your neighbor or yourself. This can be demonstrated by all students with tap water.

Never mix chemicals unless so directed because many chemical combinations will explode.

To the student you can demonstrate what may happen by the careless concoting of chemicals by the chance mixing of apparently innocuous substances. On a sheet of asbestos use dried ammonium nitrate (granular) making a flat disk of it about 5cm (2in) in diameter and 5mm (0.2 in) thick. Then on this spread a smooth layer of zinc duct (also dry). Make a cavity in the center of the layer so that the white crystals of ammonium nitrate show through the layer of zinc. Now with a long rod or tube put one drop of water in the depression you have made and await results.[10]

Never drink from laboratory glassware.

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10. H. F. Davison, "Safety First in Storing Chemicals" Journal of Chemical Education, Vol. 2, pp 782-783

Do not taste anything unless the directions tell you specifically to do so, then follow given directions for tasting.

When in doubt STOP and CHECK. Consult your teacher if you are uncertain about any procedure or technique.

When your laboratory manual or teacher tells you that special precautions are necessary, be sure to exercise the precautions.

Each pupil should be taught to wash his hands at the end of each laboratory period.

One simple maxim is universally known: "Pour acid into water - never pour water into acids."

CHAPTER III

TEACHER BEWARE

The teacher is in charge of the chemistry laboratory and cannot properly delegate this to a student. It is also important that the teacher remain with the students through all experiments.

Courts invariably hold that an instructor was at fault if he was absent from the laboratory at the time of an accident. The only reason accepted is a summons from the Principal or Superintendent. The price of a smoke or a chat can be very high.

The students' safety in a beginning course in chemistry is greatly improved when the teacher goes through each new experiment with his class before he allows them to try it. In this way he can point out the right way to do the experiment, and underline the wrong way. The teacher is responsible for each laboratory experiment and should not depend on the students to remember previous safety precautions.

The following is a partial list of the things a teacher should beware of.

Consider beforehand the consequences - should apparatus break, take fire, or develop pressure or vacuum.

In the handling of glassware, only that glassware should be used which is strong and resistant to heat and sudden cold. Such a glass is pyrex, which is used almost universally in the laboratory today.

For the safe cutting of glass tubing and rods a glass tubing cutter should be used. The breaking should be done with the aid of a towel or cloth to protect the hands. Especially is this necessary when putting a piece of glass tubing through a stopper, either cork or rubber. Many chemists have suffered painful cuts through neglect of this rule. Sooner or later some student will cut himself after failing to follow this rule, and prove your point.

In heating glassware, thin test tubes may be heated directly in a flame, beakers and flasks should be protected by wire gauze or asbestos mats. When the glass contains liquid, the flame should never touch the glass above the level of the liquid in the vessel.

Sharp cork borers should be used to make holes in corks and rubber stoppers. When making the hole, hold the cork on a flat surface with one hand, push the borer with a rotary motion about half-way through in one direction. Then bore a hole from the other end of the cork. This will give a hole with smooth edges and will permit tight joints with tubing.

In collecting gases by the displacement of water there is danger of the water "sucking back" into the hot generator. Guard against this by removing the delivery tube from the water before the flow of gas stops.

Never allow students to use mouth pipets. Using the mouth to aspire a pipet is hazardous, unsanitary, and unscientific. A cotton plug in the upper end of the pipet offers protection neither to the student nor to the reagent. A common cause of mouth burns is the use of the mouth to fill a pipet. In handling dangerous liquids it is best to apply vacuum to fill the pipet with the aid of an aspirating bulb, suction pump, or rubber tubing connected to a water aspirator, or use a burette or a measuring cylinder instead.

Keep all fire-fighting equipment, such as hand extinguishers and connected water hose in good condition. Inspect them regularly. Drill students on the location and proper use of this equipment.

Never touch and always cut yellow phosphorus under water because it reacts violently with air.

Use calcium chloride in preference to sulfuric acid as a desiccating agent, because calcium chloride is not as corrosive as the acid.

Mercury is a very toxic substance. A concentration of one mg of mercury is ten cubic meters of air has been accepted by the American Standards Association as the maximum permissible concentration. At room temperature the mercury vapor at saturation may contain fifteen to twenty mg per cubic meter; consequently mercury should not be handled in the open.

In handling spilled mercury clean up by scooping it from one paper onto another without touching it with bare hands. Mercury spilled where it cannot be recovered, like in cracks or between tiles should be covered with flowers of sulphur. This combines with the mercury to form the sulphide and moreover enclosed minute mercury droplets in a non-volatile envelope.

