Safety and Good Laboratory Practices

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1. Laboratory and its Contents

Introduction

Good laboratory practices play an important role in improving the safety and hygiene of employees by avoiding or minimizing accidents and injuries. During these sessions we hope to discuss Good Laboratory Practices that you should adhere to in carrying out your duties efficiently and safely. In this session, we consider general information about

(i) the laboratory
(ii) what you find inside a laboratory, and
(iii) some activities that take place in the laboratory (Fig. 1.1).

Session 2 deals with laboratory safety and safety symbols. Session 3 describes good laboratory practices and finally, Session 4 looks at chemical spills and chemical waste.

Fig. 1.1: Table tops with cupboards and racks, a cabinet and a fume hood [1, 2, 3]

1.1 Laboratory and its contents

Some of you may had done experiments in a laboratory during your school days or visited a laboratory in a medical centre or a hospital, for a blood test or a urine test. I wonder whether you noticed safety measures (*e.g*. protective clothing, gloves, safety glasses) taken by the laboratory staff.

What is a laboratory?

It is a place where **teaching, research** and **analyses** are carried out. In schools and universities, students carry out experiments to understand basic concepts in science. In research institutes, scientists/graduate students carry out research projects to discover new molecules, new materials, new chemical processes and new methodologies *etc*. According to the Oxford dictionary, *laboratory means a room or building used for (especially scientific) research, experiments, testing etc.*

Q 1 : Who uses a laboratory?

A 1 :	Teachers (school and university)	Undergraduates
	Technician	Researchers
	Support staff (*e.g*. lab attendants)	Analysts
	School children	Scientists

The people who use a laboratory should know **the dangers** or **the risks** associated with it. Everyone in the laboratory should act or behave in a responsible manner **to prevent accidents taking place**. For that you should be familiar with the **contents** in a laboratory.

Q : List the items that you find in a laboratory?

A : Electricity supply (*e.g.* Switches, sockets, Main Switch)

Water supply
Gas supply
Telephone and the directory
Stationery
Furniture
Ovens
Fire Extinguishers
Emergency shower
Glassware
Apparatus
Chemicals/reagents
Fume cupboards
Refrigerators/Deep freezers
First aid box and Medicines
Eye washer

Are you familiar with the items/equipment given in the above list? If you work in a laboratory you should know where these items or equipment are.

Fig. 1.2: Quick fit glassware, fire extinguisher, emergency shower and a first-aid box [4,5,6]

Given below are some of the questions for which you should know the answers.

1. Can you find the items or equipment in the above list easily?

2. Do you know how to use/operate any of the following? (i) fume cupboards, (ii) ovens, (iii) fire extinguishers (iv) balances etc.?

3. In case of emergency, do you know (i) how to close the main gas supply, (ii) how to switch off the electrical power supply?

4. Do you know how to handle, store and dispose of **chemicals** safely?

The most **important** and **dangerous items** in the laboratory are **Chemicals**. Teachers and the laboratory staff should know the **hazardous nature of chemicals** and other biological samples. Each laboratory should maintain a **Hazardous Material Inventory** itemizing all the hazardous materials present in the laboratory and **Material Safety Data Sheets** (MSDS, see section 4.4 and Appendix-1) should be available for each item in the inventory.

1.2 Chemicals

Millions of tons of chemicals are produced industrially. We make use of these man-made chemicals every day, for example, table salt, vitamins, medicines, dyes, paints, fuel, *etc*.

There are three types of chemicals: (i) **solids** (ii) **liquids** and (iii) **gases**.

Out of these three types, gases pose a major threat by inhalation as they can reach you as they are released. Therefore, toxic or poisonous gases should be handled with extreme care in a very efficient fume hood. **Volatile** solvents should be kept in closed bottles away from burners, ovens and sunlight. Solids are the least threatening substances but some are very reactive and explosive while the others are corrosive; solids may pose a serious risk when spilled while handling.

1.2.1 Grades of chemicals

We need to use chemicals to prepare solutions and reagents, and also to carry out reactions. Chemicals are available in various levels of **purity**. You need to select the right grade depending on your need before you place the order. The prices vary with the purity of the substance.

Technical Grade – chemicals used in industrial processes
General Purpose Reagent (GPR) Grade – chemicals used for general laboratory preparations
Analytical Reagent (Analar) Grade – chemicals used for the preparation of standards
Spectroscopic Grade – chemicals used in spectrophotometers
Chromatography Grade – chemicals used for running chromatograms (*e.g*. HPLC)

Activity 1

Write down the purity (minimum assay) of five chemicals found in the laboratory.

1.2.2 Hazardous chemicals

All chemicals are not hazardous, *e.g*. water and table salt (NaCl), which we use daily. However, you should **never** drink water or consume sodium chloride found in the laboratory because they could be contaminated with small amounts of toxic chemicals present in the laboratory. A chemical can be harmful as a result of

(i) inhalation (gases and vapours),
(ii) skin absorption
(iii) ingestion.

What makes a chemical hazardous?

A chemical is regarded as a **hazardous** chemical if it is

- cancer causing,
- toxic,
- corrosive,
- an irritant (*e.g*. eye, skin, respiratory system),

- a strong sensitizer,
- flammable,
- reactive,

and thereby poses a threat to **health** and **environment**.

Some common **hazardous chemicals** are given below.

Aniline ($PhNH_2$) and **nitrobenzene** ($PhNO_2$) are fat-soluble and easily *absorbed through the skin*. Aniline is *poisonous*. Severe poisoning is not likely to result from the small amounts used in laboratories.

Benzene (C_6H_6) is dangerous as a **chronic poison** if the vapour is inhaled in small quantities over a long period. Being fat soluble it can also be absorbed through the skin. It is a well known carcinogen

Benzoyl chloride (PhCOCl) is a **lachrymator** (irritant to eyes).

Bromine and **iodine** vapours are extremely dangerous to the nose, lungs and eyes. Because of the high density of liquid bromine, bottles containing it fracture easily. Liquid bromine is dangerous in contact with the skin and the greatest care should be used in handling it.

Carbon disulphide (CS_2) is highly flammable with a very low **flash point**, the vapour is very toxic, and the liquid is absorbed through the skin.

Carbon tetrachloride (CCl_4), **chloroform** ($CHCl_3$), **ethylene dibromide** and **trichloroethylene** have toxic vapours and are also absorbed through the skin; 1,1,1-tricloroethane is much less toxic.

Hydrogen sulphide (H_2S) is almost as deadly as hydrogen cyanide. It should be used only in a fume cupboard.

The toxicity of **Lead** and its compounds is well known, but there is now clear evidence of many harmful effects resulting from the inhalation and/or ingestion of small quantities.

Mercury vapour, even in very low concentration, is very **toxic** if inhaled over a long period, and mercury used without great care can very easily give rise to dangerous concentrations of vapour, especially in warm and poorly ventilated laboratories.

Sulphur dioxide (SO_2) is both corrosive and poisonous.

Strong **oxidizing agents** such as chlorates, perchlorates, and perchloric acid, nitric acid and nitrates, permanganates and peroxides are hazardous and need care in storage so that they are not accidentally mixed with readily oxidisable materials such as organic matter, charcoal or sulphur. *They should never be placed on paper or the wooden bench*.

Poisons and substances of high toxicity (NaCN, KCN) must be kept in a **locked** cupboard. No experiment involving poisons should be started without knowing what to do if something goes wrong and without having the **antidotes** at hand.

1.2.3 Carcinogenic substances

A number of chemicals are known to induce cancer, for example, benzene; *o*-toluidine; *α*– and *β*–naphthylamine; diphenyl derivatives such as 4-aminodiphenyl, 4-nitrodiphenyl, benzidine, nitrosamines, *etc*. If you have to handle carcinogenic compounds take extreme care; you must read the material safety data sheets and prepare yourself for any accidental exposure to carcinogens.

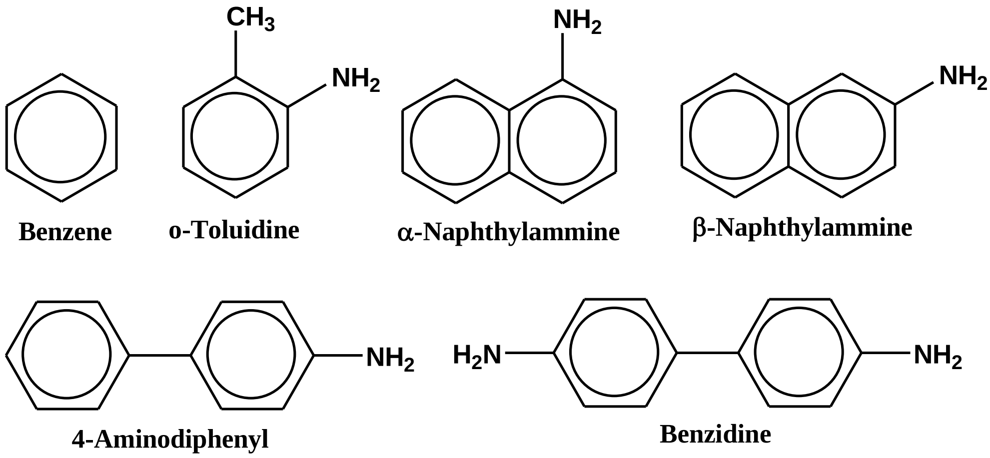

Fig. 1.3: Some carcinogens

1.2.4 Explosives

An explosive material contains a large amount of stored energy which can be liberated producing light, heat and pressure. This event is called the explosion.