Do not place bottles of volatile, flammable liquids in direct sunlight or near heat. Do not allow liquids to act as a lens in focusing rays of sunlight, and thus start fires.

If you must demonstrate the reaction of sodium with water never use a piece over two mm cube. Then let the students observe only from behind a glass shield and you wear a face shield.

For chlorates, sodium chlorate is illustrative of the class which presents a variety of hazards, such as fires and explosions, for this type compound. By itself it is a relatively stable chemical and lends itself to safe handling if the teacher knows:

1. Its chemical and physical properties.

2. Its reactions with strong acids; it can generate toxic chlorine dioxide and may cause explosions, since the reaction is exothermic.

3. Keep it out of contact (except under controlled conditions) with substances as - - -

Sulfur	alchols	oil and greases
sulfides	solvents	sawdust (wood dust)
phosphorous	ammonium compounds	lint (cotton)
sugars	powdered metals	vegetable dust

All of the above, and many other organic bodies, can cause fires or explosions when in intimate contact with the chemical.

4. Keep dry chlorate-contaminated clothing away from flames and guard against ignition by friction or percussion.[11]

The boiling point, great toxicity and exceptional fire hazard makes carbon disulfide extremely dangerous. It would be advisable for the teacher to keep it out of the laboratory as much as possible; usually a less dangerous substitute can be found. There is practically no part of the nervous system which is not affected by it. Recovery takes a long time.

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11. "Sodium Chlorate" (Revised), Manual Sheet SD-42, Manufacturing Chemists' Association, Inc.

Ammonium nitrate is a powerful oxidant so that mixtures of it and organic substances are particularly dangerous. Above one hundred and sixty degrees centigrade ammonium nitrate decomposes exothermically, producing gaseous products.[12]

Why some single compounds are explosive such as nitroglycerin, which releases approximately 1600 cal/g, is that it is identical with its heat of combustion, and it contains within itself all the oxygen necessary for combustion. The two factors are exothermic decomposition and oxygen balance. These properties characterize not only nitroglycerin, but most other hazardous compounds.

A compound containing an appreciable amount of oxygen, along with a significant quantity of nitrogen, should be suspected immediately. It would be foolhardy to ignore the potential danger of any compound, or mixture, where elemental components could undergo exothermic recombination with formation of very stable products.

Maximum explosive power is attained at about "zero oxygen balance". The oxygen balance concept is an old one and is defined as the percent excess or deficiency of oxygen required to completely oxidize all oxidizable elements in a given compound. Ammonium nitrate has the following:

$NH_4NO_2 \rightarrow N_2 + 2H_2O + 1/2\ O_2$ or an oxygen balance of plus twenty percent.[13]

In multicomponent systems explosives, the recombination of atoms from a relatively weakly bond state to much more stable state may occur

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12. H. A. J. Pieters, "Safety in the Chemical Laboratory" (New York, N. Y. 1951)

13. W. R. Tomlinson and L. F. Audriedth, "Uninvited Chemical Explosions," Journal of Chemical Education, Vol. 27 (1950) pp 606-09

where two or more components are brought together in proper proportions, especially if large volumes of gaseous products are formed. Some idea of the exothermicity of oxidant reductant mixtures can be gleaned from the reactions listed below:

REACTIONS	Heat of reaction, cal./g of mixture
1. $Ag_2O + Mg \rightarrow 2Ag + MgO$	540
2. $5BaO_2 + 2P\ (red) \rightarrow 2BaO + Ba_3(PO_4)_2$	540
3. $2KClO_3 + 3S \rightarrow 3SO_2(g) + 2KCl(g)$	395
4. $6HNO_3 + 5CH_3OH \rightarrow 5CO_2(g) + 13H_2O(g) + 3N_2$	1280

When an examination of a material for its probable decomposition products makes it apparent that such a compound approaches oxygen balance it has the earmarks of being hazardous. Certain grouping: $-ONO_2$, $-NHNO_2$, $=N-NO_2$, $-NO_2$, -NO, -N=N-, -O-O-; $-N_3$ all are potentially dangerous.

Peroxides are sold commercially, but there is not a guarantee that they are nonhazardous. Due to the extremely dangerous nature of peroxides, in general they must all be regarded as dangerous, unless the contrary is definitely known to be the case. Hydrogen peroxide is normally considered quite innocuous, perhaps because a dilute solution finds common household and industrial use. Concentrated hydrogen peroxide, on the other hand, is exceedingly dangerous. Mix peroxides with red phosphorous, sulfur, sulfides, and charcoal are likely to be very sensitive to impact and friction.

In the high school you may not have organic compounds, but each of these need close scrutiny before mixing with any other substance.

Dangerous chemicals should not be kept in quantities in the laboratory rooms, but should be safely stored under lock and key.

In preparing hydrogen always have students wrap the generator in cloth before adding the acid to the generator.

To put a piece of charcoal into a locker is punishable by fine in a certain laboratory. This is a wise and necessary precaution on the part of the teacher. Nothing holds the heat like charcoal and it is nearly impossible to tell when the fire on it is extinguished. If you must save these used pieces, place them in a sealed container when returning them to the storeroom.

A minomonic which may help pupils remember to pour acids into water - may be found in the spelling of "water". Pour the two into the mixing container in the order of the spelling. The "W" for water precedes the "A" for acid.

To protect people handling waste, have students use separate receptacles for broken glass, acids and inert dross. The receptacle should be clearly labeled as to contents and in convenient locations for student use. Volatile liquids require a clearly labeled, stoppered container. If disposal of corrosives is by pouring down the sink, they should be diluted and followed with copious amounts of water. Refuse should be collected at the close of each day or more frequently if necessary. Under no circumstances should it be permitted to accumulate. The sooner a heterogeneous mass is removed from the laboratory proper the less the chance of fire, explosions, or release of fumes.

CHAPTER IV

THE STORAGE ROOM

School facilities for science should include space for proper storage of all materials related to science. One of the essentials for the safe operation of a laboratory is an adequate, efficiently planned storage room. A safe place for glassware and chemicals must be provided. The usual common-sense rules of storage should be painstakingly followed even in the case of apparatus and supply stocks that in themselves are harmless. The storeroom for chemicals should be well ventilated and directly connected with the open. It should be equipped with fire doors, safety lamps, fire extinguishers, and a bucket of sand. The sand can be used on spilled liquids or to smother a fire.

Special attention should be given to the planning of the arrangement of reagents to prevent hazardous combinations or heating. Chemicals which might react together to produce dangerous fumes, fire or explosions demand storage space remote from each other. An example is: DO NOT store metallic sodium and metallic potassium near yellow phosphorous, if the sodium or potassium were accidentally returned to a container of phosphorous, there would be fireworks.

Good housekeeping can only be achieved by prior planning and rigid adherence to an adopted plan.

Tubing should be kept on racks and fragile apparatus stored so as to minimize the danger of breakage. They should not project beyond the shelf front. Shelf clamps should be provided for bulky or fragile apparatus, and wooden ridges along the front of storage shelves reduces the danger of tubing being spilled. The litter used by manufacturers to protect glassware from breakage during shipment is flammable. Do not leave the glassware in the container in the storeroom. Unpack it and store on shelves.

In addition to the storeroom door being locked it should be a strict requirement that every school must store its chemical in such a manner that no student may have access to heavy poisons. This can best be accomplished by having additional locked storage space in the storeroom. In this manner only, can the laboratory teacher be assured that no accidental dispensing occurs. When dispensing heavy poisons a check method should be followed step-by-step from the time it leaves the locked storage shelves through the final disposal. By preplanning the movement of all unsafe chemicals and overseeing their final dissipation, conscientious proof of a well directed safety program is assured.

Extremely hazardous compounds such as cyanides, fluorine compounds are of the heavy poison type. Also those that are prominently displaying the skull and crossbones and the word POISON. The extreme caution for cyanides is that the minimum lethal dose of some cyanides may be contained under a fingernail. This and other particularly lethal reagent need segregation from the other chemicals, by locked storage.

When arranging chemicals on shelves, provide ample space between bottles for grasping the bottles firmly, with the labels prominently displayed. The spacing can be maintained by wooden strips fastened in shelves.

If there is any hydrofluoric acid in the old type wax bottle, it should be stored where there is no possibility of the temperature reaching the softening or melting point of the wax bottle. More recent hydrofluoric acid containers are ployethylene and are not subject to this hazard.

Acids, bases, and solvents should not be stored adjacent to each other. There should be some segregation to decrease the possibility of forming dangerous mixtures in the case of breakage. Store the largest containers on the bottom shelves as near the floor as possible.

Two-liter bottles should be largest size containers in the storeroom for such reagents as concentrated sulfuric, hydrochloric and nitric acids. The glass containing liquid reagents of this type should be stored on lead lined trays, or in boxes containing a sufficient quantity of inorganic absorbent material (expanded vermicule or glass wool) to soak up their entire content, should the bottle break.