The following substances may cause an explosion:

acetylide	nitrile
amine oxide	ozonide
azide	perchlorate
chlorate	peroxide
diazo and diazonium salts	peracid
hydroperoxide	picric acid
nitrate	

Benzoyl peroxide, if used at all, should only be purchased in small quantities and, once opened, checked regularly as it is explosive when dry. It can be stored safely in a closed vessel and maintained at high humidity. Picric acid is also stored in small quantities in water.

Care should be taken to store chemicals well apart from the other chemicals which might react together to give off dangerous fumes or cause fire or explosions on accidental breakage.

1.3 Common accessories

In this section, we will briefly consider some of the common accessories and items found in the laboratory. *You should learn how to use them properly and safely*. Therefore you should *read and understand the instruction manuals before you start using them*. So, operate/use them now and record your observations.

Fume Cupboard/Hood

Some chemicals particularly solvents can cause respiratory hazards and they should be handled in a fume hood. If you smell a chemical, it is obvious that you are inhaling it. On the other hand, many chemicals can be present at hazardous concentrations without any noticeable odour.

The fume hood keeps fumes, vapours, dusts or air contaminants away from your breathing zone. You should learn how to use a fume hood safely. It should be **checked a few times annually**. The fume cupboard should be maintained at an **efficient** air-flow (*ca*. 0.5 m/s). *Fume cupboard is not a storage place for hazardous chemicals.*

Refrigerator

A refrigerator (or a fridge) is a cooling device which consists of a thermally insulated body and a heat pump which transfers heat to environment.

Everything in a laboratory fridge must be **properly labelled** with the following details: date, name of the compound/specimen or the experiment number, name of the person who left the sample in the fridge and the solvent used; the sample should be properly sealed. *Never keep food in the laboratory refrigerator*.

Ovens

A Laboratory oven generally provides uniform temperature throughout. They can be used for drying and other laboratory functions. Typical sizes are from one cubic foot to 32 cubic feet with temperatures reaching up to 340 ^{o}C.

Balances

You may find a number of different types of balances in the laboratory which are used to weigh samples with varying accuracies, for example, 100.0 g, 23.45 g and 2.23 mg. You should *read and understand the instruction manuals before you start using these balances*.

Fig. 1.4: Balances [7,8]

Water distillation plant

Water is a very important solvent in the laboratory. We do not use tap water for the preparation of solutions and for other experimental work because it contains chlorine and some metal ions. Generally we use **distilled water**, **double distilled water** or **deionised water**. A number of different water distillation plants are available commercially though the principle is the same: first boil the water, condense the vapour and collect the pure liquid into a separate container as shown in section 3.4.2. Deionised water is obtained by passing water through a cation exchange resin.

Rotary evaporator

A rotary evaporator is an apparatus used in many laboratories to remove solvents from solutions by evaporation. The solution is rotated by a motor in order to increase the solvent evaporation, thus it is called “rotary evaporator”.

Fig. 1.5: Rotary evaporators [9,10]

The solution can be warmed using a **water bath** to a desired temperature and the pressure can be reduced to a required pressure (using a **water pump or an oil pump**) to facilitate the gentle removal of the solvent. The resulting vapour of the solvent is cooled and condensed by an **inbuilt water condenser**; solvent is collected to the **receiving flask**. This process is similar to vacuum distillation. The designs of a rotary evaporator are shown below; *identify the main components*.

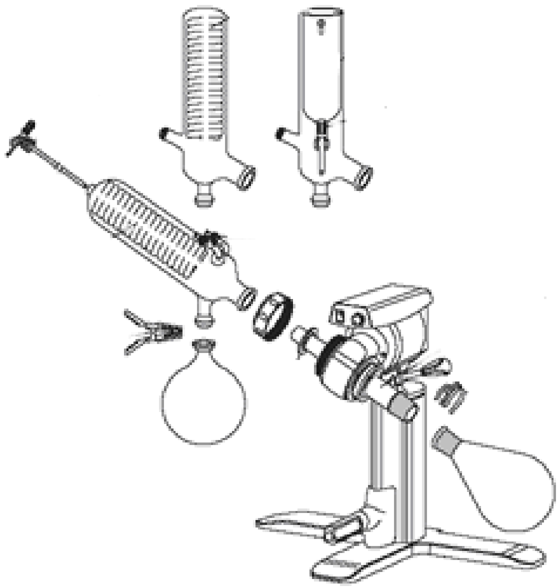

Fig. 1.6: Parts of a rotary evaporator [11]

Fire extinguisher

One of the major risks in a laboratory is Fire. Laboratories contain various combustible materials (*e.g. paper, cloths, chemicals, solvents and gases*). Fire can be extinguished by three methods: *starvation* (fuel), *smothering* (cutting off the oxygen supply), and *cooling* (absorption of heat).

A **fire extinguisher** is a device used to extinguish small fires, often in emergency situations. A fire extinguisher consists of a hand-held cylindrical *pressure vessel* containing an agent which can be discharged to extinguish a *fire*. There are four types of fire extinguishers depending on its contents: *e.g.* water, foam, carbon dioxide and dry chemical powder. A **fire blanket** can be used to put out a small fire. In the case of a major fire you should immediately call the fire brigade. There should be an **emergency evacuation plan**, with a designated **assembly place** (open space) away from the laboratory, in place if a major fire breaks out.

First Aid Box

Each laboratory should have a **First Aid Box**. Staff should be trained to deal with minor accidents before seeking medical advice.

The contents of a First Aid Box are given below.

Small sterilised dressings	Eye ointment tube
Medium sterilised dressings	Sterilised eye pad
Large sterilised dressing	Rubber pressure bandage
Adhesive wound dressing	Packets safety pins
Triangular bandages	Pair of dressing scissors, 125 mm
25 mm x 10 m Zinc oxide plaster	Pair of forceps
15 g sterilised cotton wool	Eye wash bottle
Tube of antiseptic cream	

A telephone, centrifuges, autoclaves, desiccators, hot plates, heating devices, emergency shower (see Fig. 2) and eye washer are some of the other accessories or items found in the laboratory.

Summary

- Laboratory is a place where teaching, research and analyses are carried out.
- The people who use a laboratory should know the dangers or the risks associated with it.
- Everyone in the laboratory should act or behave in a responsible manner to prevent accidents taking place.
- Each laboratory should maintain a Hazardous Material Inventory and Material Safety Data Sheets (MSDS) for all the hazardous materials present in the laboratory.
- There are three types of chemicals: (i) solids (ii) liquids and (iii) gases. Gases pose a major threat as they can reach you as they are released. Solids are the least threatening substances but some are very explosive/corrosive/reactive.
- Chemicals are available in various levels of purity and you need to choose the right grade depending on your need. The prices vary with the purity of the substance.
- A chemical can be harmful as a result of (i) inhalation (gases and vapours), (ii) skin absorption or (iii) ingestion.
- Everything in the laboratory refrigerator must be properly labelled.

- There are different types of balances in the laboratory which are used to weigh samples with varying accuracies.
- We do not use tap water for the preparation of solutions and for other experimental work because it contains chlorine and some metal ions
- A rotary evaporator is an apparatus used in many laboratories to remove solvents from solutions by evaporation. Fire can be extinguished by three methods: starvation (fuel), smothering (cutting off the oxygen supply), and cooling (absorption of heat).
- Staff should be trained to deal with minor accidents before seeking medical advice.

Learning Outcomes

Once you have completed studying this session you should be able to

- list the items/equipment found in the laboratory
- describe risks and dangers of the hazardous chemicals in the laboratory
- operate/use common items/equipment in the laboratory.
- use information from a Hazardous Material Inventory and Material Safety Data Sheets to handle hazardous chemicals safely
- identify different grades of chemicals

Activity 2 - Review Questions

2.1 What is meant by "hazardous chemicals"?
2.2 Write names of five carcinogenic substances.
2.3 Write names of five explosive substances.
2.4 Give names of three strong oxidizing agents.
2.5 Give names of two substances which could explode when dry.
2.6 What information would you write on a label of a sample bottle before leaving it in the fridge?
2.7 What are the three main methods that a chemical can be harmful to a person?
2.8 What are the three main types of chemicals?
2.9 Make a list of items that you find in your laboratory that are not mentioned in the session.
2.10 What are the three methods that can be used to put out a fire?
2.11 Name four types of fire extinguishers.
2.12 Name four items to be found in the first-aid box.
2.13 Indicate whether the following statements are true or false.

(a) Everyone in the laboratory should act in a responsible manner to prevent accidents taking place. (True/False)

(b) General purpose grade chemicals can be used for the preparation of standard solutions. (True/False)

(c) Aniline, nitrobenzene, benzene, carbon tetrachloride and chloroform can be absorbed through the skin. (True/False)

2. Laboratory safety

Introduction

In session 1, we discussed the items and equipment that you find in a laboratory and general information that you need to know to perform your work efficiently and safely. In this session, we will concentrate more on **laboratory safety**. Accidents often happen due to **failure to use prevailing common sense**, **failure to follow proper instructions** and **indifferent attitude**. Safety is a **collective responsibility** that requires the cooperation of all stakeholders in the laboratory. Do not hesitate to report to the adviser/safety officer when someone is engaged in unsafe practices or operations. All **accidents** and **near misses** should be reported (in writing). *Recommendations for the prevention of recurrences should be discussed with the safety officer (maintain an incident book).*

2.1 Laboratory safety

Laboratory safety[12] is an important aspect of any science laboratory. Safety rules and symbols are important so that you do not injure yourselves or others. Practicing laboratory safety rules prepares you better to deal with accidents when they do occur. Some of the main areas of safety are personal safety, electrical safety, mechanical safety and glassware safety.

2.1.1 Personal safety

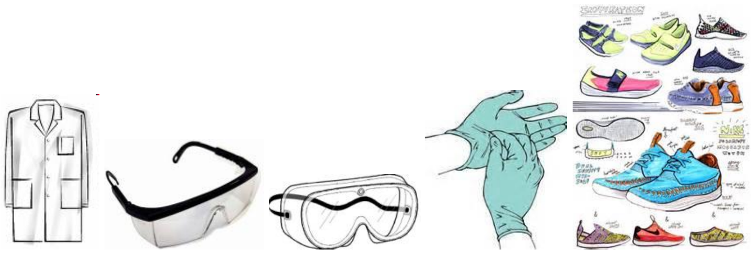

Fig. 2.1: Some personal safety equipment [13,14,15,16,17]

Your personal safety and the safety of other human beings are more important than anything else. Some important rules and practices are listed below.

Keep your workplace **tidy** (see good house keeping, section 3.1).
Wear your **safety gear** (safety glasses, coats, gloves, shoes *etc*,).
Think before **you start** any work or experiment.

Treat all **Chemicals** as **DANGEROUS** substances.
Use an effective **fume cupboard** whenever possible.
Never eat, drink or **smoke** in the laboratory.
Never visit the office/places wearing **lab-coats** particularly where **food is consumed**.
Never work alone in a laboratory; No jokes or tricks in the work area.
Never perform unauthorized work or experiments.
Never pipette by mouth.
Never remove chemicals from the laboratory.
Wash your hands and arms **thoroughly** before leaving the laboratory.
If a problem occurs save **YOURSELF** and **others** not the apparatus or the chemicals.

Some of the **symbols** of personal protection equipment along with the accompanying **instructions** are shown in Table 2.1.

Table 2.1 Symbols of Personal Protection Equipment

Caution Use caution around areas signed with this symbol. This symbol may also be used to draw attention to a particular piece or procedure.	
Eye Protection Goggles must be worn at all times.	
Face Shield Full face shield must be worn at all times.	
Foot Protection Foot protection must be worn at all times.	
Gloves Gloves must be worn at all times (check a glove chart to ensure that you are using the **right glove for the right task**).	
Head Protection Hard protective hat must be worn at all times.	
Lab Coats	

Lab coats or an outer protective layer must be worn at all times.	
No Food or Drink Absolutely no food or drink is permitted in this space.	
No Gloves No lab gloves permitted beyond the posted sign (typically on the inside of each lab door indicating they are not to be worn beyond the lab).	
Radioactivity Tag A dosimeter must be worn at all times.	
Respirator A respirator with the correct cartridges must be worn at all times. All users of respirators must have appropriate training before using them.	

Avoid wearing contact lenses. Long hair must be tied back and avoid wearing loose clothing.

Activity 3

Make a list of different types of gloves and eye protection equipment used in your laboratory.

2.1.2 Electrical safety

In all laboratories we use electricity. Electrical equipment should be **periodically checked** to ensure **safety** and **functionality**. Particular attention should be paid to cords and switches that may have become damaged due to contact with solvents, acids or other chemicals. The use of two- or three-way adapters and extension leads must be avoided.

Electrical accidents occur mainly due to the following reasons.

-Faulty equipment and installation

-Unsafe work practices

-Unsafe environment (heat, gases, solvents, acids *etc*)

Some of the electrical safety symbols are shown below.

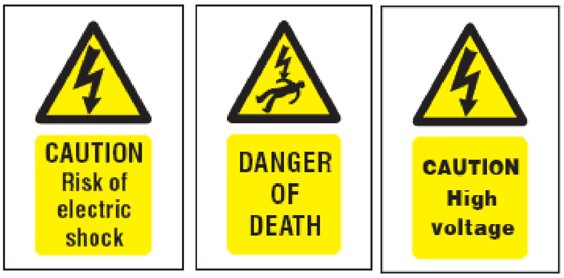

Fig. 2.2: Some electrical safety symbols [18]

2.1.3 Glassware safety

Most of the equipment used in the laboratory is made of glass. Glass is used because of its relative inertness to just about all types of chemicals. The glassware used in the laboratory can be roughly divided into "soft" glass and "hard" glass.

"Soft" glass is made of soda-lime glass; it is not heat resistant because it has a low melting point (600-800 °C) and a high coefficient of expansion; particularly when it is subjected to sudden temperature changes, it will break or crack. It cannot be used with high heat, as from a hot plate or an open flame. "Hard" glass is made of heat-resistant borosilicate glass (*e.g.* Pyrex glassware); it can be subject to direct high heat.

Glass apparatus is an integral part of the **laboratory analysis** and care must be taken when **using** and **handling** glassware. Most minor accidents happen when we use glassware while setting-up and cleaning.

The following points should be observed when selecting/using glassware.

- use **clean** and **unscratched** glassware
- use the **appropriate** vessel and supports
- **strong** glassware should be used for **pressure** or **vacuum work**
- appropriate **safety equipment** must be worn
- **broken** glassware should **not** be used, **get it repaired or dispose of it**
- **Pyrex glass** cannot be recycled

You should take care when handling glassware particularly when cutting glass tubing, handling broken glass, and disposing of broken glassware. How you should cut a glass tube is shown below; wear gloves to protect you fingers.

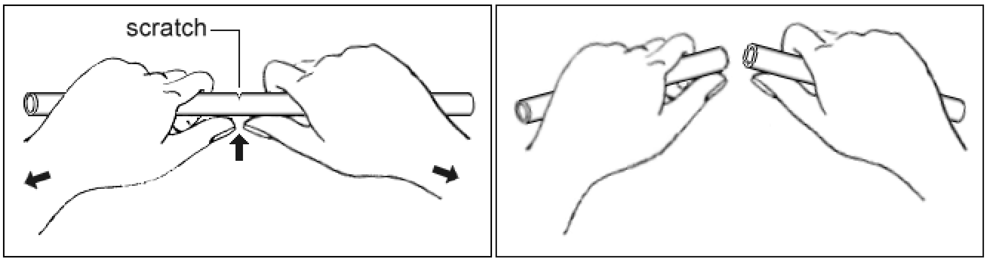

Fig. 2.3: Cutting of a glass tube [19,20]

Activity 4

Cut a glass tube after making a scratch with a glass cutter.

2.1.4 Mechanical safety

We use a number of mechanical equipment/devices in the laboratory. Some of them are powered by electricity.

We have to be careful when

- we carry/transport solvent bottles and other chemicals; use a solvent carrier or a trolley. Never carry a bottle by its neck.
- we transport/locate chemicals, large vessels, and chemical waste and gas cylinders
- we use gas cylinders (checklist is given in Appendix-II)
- we use rotary equipment (rotary evaporators, stirrers, *etc*)

2.2 Safety symbols

A large number of different languages are being used by people in different countries. Therefore, it is important to have pictorial signs/symbols to indicate the properties of chemical substances. The various safety symbols are given below.

FLAMMABLE

Fig. 2.4: Safety symbols for flammable substances [21,22,23]

Flammable substances are any solid, liquid, vapour or gas that can be ignited readily. When ignited, it burns so vigorously and persistently as to create a serious hazard. Liquids with flash points less than 60 ^{o}C are considered as flammable liquids. For example,

Acetone	Cyclohexane
Acetic acid, glacial	Ethanol
Amyl nitrate	Methanol
Benzene	Isopropyl alcohol
Carbon disulfide	

CORROSIVE

Fig. 2.5: Safety symbols for corrosive liquids [24,25]

A corrosive liquid is a liquid or solid that causes visible destruction of, or irreversible alteration in, living tissues by chemical action at the site of contact; or a liquid that causes a severe corrosion rate on steel or aluminium. For example,

Sulphuric acid	Hydrochloric acid
Nitric acid	Hydrogen fluoride
Phosphoric acid	Potassium hydroxide
Potassium chromate	Sodium hydroxide
Glacial acetic acid	

POISONOUS MATERIAL

Fig. 2.6: Safety symbols for poisonous material [26,27,28]

A poisonous material is a material, other than a gas, which can be be toxic to humans or causes extreme irritation as to cause a hazard to health. For example,

Aniline	Mercury(II) chloride
Arsenic trichloride	Methyl isocyanate
Calcium cyanide	Nitrobenzene
Carbon tetrachloride	Phenol
Chloroform	Toluene diisocyanate

EXPLOSIVE

Fig. 2.7: Safety symbols for explosives [29]

An explosive is a material that produces an instantaneous release of pressure, gas, or heat when subjected to abrupt shock, pressure, or high temperature (see section 1.2.4). For example,

Ammonium perchlorate	Picric acid
Ammonium picrate	TNT (Trinitrotoluene)
Barium azide	Tetrazol-1-acetic acid

PYROPHORIC

It describes a material, even in a small quantity, which can ignite **spontaneously** after coming into contact with air. For example,

Activated carbon	Pentaborane
Aluminium alkyl halides	Phosphorus (yellow and white)
Aluminium alkyl hydride	Uranium metal
Aluminium borohydride	Zinc powder
Magnesium powder	Zirconium powder

Reactive reagents (*e.g.* tertiary butyllithium) can ignite spontaneously after coming into contact with paper or clothes.