Store yellow phosphorous by submerging in water in a glass container which is placed in another container of metal, as the metal is less likely to be broken than the glass.

Carbon disulfide is so easily ignited that it can take fire from static electricity as it is being siphoned through a rubber tube. Volatile chemicals of this type should be stored in a cool place away from heating coils and protected from sunlight. The solvents should not be stored in glass bottles over one liter in size. Large quantities should be stored in metal safety cans. Quantities requiring containers larger than one gallon should be stored outside the laboratory.

The labeling of chemicals and solvents is done very carefully by the manufacturers. Yet a common failure in the labeling program has been the use of empty containers for other substances, the labels are not removed and serious accidents have resulted. When empty containers are salvaged, all marks and labels should be removed at the time the container is being cleaned. If the containers are not labeled, label them before filling.

"Warning Labels" is the title for the Manufacturing Chemists' Association publication which contains precise wording recommended for some 250 industrial and agricultural chemicals. It also covers labels for small packages and for samples and new products for investigational use. For example containers holding sulfuric acid will have attached labels bearing the following warning:

SULFURIC ACID

Danger! Causes severe burns
Do not get in eyes, on skin, on clothing.
In case of contact, immediately flush skin
or eyes with plenty of water for at least
15 minutes; for eyes, get medical attention.
Do not add water to contents while
in a container because of violent
reaction.

This type of brief information is intended solely for guidance of the industrial worker to warn him about the precautions to be observed for a particular material. Such brief warning can be useful for high school laboratories. The 98 page booklet is available from the Manufacturing Chemists' Association, Inc. 246 Woodard Building, Washington 5, D. C. for $1.00.

It should be noted that the definition of a "poison" as placed on the label by manufacturers included only chemicals capable of causing acute effects by ingestion and inhalation. This definition "excludes" chemicals capable of causing injuries as a result of skin absorption or chronic exposure by ingestion or inhalation which have cumulative or chronic toxic effects.

Unnecessary and all inadequately identified containers of chemicals should not be allowed to accumulate in the laboratory.

The preceeding is not all-inclusive. The purpose is to point out only a few of the common laboratory hazards for chemistry teachers to recognize and guard against. To anticipate an accident, and to prevent it from happening is safety.

CHAPTER V

IDEAS FOR USE IN THE LABORATORY

The selection of the ideas in this chapter were those that may not be commonly known by the high school teacher.

1. Fire blankets are not as effective for clothing fires as water. Tests show that fires can be extinguished ten times more rapidly with a good shower as with a "fire blanket". Such a shower should be fed by a one-inch water line which does not run close to a steam pipe. The valve controlling the shower should be a quick-opening type which automatically stays open when released.[14]

If the school is not equipped with a permanent safety shower an ingenious method is to use a dime-store variety shower. Clamp the flexible rubber hose shower to the cold water faucet with a thumb screw clamp. The clamp is needed to prevent the hose from slipping off when the hose is on hydrant pressure.

2. Substitute glass tubing cutters of the Griffin type for the use of triangular files in cutting glass tubing because of the problem of files getting wet in a laboratory which ruins their sharpness. Also tubing cutters make cleaner breaks, and for the students who do not wrap a cloth around the tubing for breaking, the risk of cuts is diminished. Tubing cutters also eliminates the problem of replacing rust dulled files.

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14. William B. Cook, and Alfred J. Perkins, "Safety in Chemical Laboratories", Journal of Chemical Education, Vol. 31, (1954) pp. 95-96

3. One method for removing a piece of broken glass stem or tubing from a stopper is to place the stopper on the floor, and by rolling and crushing, pulverize the glass in the stopper with the sole of your shoe. Another method is to slide a cork borer into the tube and twist it into the stopper hole around the tube. When the borer is completely through the stopper, the tube will slide out easily.

4. To get overly-snug tubing into a stopper, insert the cork borer into the stopper. Then slide the tubing inside the borer to the desired position while removing the borer. The reverse of the preceeding will then remove the glass from the stopper.[15]

5. Hospitals are willing to give to science teachers the glucose bottles used in intravenous injections. These bottles are calibrated and by removing the label, the metal band and the rubber stopper, they can be utilized as excellent reagent bottles. The neck has threads, and a screw cap the size of the neck threads can be easily secured.[16]

6. Waste materials are troublesome problems and have a variety of attempted solutions, none of which will work in the midst of poor discipline. The general method is to place earthenware crocks of three to five-gallon capacity at convenient places. Some use catch jars on the tables, draining into center troughs and to the sinks, or movable sink baskets of polythylene, or rubber coated wire.