CARCINOGEN

Fig. 2.8: Safety symbol for carcinogens [30]

Carcinogen is a material that either causes cancer in humans or considered capable of causing cancer in humans (because it causes cancer in animals), See section 1.2.3. For example,

Acrylonitrile	Lead
Asbestos	PCBs (Polychlorobiphenyls)
Benzene	Perchloroethylene
Carbon tetrachloride	Styrene
Formaldehyde	Toluene-2,4-diisocyanate

OXIDISER AND OXIDISING AGENT

Fig. 2.9: Safety symbol for oxidising agents [31]

An oxidizer is a substance that gives oxygen readily to cause or enhance the combustion (oxidation) of organic matter. An oxidizer is a significant hazard in a fire situation. Contact may cause caustic burns. For example,

Ammonium dichlorate	Potassium nitrate	Lead nitrate
Ammonium nitrate	Potassium permanganate	Sodium nitrate
Hydrogen peroxide	Silver nitrate	Nitric acid

RADIOACTIVE MATERIAL

Fig. 2.10: Safety symbols for radioactive material [32,33,34]

A source giving ionizing rays by the disintegration of atomic nuclei is radioactive. For example,

Carbon-14	Phosphrous-32
Technetium-99	Plutonium-241
Iodine-131	Rubidium-87
Krypton-85	Thorium-228
Niobium-95	Tritium-3
Radium-225	Uranium-238

Over-exposure of living tissues to ionizing radiation results in cellular damage.

IRRITANT/HARMFUL

Fig. 2.11: Safety symbol for irritants [35]

A substance capable of causing a reversible or irreversible inflammatory effect on living tissues by chemical action is called an irritant (lacrymator).

COMBUSTIBLE

Fig. 2.12: Safety symbol for combustibles [36]

Materials with low flash points (which ignite easily) are considered as combustible, *e.g*. liquids with flash points between 60 ^oC and 90 ^oC.

HAZARDOUS CHEMICAL

Fig. 2.13: Safety symbol for hazardous chemicals [37]

In a broad sense, any substance or mixture of substances having properties capable of producing an adverse effect on the health or safety of a human is called a hazardous chemical.

ENVIRONMENTAL HAZARD

Fig. 2.14: Safety symbol for environmental hazards [38]

Laboratory chemicals pose some environmental hazards if not disposed of correctly; chemical waste require *particular* care to be taken on disposal

Summary

- Safety is a collective responsibility of everyone in the laboratory.
- Accidents often happen due to failure to use common sense or failure to follow proper instructions.
- All accidents and near misses should be reported (in writing).
- Practicing laboratory safety rules prepares you better to deal with accidents when they do occur.
- Your personal safety and the safety of other human beings are more important than anything else.
- Electrical equipment should be periodically checked to ensure safety and functionality.
- Laboratory glassware is made of soft (soda-lime) and hard (borosilicate) glasses. Soft soda-lime glassware is not heat resistant and may crack when subjected to direct heat while borosilicate glassware can be subject to direct high heat.
- You must take care when handling glassware.
- You have to be careful when you transport/carry bottles, chemicals and gas cylinders.
- You should have a thorough knowledge of safety symbols and the risks associated with hazardous/toxic chemicals.

Learning Outcomes

Once you have finished studying this session you should be able to

- use the laboratory safely
- discuss what is meant by personal/electrical/glassware/mechanical safety.
- identify safety symbols.
- identify common hazardous chemicals in the laboratory.

Activity 5 - Review Questions

5.1 Name five flammable solvents.
5.2 Name five corrosive substances.
5.3 Name five poisonous substances.
5.4 What is meant by the term “pyrophoric”?
5.5 Name five carcinogens found in the laboratory.
5.6 Identify the danger/risk(s) associated with the following substances.

a) Hydrogen peroxide ………………………
b) Carbon tetrachloride ………………………
c) Thorium-228 ………………………
d) Phosphorus ………………………
e) Sulphuric acid ………………………
f) Acetone ………………………
g) Hydrogen fluoride ………………………
h) Carbon disulfide ………………………
i) Picric acid………………………
j) Potassium permanganate ………………………

5.7 Name five things that you should not do regarding your personal safety.
5.8 How would you prevent electrical accidents?
5.9 What precautions would you take to avoid accidents due to glassware?
5.10 Identify the following symbols.

(a) 

(b) 

(c) 

(d) 

3. Good laboratory practices

Introduction

In session 1, we discussed about hazardous chemicals including carcinogens and explosives. In session 2, we considered laboratory safety including safety symbols. In this session, we will concentrate on good laboratory practices. We know that the laboratory is used by a number of people (see section 1.1) with different types of duties/responsibilities. Everyone should know his or her role and the type of work expected from them; the type of work includes *good house keeping, safe handling of chemicals, purification of solvents, and carrying out experiments and research work, etc*.

3.1 Good house keeping

Laboratory should be kept clean and tidy. One of the ways for a good house keeping is to establish **5S** (**S**ort, **S**tabilize, **S**hine, **S**tandardize and **S**ustain). 5S is a methodology for organizing items and services within a workplace (or laboratory), thus carrying out day-to-day work more productively and efficiently.

This can be accomplished through the following phases:

1. **Sort** - getting rid of what is unwanted and not needed anymore
2. **Stabilize** - designating the proper location for items needed
3. **Shine** - clean and organize workplace
4. **Standardize** - everyone doing and identifying things the same way
5. **Sustain** - integrating 5S into the daily activities

Fig. 3.1 Phases of 5S (sort, stabilize, shine, standardize and sustain) [39]

Good laboratory practices create a healthy environment for you to carry out your work safely and efficiently. Let us now consider other important laboratory work. They include the maintaining of an inventory and storage, labelling and transport of chemicals. Disposal of chemical waste is discussed in the next session.

3.1.1 Inventory and storage of chemicals

Each laboratory should maintain inventories for chemicals and equipment. The **inventory** should be regularly **updated** so that one can easily find the **stocks available** and amounts to be ordered for future activities/experiments. The bulk of the chemicals should be stored (in the alphabetical order) in a **chemical store** with adequate ventilation and light, preferably outside the laboratory. Solvents should be stored separately in **appropriate solvent cabinets:** (flammable liquid cabinets, acid cabinets) and racks (for common reagent bottles). Different sizes of vessels/bottles/ containers (5 mL to 10 L, glass or plastic) are used for storing solvents (see Figure 4). **Winchester** bottle contains 2.5 L of solvents.

Fig. 3.2 Flammable liquid cabinets, acid cabinets and other cupboards [40,41]

It is important that **incompatible chemicals** (see Appendix-III) should **not** be stored together or close by.

Q4: What is meant by “incompatible chemicals”?

A4: Incompatible chemicals are the substances which react violently or generate toxic fumes when they come into contact with another.

Storage of reactive substances

Some chemicals are **air sensitive** (react with oxygen and/or moisture) and they should be stored in an inert atmosphere (under nitrogen or argon). Some chemicals are **light sensitive** and they should be stored in the dark or in Amber bottles (*e.g.* $AgNO_3$). Some chemicals react with water violently (*e.g.* Na, K) and they are stored in oil. As we mentioned before, some chemicals explode when they are dry (benzoyl peroxide, picric acid) and they are stored in water. Some chemicals are **unstable** and decompose above certain temperatures; they should be stored in a fridge or freezer. You must know the properties (read MSDS) of the chemical before you store it.

Activity 6

Locate six different sizes of solvent bottles and prepare a table giving the following information: name of the liquid, chemical formula, the quantity (volume or weight) and the safety symbol.

3.1.2 Labelling of chemicals

When you buy a chemical from a reputed chemical company you can see a proper label on the bottle/container giving the name of the compound, the quantity, molecular weight, chemical abstract service number (CAS number), minimum assay, maximum levels of impurities, and warning symbol when required. If you prepare a new compound you should label it properly giving the following information: experiment number, date, colour, and purity. For a solution, you should indicate the date of preparation, solvent(s) used, name and the quantity of the solute(s).

3.1.3 Transport of chemicals/solvents

A suitable carrier must be used when transporting chemical and Winchester bottles; a maximum load of two carriers per person. All flammable solvent containers must be transported around the laboratory using the appropriate carrier. You should **not** carry them by the neck or under your arms; you may contaminate yourself or drop them causing a potential fire.

So far, we have discussed about *good house keeping*. But, if we were to sustain laboratory safety and efficiency, we need to go one step further and establish a chemical hygiene plan leading to good laboratory practices.

3.2 Chemical hygiene plan

Each laboratory should develop a **Chemical Hygiene Plan** (CHP) that documents the necessary **work practices**, **procedures** and **policies** intended to keep the laboratory a safe place for everyone to work efficiently. The permanent staff should prepare and maintain a **Hazardous Material Inventory** itemizing all the hazardous materials present in the laboratory and material safety data sheet (MSDS, see Appendix-I and section 4.4) should be available for each item in the inventory. Employees should be aware of the dangers/risks and take necessary precautions to minimize the exposure to harmful solvents and chemicals. There should be an **emergency evacuation plan** in place if a major fire breaks out; **Fire alarms** should be regularly tested and there should be a designated **assembly place** (open space) away from the laboratory.

Good laboratory practices play an important role in improving the safety and hygiene of the employees.

3.3 Good laboratory practices

Adhering to good laboratory practices increase the safety of the employees and avoid/minimize the accidents and injuries.

Q: What are the possible accidents that could happen in a laboratory?

A: Fire, explosion, implosion, intoxication/poisoning, injuries, floods

Good laboratory practices safe guard you by preventing accidents and injuries.

Good laboratory practices include

- *Well thought out rules and guidelines*: Rules and guidelines have to be documented. There should be safety workshops to inform/educate the staff about good practices (see section 3.2).
- *Good house keeping, maintenance and inspections*: Regular cleaning, and inspecting/servicing of equipment should be carried out (see section 3.1).
- *Use of appropriate protective equipment*: Identify the risks and wear the glasses, gloves, *etc* and also be prepared for an emergency situation (see section 2.1).
- *Procedures for dealing with spills and accidents*: Read MSDS before you start your work (see sections 4.1 and 4.4).
- *Access to more recent literature and training*: Use internet for new information
- *Good facility for waste disposal*: immediate disposal of harmless waste and you should have proper storage facilities for hazardous materials (see section 4.2)

Amount of solvents used in a laboratory and solvent waste generated are significantly large when compared to usage and waste generated from solids and gases. Most experiments are carried out using solvents, thus, they pose a major health risk. Therefore, it is important to discuss the good practices that you should follow when using solvents.

3.4 Solvents

Solvents are liquids therefore chemical hazards arise from **inhalation**, **ingestion**, **skin absorption** and **injection**. Solvents are classified in order of general risk to health *i.e*. toxic, harmful, irritant. Solvents may also evolve **toxic fumes** under certain conditions such as in a **fire**. Solvents can pose a serious risk due to their **flammability** when used in large quantities. Diethyl ether, chloroform, benzene, *n*-hexane acetonitrile and carbon disulphide are particularly dangerous. One of the routine operations in a laboratory is the purification of solvents.

3.5 Purification of solvents

A liquid can be purified by distillation. In some cases, before distilling, you have to dry the solvent and/or remove other contaminants. A specific **chemical drying agent** is used for each solvent; this is important because one drying agent may react violently with another solvent. **Always follow a well-established procedure**.

Table 3.1 Recommended drying agents for some common solvents

Solvent	Drying agent
Tetrahydrofuran (THF)	sodium wire/benzophenone
EtOH, MeOH	Magnesium
MeCN, Me_2CO, CH_2Cl_2, EtOAc	Calcium hydride/P_4O_{10}
Toluene, Xylene	Sodium
Diethyl ether	Sodium wire/benzophenone
40-60 Petroleum ether	CaH_2 or Sodium wire/benzophenone
Hexane, Pentane, Heptane, Benzene	Calcium hydride or Sodium wire

Normally the wet solvent is boiled **under reflux** before it is distilled off.

3.5.1 Refluxing

Refluxing is carried out to maintain a reaction mixture at the **boiling temperature** of the solvent for a required time period. During refluxing, the solvent vapour is cooled by the water condenser and the condensed liquid (or the solvent) is collected back into the flask. Normally a solvent is refluxed with a drying agent for few hours before it is distilled off. A set up used for refluxing is shown in Fig. 3.3.

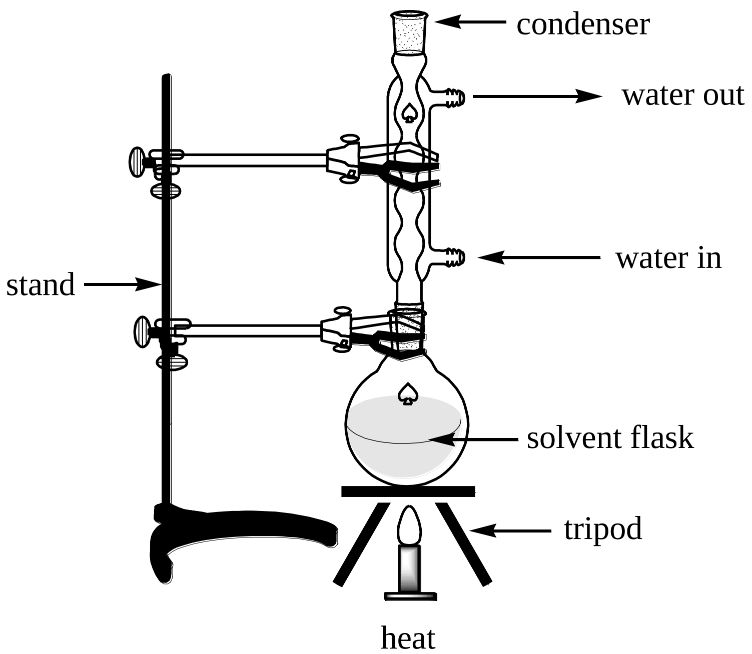

Fig. 3.3 Set up used for refluxing a reaction mixture [42]

3.5.2 Distillation

Distillation is the process of heating a liquid until it boils, *cooling* the resultant hot vapour, and collecting the condensed vapour (liquid) to a separate vessel/flask (see Fig. 3.4). This liquid is called the "**distillate**". Humans have applied the principles of distillation for many years. Distillation was used by ancient chemists to isolate perfumes. The **thermometer** indicates the boiling point of the distillate. *Anti-bumping granules (or magnetic stirrer) must be used for smooth heating*. The glassware and other items needed for solvent distillation is given Fig. 3.4.

Activity 7

Take 50 mL of methanol, reflux it for 30 min and then distil off it into a conical flask.

Nowadays distillation is used as a powerful tool to identify and purify organic compounds. The boiling point of a pure solvent is well-defined and it is one of the physical properties of a **compound by which it is identified**. Distillation is used to **purify a liquid** by separating it from a non-volatile or less-volatile material. When a liquid contains a mixture of different compounds with different boiling points, they can be separated into individual components when the mixture is carefully distilled. This process is called "**fractional distillation**". Crude oil is separated into its components by fractional distillation. In order to have a better separation of the components a **fractionating column** is used as shown in Fig. 3.5.

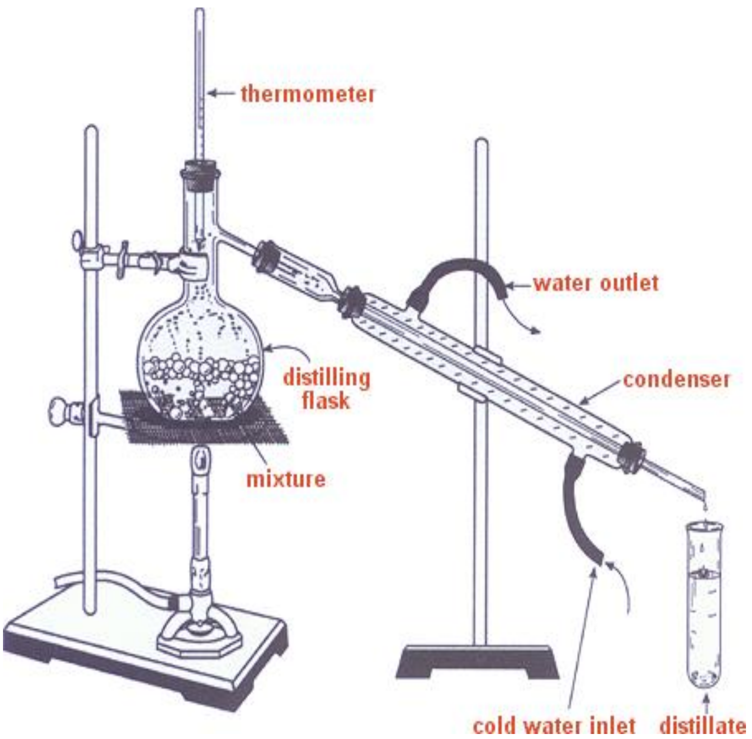

Fig. 3.4 Simple distillation set up [43]

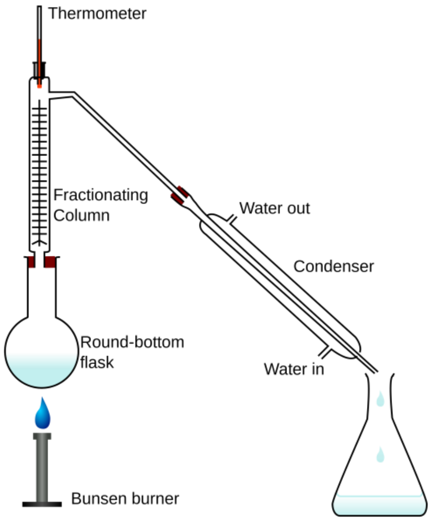

Fig. 3.5 Set up for fractional distillation [44]

It is important that you read more on distillation and fractional distillation.

Activity 8

Identify the components given in Figure 3.5.

3.5.3 Operation and construction of solvent stills

Most chemistry laboratories maintain dedicated **solvent stills** for the purification of solvents particularly in a fume hood. This technique is used when you need *dry and oxygen free solvents*, thus, the drying and distillation are carried out *under an inert gas* such as nitrogen or argon. In solvent stills both refluxing and distillations are carried out in turns with the help of a **solvent still head** (see Fig. 3.6). **You are strongly advised to consult and get the help of a senior staff member before you set up a solvent still.**

Fig. 3.6 Fume hood containing a series of solvent stills and solvent still head [45]

You need to consider the following facilities before you construct a solvent still.

A. Location of Stills

Solvent stills are potentially dangerous and should be kept in a dedicated fume hood wherever possible. Stills for **diethyl ether** or for toxic solvents must only be located in a fume cupboard.

B. Water Supply

All water connections, from the tap to the still and from the still to the drain, are to be secured using nylon ties. Water flow switches must be cleaned regularly as algae may stop proper functioning of the switch.