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15. Charles D. Drayton, Jr., "Glass Tubing and Stopper: You Don't Have to Fight Them", Science Teacher, Vol. 24, (1957)

16. C. W. Owens, N. R. Crozier, "Securing Free Material", Science Teacher, Vol. 25, p.276 (1958)

7. An invaluable aid to every laboratory instructor is a laboratory safety chart which may be obtained without cost from any Mallinckrodt distributor. The chart will take little wall space and contains much pertinent safety information. The pull-out-card feature enables the appropriate card to be taken to the scene of an emergency.

Although the chart is meant to be helpful at the time of an emergency, it can also be used by laboratory teachers as a refresher course in first aid and accident prevention.

CHAPTER VI

HIGH SCHOOL LABORATORIES CAN DO WITHOUT THESE

The fact that accidents may occur with "safe" chemicals but accidents surely will occur sooner or later with chemicals which are known to be dangerous is the reason for the title "High School Laboratories Can Do Without These". Many experiments involving risky demonstrations can be replaced by equally educational demonstrations or experiments that are safe.

For instance, the preparation of smoke rings from phosgene can be completely eliminated in the high school chemistry laboratory. The production of chemical light with luminol and an alkaline solution of hydrogen peroxide is an excellent and safe substitute. No beginning student need use potassium or sodium metals or see their action on water. The action of metallic calcium on water is equally instructive and completely safe.

Burns has offered the following suggestions for helping to eliminate the appalling accidents which occur both in the chemistry laboratory and outside the laboratory.[17]

(1) Eliminate potassium metal and red and yellow phosphorous from high school and home chemistry laboratories.
(2) Emphasize the idea that potassium chlorate may be as dangerous as potassium cyanide.
(3) Attempt to have some uniformity of ideals and practice by the retail chemical supply houses toward sale of chemicals to minors.

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17. Craig Burns, "Chemical Accidents Involving Minors", Journal of Chemical Education, Vol. 33 (1956), pp. 508-511

(4) Discourage (parent may prohibit) interest in pyrotechny and rocketry.
(5) Encourage amateur chemists to confine their activities to a chemistry laboratory in a basement, garage, or shed.
(6) Inform adolescents and particularly amateur chemists of the dangers of potassium chlorate and gunpowder explosives, colored flares, and rocketry.

In addition to the explosive substance hazards there are skin absorption and gaseous toxic poisons that sometimes are not recognized by the teacher.

Skin absorption refers to the systemic effects resulting from absorption through the skin. In the case of some chemicals, the effects due to absorption through the skin are approximately as severe, dose for dose, as from inhalation and/or swallowing.[18]

There is a considerable group of chemicals which produce toxicity by skin absorption and are very definitely a hazard. A few of these are:

Acrylonnitrile	Cyanides
Allyl alcohol	Ethylene amine
Allyl chloride	Ethylene chlorhydrine
Aniline	Phenol
Antimony trichloride	Tetrachloruthane
Arsenic trichloride	Toluidine
Cresols	Xylidine

To eliminate cyanides from the high school laboratory, teachers need to read the requirements for all areas in which cyanide compounds are manufactured and handled. From this there will be no doubt that it's elimination from labs should be a reality. In any case call a physician immediately.

A first-aid kit containing the following items should be readily available.

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18. H. A. J. Pieters, "Safety in the Chemical Laboratory" (New York) 1951

2 boxes (2 dozen) of Amyl Nitrite pearls (ampules)
2 sterile ampules of Soduim Nitrite solution (10cc of a 3% solution in each)
2 sterile ampules of Sodium Thisulfate solution (50cc of a 25% solution in each)
1 10cc and 1 50cc sterile glass syringe with sterile intravenous needles
1 tourniquet
1 stomach tube
1 dozen gauze pads and 1 small bottle of 70% alcohol
2 one-pint bottles of 17% Sodium Thiosulfate solution

A summary of the treatment for cyanide poisoning for physicians is gastric lavage and administering sodium nitrite and sodium thiosulfate intravenously. The details for cyanide treatment are described in an article by Chen, Rose and Clowes in the Journal of the Indiana State Medical Association, Vol. 37 (July, 1944), pages 344-350, "The Modern Treatment of Cyanide Poisoning".