C. Nitrogen Supply and Vent

Solvent still must **not** be sealed off from its vent. Every still must have a separate nitrogen **supply** and a **bubbler**. All exit tubing to be attached so as to minimize the danger of kinking, and vented to fume hood or the exterior of the building.

D. Electrical Supply

The electricity supply must be controlled by a **water flow switch**, which will turn off the electricity if the **water supply drops** below a minimum safe flow rate.

Some important operational instructions are listed below.

(i) All still flasks must be properly **labelled**, stating the **solvent** and the **drying agent**.

(ii) All flammable solvent stills **must only** be filled or re-filled after they are **cooled to room temperature**.

(iii) Stills to be **turned off** when left **unattended**.

(iv) You should educate the staff by providing clear instructions as if something has gone wrong.

3.5.4 Do's and don'ts when using solvents

Particularly flammable solvents are dangerous and should be handled carefully at all times. The following is a list of the do's and don'ts when using solvents in the laboratory:

1. Only the **minimum** amount of flammable chemicals should be kept in the laboratory. Store them in a **cool** area away from **sunlight**. All containers should have firm **closures**, and be **closed** immediately after use.

2. Flammable liquids should **not** be **poured** from one vessel to another near an **open flame**, nor **heated** near open flame. Burners should not be alight in the neighbourhood of flammable solvents. **Never heat a flammable solvent over an open flame**.

3. Flammable solvents should be kept away from motor driven electrical equipment when in operation – especially blenders, unless they have been made spark-proof.

4. **Open** containers containing solvents must **never** be put in refrigerators. Small quantities of standard solutions in flammable solvents may be stored in a refrigerator provided they are **well closed**.

5. Glass apparatus used for heating flammable liquids should be carefully examined for **defects** such as cracks. All joints including rubber tubing to glass should fit perfectly so that **no leaks** can occur.

6. Solvents with low boiling points should be heated on a **hot water** or steam bath and **not** on a gas flame or hot plate.

7. Vapours given off must be **efficiently** condensed so that **none escapes** into the laboratory. Check the **flow** of cooling water frequently. Adjust heating so that liquid does not accumulate in the condenser. Use **ice water** and water pump in hot weather, if necessary.

8. Do not **evaporate** flammable solvents on a **hot plate**, always use a **steam bath**. A fan should be used and the **fume hood** lowered to an appropriate level to prevent solvent vapours from escaping.

9. **Never put solvents down the sinks**, always use a waste solvent container. Do not place rags impregnated with solvent in waste bins, evaporate solvent first in a fume cupboard.

10. All flammable solvents should be stored in **solvent cabinets**, **under** fume cupboards or in the laboratory store area, when not in use.

3.6 Exposure limits

When you handle any volatile compound you should not expose yourself (or others) to high concentrations of its vapour, which exceeds the published Occupational Exposure Standards (OES). The list below shows long term (8h, time weighted average) exposure limit data in mg/m^3.

	mg/m^3		mg/m^3
Acetone	1780	Ethanol	1900
n-Hexane	70	Methanol	260
Pet. Ether-30/40	70	Diethyl ether	1200
Pet. Ether-60/80	70	Pyridine	15
Chloroform	10		

When you are in a laboratory, you should know (i) how to protect yourself from possible health risks or accidents (ii) how to safeguard the facilities and other contents in the laboratory. If you are the last person to leave the laboratory after finishing your work, you have the additional responsibility to leave the laboratory in the safe mode.

3.7 Leaving a laboratory

The most serious **fires** or **floods** usually begin in **unoccupied** laboratories because something has been left on **inadvertently** or **incorrectly**. When you leave your laboratory in the evening you have the responsibility to check that:

I. There is **no obvious problem** with any **reaction or equipment left going**. However, for overnight experiments, there should be a note, authorised by a senior staff member, describing the reaction conditions and precautionary measures.
II. There are **no** large amounts of **flammable** solvents left outside the closed storage cupboards.
III. **Unnecessary** electrical equipment is turned off and there is **no naked flame or flammable gas left on**.
IV. If water has to be left running, the tubing is **anchored down a drain** so there is **no splashing** or any risk of **overflowing** *if the water pressure varies*.
V. All fume cupboards are closed.
VI. **Lights are turned off** as they can ignite leaking gas or solvent vapours.
VII. That all **doors** between the laboratory and leading to the corridor are fully **closed**.

Summary

- The laboratory should be kept clean and tidy.
- 5S is a methodology for organizing items and services within a workplace (or laboratory), thus carrying out day-to-day work more productively and efficiently.
- Each laboratory should maintain inventories for chemicals and equipment.
- Incompatible chemicals (see Appendix-III) should not be stored together or close by.
- New compounds should be labelled giving the experiment number, date, colour, and purity.
- Solutions should be labelled giving the date of preparation, solvent(s) used, name and the quantity of the solute(s).
- Each laboratory should develop a Chemical Hygiene Plan (CHP) that documents the necessary work practices, procedures and policies intended to keep the laboratory a safe place for everyone to work efficiently.
- Adhering to good laboratory practices increase the safety of the employees and avoid/minimize the accidents and injuries.
- Solvents are liquids therefore chemical hazards arise from inhalation, ingestion, skin absorption and injection.
- Solvents can pose a serious risk due to their flammability when used in large quantities. Diethyl ether, chloroform, benzene, *n*-hexane acetonitrile and carbon disulphide are particularly dangerous.
- Distillation is the process of heating a liquid until it boils, and cooling the resultant vapours, and collecting the condensed vapour (liquid) to a separate vessel.
- Distillation is used for the identification and purification of organic compounds.
- A mixture of compounds (liquids) can be separated into individual components by fractional distillation.
- During refluxing, the solvent vapour is condensed as the vapour is cooled by the water condenser and collected back into the flask.
- Solvent stills are used when we need dry and oxygen free solvents.
- The most serious fires or floods usually begin in unoccupied laboratories.

Learning Outcomes

Once you have finished studying this session you should be able to

- discuss the ways and means of achieving good house keeping in the laboratory
- appreciate the importance of a chemical hygiene plan
- make a list of good laboratory practices
- describe the processes such as distillation and refluxing
- maintain a solvent still
- discuss how you would purify solvents
- write down the checklist required by the last person to leave the laboratory

Activity 9 - Review Questions

9.1 What is meant by a chemical hygiene plan?
9.2 How would you obtain dry and oxygen free dichloromethane?
9.3 What is meant by “distillation”?
9.4 What is in your checklist if you are the last person to leave the laboratory?
9.5 Briefly point out the good laboratory practices.
9.6 What happens when you are refluxing a solution?
9.7 What are the key phases in 5S?
9.8 What protective gear would you put on before and during distillation of aniline?
9.9 Indicate whether the following statements are true or false.

a) A first-aid kit should be readily available in every laboratory. (True/False)
b) Each laboratory should have its own master controls for gas and water and the main electrical supply which should be easily accessible and clearly labeled. (True/False)
c) Stores should have good permanent ventilation. (True/False)
d) All equipment must be regularly inspected and tested by a competent person. (True/False)

4. Chemical spills and chemical waste

Introduction

In the previous sessions we considered items that you may find in a laboratory, safety signs and related issues, and the importance of having good policies and laboratory practices. However, accidents and mishaps do occur due to human error.

Let us examine the types of common mishaps that could happen inside a laboratory. Chemical spillage is one such mishap.

In this session we will briefly discuss the steps that you should take to prevent chemical spillages and how you should dispose the resulting chemical wastes in case there was a chemical spill.

4.1 Chemical spills

We should take every step to avoid chemical spillages. Hazardous chemicals (solids, liquids and gases) should be handled after reading the material safety data sheets (MSDS) and wearing protective clothing. Toxic gases should **only** be handled in an efficient fume cupboard.

A **chemical spill** can be a potentially dangerous situation if you do not know how to handle it.

Here are some useful steps to follow.

i. Be prepared (Read the MSDS) - *Before you start the work you should read the MSDS.*

ii. Protect yourself from injury - *Wear proper protective gear, e.g. lab-coat, safety glasses, gloves, shoes etc)*

iii. Evacuate the immediate area - *Inform others about the spill and ask them to leave the area immediately*

iv. Isolate the spill from other hazards/equipment - *Take steps to avoid the spill reaching other chemicals and equipment etc.*

v. Dispose the waste material - *You should be able to dispose the waste material properly.*

vi. (iv) Learn from the experience - *Every accident should be **recorded** in a book and others should be **informed** about it. More importantly, steps should be **taken to prevent** it from happening again.*

All spills should be cleaned up promptly, efficiently and properly. Mopping-up cloths should always be available, as should a mop bucket. Sand, saw dust and sodium bicarbonate should be available for putting on spills. For chemical spills on the skin or in the eyes, treatment must begin immediately.

Hazardous Spills

The following compounds are *very hazardous*. When you clean them you should take extreme care. For example, aromatic amines, nitro compounds, bromine, ethers, carbon disulfide, hydrazine, cyanides, nitriles and organic halides.

4.1.1 Clean-up of chemical spills

Chemical spills that do not pose a fire, toxic, or corrosive hazard, must be cleaned up immediately by the laboratory staff. Use an absorbent material that neutralizes the spill. Examples of spill clean-up materials include:

- Sodium phosphate
- Sand
- Sodium bicarbonate for acids
- Powdered citric acid for bases
- Paper towels

A dustpan and brush should be used and rubber gloves and safety glasses must be worn during the clean-up. Decontaminate the area with soap and water after the clean-up. Place residue in a container for waste collection.

Types of chemical spills and some steps to be taken to clean up the spill are listed below.

Solid dry substances: These chemicals can be swept together, brushed on to a shovel, dustpan or cardboard and then deposited in the proper waste container.

Acid solutions: Acid spills should be diluted with water and flushed to a drain (or sink). *Soda ash or sodium bicarbonate solid or solution* can be used to neutralize any residual acid, followed by flushing with water.

Alkali solutions: These should be flushed with water to a drain.

Volatile solvents: Volatile solvent evaporates rapidly and this kind of spill can cause a fire hazard. If minor quantities are spilled, wipe up the liquid with rags and discard them in the proper waste container/receptacle. If a large amount of solvent is involved in the spill, use a mop and pail. Squeeze out the mop in the pail and continue as needed.

Oily substances: Remove the excess liquid by mopping. Pour a suitable non-volatile solvent on an absorbent rag, and then wipe up the spilled substance. Finally, a thorough detergent-water scrub will clean up any oily remains.

Mercury: Sprinkle sulphur powder on the mercury, wait for it to absorb the mercury, then collect and dispose of as solid hazardous waste.

4.2 Chemical waste

A material is defined as a waste when it is determined that the material is *no longer to be used and it is time to discard it.* Laboratory staff members have to *decide the unwanted material as a waste when it is abandoned or contaminated or decomposed*. It is wise to consider all waste chemicals to be hazardous waste. Spilled materials often are wastes.

Some chemicals can be disposed **safely into the environment**. Some acids and bases can be disposed in small quantities **after neutralizing them**. In developed countries, disposal of certain chemical wastes is governed by the state (Government) or local authorities and strict guidelines have to be followed. Some hazardous wastes are to be taken away for **burial** or **incineration**. For this the academic institutions should work with a reliable and competent disposal contractor. The contractor must have the necessary permission/authorization by the state to perform the following services: packing, labelling, transporting, and disposing chemical wastes.

Disposal of hazardous wastes is expensive, therefore we have to **minimize the waste generation** by reducing the scale of the process or following alternative methods which generate non-hazardous wastes.

4.3 Disposal of chemical waste

The safety officer should provide the staff with detailed instructions on how to dispose of regulated waste. Some helpful hints are as follows.

(i) Properly dispose of waste *after each experiment*;
(ii) Keep each different class of chemicals in *separate specially labelled and dated disposal containers*;
(iii) Never pour chemicals into a sink or drain *without* properly *neutralizing them*;
(iv) Follow *specific instructions* regarding any highly reactive materials – peroxides, potassium and heavy metals *etc*.

Given below is a broad classification of chemical waste. Different types of wastes are destroyed or disposed of by taking into their properties.

Acidic or basic solution waste: After neutralizing, pour the waste into the sink *while running water continuously from the tap*. When you have finished pouring the waste into the sink, run a large volume of water to dilute any *corrosive effect*.

Organic solvent waste: Discard the organic solvent waste into a waste-disposal vessel (*chlorinated and non-chlorinated solvents separately*). A proper waste-disposal vessel may retain solvent vapour and pose no fire hazard.

Organic waste residues: These are insoluble in water. Discard the bulk of the residues into a waste-disposal container.

Sodium and potassium waste: Destroy properly by adding slowly iso-propanol or ethanol to the waste. *Note that severe injuries and deaths have been reported due to improper destruction of Na and K.*

White Phosphorus should be smothered with wet sand or wet absorbent.

Laboratories should be equipped with an adequate supply of waste boxes, preferably of three distinctive kinds: one for dry waste, one for broken glassware and one for wet waste such as filter papers and biological material. Chlorinated and non-chlorinated solvent waste should be collected separately to a proper waste-disposal vessel.

Fig. 4.1 Various containers/boxes used for the collection of waste [46]

4.4 Information given in a Material Safety Data Sheet (MSDS)

Material Safety Data Sheet (MSDS) is like an “unauthorised” biography on a hazardous material. Main objective of this sheet is to protect you. It provides concise information about the hazardous nature of the material. Thus, you can protect yourself and respond to emergency situations.

The following information is given in a Material Safety Data Sheet (MSDS).

(a) Reference Number, Chemical Name, Trade Name(s)
(b) CAS Number (Chemical abstract service number)
(c) Physical/Chemical properties: State, Colour, Appearance**,** Odour, Miscibility, Melting Point, Boiling point, Vapour pressure, Solubility in water, Molecular Weight, Molecular formula,
(d) Acute Toxicity data
(e) LD_{50} Value
(f) Chronic Toxicity data
(g) Environmental Effects
(h) Health Effects
(i) Type of use
(j) Precaution in terms of transport, storage, protective gear, *etc*
(k) Treatment for Poisoning
(j) Legal Status
(l) Source (Code)

Summary

- Accidents and mishaps occur due to human error; a common mishap is chemical spill.
- We should take every step to avoid chemical spillages.
- By reading the material safety data sheets (MSDS) and wearing protective gear and taking prompt actions you could avoid/minimise injuries and damages to equipment in the laboratory.
- Every accident should be recorded in a book and others should be informed about it. Steps should be taken to prevent it from happening again.
- A chemical spill that does not pose a fire, toxic, or corrosive hazard, must be cleaned up immediately by the laboratory staff. Volatile solvents evaporate rapidly and this kind of spill can cause a fire hazard.
- A laboratory staff member has to decide the unwanted material as a waste when it is abandoned or contaminated or decomposed. Spilled materials often are wastes.
- The safety officer should provide the staff with detailed instructions on how to dispose of regulated waste.
- Discard the organic solvent waste into a waste-disposal container (chlorinated and non-chlorinated solvents separately).

Learning Outcomes

Once you have finished studying this session you should be able to

- write down the steps that you should take to avoid chemical spills and to clean up chemical spills and to prevent it from happening again
- define chemical waste, how to minimize the waste generation, how to collect and store chemical waste and how to dispose of chemical waste
- obtain the information from MSDS

Activity 10 - Review Questions

10.1 What steps would you take to minimize the damage due to a chemical spill?
10.2 What protective gear would you put on before you clean-up a chemical spill?
10.3 What items would you need to clean-up a chemical spill?
10.4 How would you clean-up an acid spill?
10.5 What is meant by "chemical waste"?
10.6 How would you dispose of acid waste?
10.7 How would you dispose of potassium waste?
10.8 How would you dispose of organic solvent waste?
10.9 What information can you get from a MSDS in terms of precautions?
10.10 What is meant by CAS number?
10.11 What information can you get from a MSDS in terms of physical properties?
10.12 Select the correct answer for the following statements on chemical spills.

a) Anticipate spills by having the appropriate safety equipment on hand. (True/False)
b) If a spill occurs, do not alert personnel in the area but do what is necessary to protect life. (True/False)
c) Call for assistance if the spill is large, a threat to personnel or the public. (True/False)
d) White Phosphorus should be smothered with dry sand. (True/False)

Answer guide to activities

Session 1

2.1 Hazardous chemicals are the substances that are toxic, corrosive, irritant, reactive and cancer causing, thereby poses a threat to health and environment.

2.2 Benzene; *ortho*-toluidine; asbestos; benzidine; formaldehyde;

2.3 Acetylides, amine oxides, chlorates, peroxides, trinitrotoluene (TNT);

2.4 Nitric acid, hydrogen peroxide, phosphoric acid, potassium dichromate;

2.5 Benzoyl peroxide and picric acid

2.6 Date, name of the compound/specimen or the experiment number, name of the person who left the sample in the fridge and the solvent used.

2.7 Inhalation (gases and vapours), skin absorption, and ingestion

2.8 Solids, liquids and gases

2.10 Starvation (of fuel), smothering (cutting off oxygen supply), and cooling (absorption of heat)

2.11 Fire extinguishers based on: water, foam, carbon dioxide and dry chemical powder

2.12 Sterilised dressings, bandages, antiseptic cream, eye wash bottle;

2.13 a) True b) False c) True

Session 2

5.1 Acetone, cyclohexane, acetic acid, ethanol, methanol, benzene;

5.2 Nitric acid, hydrogen fluoride, phosphoric acid, potassium chromate, sodium hydroxide;

5.3 Aniline, mercury (II) chloride, arsenic trichloride, methyl isocyanate, calcium cyanide;

5.4 Pyrophoric substances are the substances that can ignite spontaneously, even in small quantities, after coming into contact with air.

5.5 Acrylonitrile, lead, carbon tetrachloride, benzene, formaldehyde;

5.6 (a) Oxidizing agent
(b) Toxic, poisonous
(c) Radioactive
(d) Pyrophoric
(e) Corrosive
(f) Flammable
(g) Corrosive
(h) Flammable, toxic
(i) Explosive
(j) Oxidizing agent

5.7 Never eat, drink or smoke in the laboratory. Never work alone in the laboratory. Never perform unauthorized work or experiments. Never pipette by mouth.

5.8 Refer section 2.1.2.

5.9 Wear appropriate safety gear (goggles, gloves, lab-coat, shoes *etc*), use unscratched and appropriate glassware

5.10 a) Radioactive material b) Poisonous material/Toxic
c) Explosive d) oxidizing agent

Session 3

9.1 Chemical Hygiene Plan (CHP) gives the necessary work practices, procedures and policies intended to keep the laboratory a safe place for everyone to work efficiently.