Hydrofluoric acid vapor, bromine vapor, and chlorine are gaseous poisons. Anhydrous hydrofluoric acid at atmospheric pressure is a liquid when kept at 19.4 degrees Centigrade or below. Above this temperature, and at atmospheric pressure it vaporizes. Aqueous hydrofluoric acid at normal temperature and atmospheric pressure is a liquid; however, vapors are emitted from the aqueous acid which can vary in strength from very dilute to 80 percent hydrofluoric. The vapor is extremely irritating to the respiratory tract and can cause death through the development of pulmonary edema.

The generally accepted maximum concentration of hydrofluoric acid vapor is 3 ppm by volume in air for an 8-hour working day. Concentrations of 50 ppm or more may be fatal in 30 to 60 minutes.

Vapors from liquid bromine presents serious hazards similar to chlorine gas in its toxic properties. The permissable concentration for regular daily exposure is less than 1 ppm and the painful effect upon the eyes may be apparent at concentrations as low as about 0.3 ppm under some conditions.

Why do teachers risk their students to these perilous substances? The significant question: Why? Need only be answered by the teacher, "Why do this experiment anyway?" The experiment must make sense to the student and should be set up as a specific problem to be solved. These should not involve hazardous substances dangerous to the student.

CHAPTER VII

SUMMARY AND CONCLUSION

The basis for a guide for high school chemistry teachers is for the protection of students from danger at all times.

To protect himself, the student must be taught the safety rules, how to use tools, and where equipment is located.

Adequate and proper storage for chemicals must be provided. Poisonous chemicals require extra precautions. They must be kept in locked storage and dispensed with care.

Some examples of unnecessary substances in the high school chemistry laboratory are explosives, florides, sodium, hydrofluoric acid and cyanides.

The general directions for first aid are not included in this report but can be found in the _Textbook on First Aid_ of the American Red Cross. First aid materials should be handy for use in emergencies.

High school students are usually in the laboratory only one hour a day and do not have the risk to accidents caused by exposure from skin absorption and gaseous toxic poisons as the industrial chemist who is in the laboratory daily.

The laboratory has not deteriorated but needs the qualified chemistry teacher who can provide suitable opportunities for safe experimentation, exploration, and discovery for all chemistry students. Many students will enjoy trying to rediscover or verify some fundamental principle upon which those of chemistry has been founded.

That the high school chemistry laboratory can be operated with greater safety by elimination of all hazardous materials would be a falacy but that the number of accidents can be decreased is a reality.

Finally, it is not obstructionist perfectionism for the teacher to insist that his pupils be safeguarded with adequate hoods, safety showers, face shields and other equipment which are commonly found in industrial laboratories but are too frequently lacking in the high school laboratory. It is, rather, a demonstration of his acceptance of the worthwhileness of every student entrusted to his care.

BIBLIOGRAPHY

Burns, Craig. "Chemical Accidents Involving Minors". *Journal of Chemical Education*, 33 (1956) 508-11

Cook, Wm. B. and Alfred J. Perkins. "*Safety in the Chemical Laboratory*". *Journal of Chemical Education*, 31 (1954) 95-96

Davison, H. F. "Safety First in Storing Chemicals". *Journal of Chemical Education*, 2 (1924) 782-83

Drayton, Charles D. Jr. "Glass Tubing and Stopper: You Don't Have to Fight Them". *Science Teacher*, 24 (1957)

Nechamkin, Howard. "*Laboratory Problems in General Chemistry*" Thomas Y. Crowell Co. (New York) 1952

Manufacturing Chemists' Association, Inc. "*Guide for Safety in the Chemical Laboratory*", D. Van Nostrand Company, Inc. (New York) 1954

Owens, E. W. and N. R. Crozier. "Securing Free Material". *Science Teacher*, 25 (1958) 276

Pieters, H. A. J. and J. W. Grayghton. "*Safety in the Chemical Laboratory*". Academic Press, Inc. (New York) 1951

Shaw, John S. "Is the School Laboratory a Frankenstein?" *Journal of Chemical Education*, 21 (1944) 539-42

Tomlinson, W. R. and L. F. Audriedth. "Uninvited Chemical Explosions", *Journal of Chemical Education*, Vol. 27 (1950) pp 606-09

Turrill, Park Lovejoy. "Public Liability and Chemical Education." *Journal of Chemical Education*, 10 (1933) pp 552-555

Walker, Fredric. "Safety in Chemical Laboratories". *Journal of Chemical Education*, 11 (1934) 506-09

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