9.2 Dichloromethane should be dried with CaH_2 under N_2 before distilling under N_2.

9.3 Distillation is the process of heating a liquid until it boils, capturing and cooling the resultant hot vapours, and collecting the condensed vapour (liquid) to a separate vessel.

9.4 Refer page 30 and 31.

9.5 Adhering to rules and guidelines, good house-keeping, use of appropriate protective equipment, training of staff, proper waste disposal;

9.6 The solvent vapour is condensed and collected back to the flask as vapour is cooled by the water condenser.

9.7 Sort, stabilize, shine, standardize and sustain

9.8 Goggles, gloves, lab-coat and shoes

9.9 (a) True; (b) True; (c) True; (d) True

Session 4

10.1 Refer page 37.

10.2 Lab-coat, rubber gloves, goggles and shoes.

10.3 Gloves, appropriate safety glasses, dust pan & brush, appropriate neutralizing agents;

10.4 Acid spills should be neutralized with a suitable base before discarding the waste into a drain/sink using a large amount of water.

10.5 A material is defined as a waste when it is determined that the material is no longer to be used and it is time to discard it.

10.6 After neutralizing, pour the waste into the sink while running water continuously from a tap.

10.7 Destroy the potassium waste properly by adding *iso*-propanol or ethanol to the waste. Then pour the waste into the sink while running water continuously from the tap

10.8 Discard the organic solvent waste into a waste-disposal vessel (chlorinated and non-chlorinated solvent waste should be collected separately).

10.9 Toxicity data, health effects, protective gear, treatment for poisoning;

10.10 Chemical abstract service number

10.11 State, colour, appearance, odour, miscibility, melting point, boiling point, vapour pressure, solubility in water, molecular weight, molecular formula *etc*.

10.12 (a) True; (b) False; (c) True; (d) False

List of abbreviations

HPLC	: high performances liquid chromatography
MSDS	: material safety data sheet
Ph	: phenyl
L	: litres
CAS	: chemical abstract service number
CHP	: chemical hygiene plan
e.g.	: for example
i.e.	: that is
etc	: *et cetera*
o-	: *ortho*

Glossary

Absorb	: To soak up; incorporation of a liquid into a solid substance, as by capillary, somatic, solvent or chemical action.
Acute exposure	: Exposure for a short duration, usually to relatively high concentration of amount of material.
Acute toxicity	: Adverse health effects resulting from brief exposure to a chemical.
Ambient	: Usual or surrounding conditions of Temperature, humidity, etc.
Antidote	: A remedy to counteract a poison's toxic effect; it may act to eliminate, absorb, or neutralize the poison.
Aqueous, aq	: Describe a water based solution or suspension.
Boiling Point, BP	: The temperature at which a liquid's vapor pressure is equal to the surrounding atmospheric pressure so that the liquid is rapidly vaporized.
CAS Number	: An assigned number used to identify a chemical.
Chronic Exposure	: Continuous or intermittent exposure extending over a long time period, usually applies to relatively low material amount or concentrations.
Chronic Toxicity	: Adverse health effects resulting from long term exposure to a chemical.
Ingestion	: Swallowing a chemical substance; may result from drinking, eating or smoking in the work place or with contaminated hands.
Inhalation	: Entry of a chemical substance to the lungs by breathing.
LD_{50}	: Lethal dose 50.The single dose of a substance that causes the death of 50%of an animal population from exposure to the substance by any route other than inhalation.
Toxic	: Poisonous; having properties of causing adverse health effects when the body is exposed.

Appendix-I

Contents of a Material Safety Data Sheet

Reference No : 145
Chemical Name : Benzene
Trade Name(s) : Benzol
Annulene
Coal Naphtha
Phene
Pyrobenzol

CAS No : [71-43-2]

Physical/Chemical properties:

State	-	Liquid
Colour	-	Colourless/Yellow
Appearance	-	Mobile; non polar
Odour	-	Aromatic
Miscibility	-	Alcohol, ether, CCl_4

Melting Point : 5 ^{o}C
Boiling point : 80.1 ^{o}C
Vapour pressure : 100 mm (26.1^{o}C)
Solubility in water : Slightly soluble
F-Solubility : Miscible in oils, waxes
Molecular Weight : 78.11
Molecular formula : C_6H_6

Acute Toxicity data : Local : Irritant – moderate toxicity
Local : Ingestion – slight toxicity
Local : Inhalation – slight toxicity
Systemic : Ingestion – moderate toxicity
Systemic : Inhalation – moderate toxicity
Systemic : Skin absorption – moderate toxicity

LD_{50} Value : Orl-rat : 4894 mg/kg

Chronic Toxicity data: Local : No toxicity
Systemic : Ingestion – severe toxicity
Systemic : Inhalation – moderate toxicity
Systemic : Skin absorption – Severe toxicity

Environmental Effects : Flammable
Dangerous fire risk

Health Effects : Low toxicity
Toxic by ingestion, inhalation and skin absorption
A suspected carcinogen
Exposure may cause nausea and headache

Prolonged exposure may cause narcotic effect
May cause dizziness
May cause blood disorders

Bioaccumulation : Carbon dioxide and carbon monoxide

Type of use : Detergents
For nylon
For aniline
Solvent

Special Precaution in Transport & Storage: Keep away from heat, sparks and open flame store under nitrogen

Other precautions : Wear appropriate OSHA/MSHA approved respirator
Wear chemical resistant gloves
Wear safety goggles
Wear other protective clothing
Use safety shower and eye bath
Use only in a chemical fume hood
Do not breathe in the vapour
Do not get in eyes, on skin, on clothing

Treatment of Poisoning: If inhaled remove to fresh air
If not breathing give artificial respiration
If breathing is difficult give oxygen
Call a Physician
Wash contaminated clothing promptly before reuse

Legal Status : SWT : Prohibited
CHL : Prohibited
DEN : Prohibited
FIN : Prohibited
JPN : Prohibited
NZL : Available for commercial users only

For the MSDS of toluene, visit http://www.cen.iitb.ac.in/chemical_approval/msds/91_msds.pdf

Appendix-II

Checklist for using Gas Cylinders safely

1. Cylinder contents must be properly identified
Do not accept cylinders that do not identify contents by name. Do not rely on colour codes for identification. Do not destroy identification tags or labels.

2. Cylinder valves must be protected
Accept only cylinders provided with cylinder valve protective caps. Leave caps in place until ready to use gas.

3. Store properly
Provide definitely assigned location, preferably in fire resistant, dry and well ventilated area, away from sources of ignition and heat. Outdoor storage area should have proper drainage, and be protected from direct rays of the sun.

4. Stabilize cylinders
Secure cylinders by chaining or other means to keep them from falling accidentally.

5. Transport correctly
Transport cylinders by means of a hand truck. Do not roll.

6. Don't drop
Never drop cylinders or permit them to strike each other violently.

7. Return in condition received
Close valve, replace cylinder valve protective cap, and dust caps. Mark the cylinder as 'EMPTY'..

8. Prevent confusing empties with full cylinders
Store empties apart from the full cylinders, to await return to supplier. Connecting empty cylinder to pressurized system by mistake could cause contamination or violent reaction in cylinder.

Appendix-III

CHEMICAL	INCOMPATIBLE CHEMICALS
Alkali metals	: water, carbon dioxide, carbon tetrachloride, and other chlorinated hydrocarbons
Acetic Acid	: chromic acid, nitric acid, hydroxyl containing compounds, ethylene glycol, perchloric acid, peroxides, permanganates
Acetone	: concentrated sulphuric and nitric acid
Acetylene	: copper (tubing), fluorine, bromine, chlorine, iodine, silver, mercury and their compounds
Ammonia (anhy.)	: mercury, halogens, calcium hypochlorite, hydrogen fluoride
Ammonium nitrate	: acids, metal powder, flammable fluids, chlorates, nitrates, sulphur or finely divided organics or combustibles
Aniline	: nitric acid, hydrogen peroxide
Bromine	: ammonia, acetylene, butadiene, butane, hydrogen, sodium carbide, turpentine, fine divided metals
Chlorates	: ammonium salts, acids, metal powders, sulphur, finely divided organics or combustibles, carbon
Chromic Acid	: acetic acid, naphthalene, camphor, alcohol, glycerol, turpentine and other flammable solvents
Chlorine	: ammonia, acetylene, butadiene, benzene, and other petroleum fractions, hydrogen, turpentine, finely divided and powdered metals
Cyanides	: acids
Hydrogen Peroxide	: copper, chromium, iron, most metals or their salts, flammable materials, aniline, nitromethane
Hydrogen Sulphide	: nitric acid, oxidising gases
Hydrocarbons	: fluorine, chlorine, bromine, chromic acid, sodium peroxide
Iodine	: acetylene, ammonia

Nitric Acid : acetic, chromic and hydrocyanic acids, aniline, carbon, hydrogen sulphide, flammable media, fluids or gases and substances which are readily nitrated.

Mercury : acetylene, fulminic acid, and hydrogen.

Oxygen : oils, grease, hydrogen, flammable liquids, solids and gases.

Oxalic Acid : silver, mercury

Perchloric Acid : acetic anhydride, bismuth and its alloys, alcohol, paper, wood and other organic materials.

P_4O_{10} : glycerol, ethylene glycol, benzaldehyde, sulphuric acid

$KMnO_4$: glycerol, ethylene glycol, benzaldehyde, sulphuric acid

Sodium Peroxide : any oxidisable substance, *e.g.* methanol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulphide, glycerol, ethylene glycol, ethyl acetate, furfural.

Sulphuric Acid : chlorates, perchlorates, permanganates, water

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