Chapter 13

Laboratory and Practical Skills

Student Learning Outcomes

After studying this chapter, students will be able to:

- Explain, with examples, the types of chemical hazards in the lab and suggest safety precautions. (Types of chemical hazards to be identified: flammable or explosive hazards, corrosive hazards, toxic hazards, reactive hazards, radiation hazards and asphyxiation hazards)
- Recognize the meaning of different chemical hazard signs in the lab and on chemicals.
- Recognize the importance of personal protective equipment (PPE) by correctly identifying the types of PPE needed for different lab. activities.
- Locate the nearest fire extinguisher and emergency shower.
- Show awareness of emergency procedures in the event of an emergency in the lab.

Introduction

A chemistry laboratory is a place where a student is trained to observe the physical and chemical characteristics of substances by following definite procedures. Before starting the laboratory work, a student should get himself familiarized with the layout of the laboratory and various fittings provided in the laboratory table as well as the side shelves. Students are expected to conduct themselves in a responsible manner at all times in the lab. They are advised not to work alone in the lab. Experiments should be performed in the presence of lab. instructor and other laboratory staff. All equipments should be checked before use whether they are working properly according to the requirements of the experiments. Determine the potential hazards related to any equipment or the experiment before beginning any work. Appropriate safety precautions must be observed at all cost. There must not be any crowding in the lab and students should stick to their work places at a safe distance from each other. Don't bring any food items in the lab. Never taste or smell any compound or a gas. If it is necessary to smell a gas it is always advised to waft the fumes or vapours towards your nose.

Warning signs are displayed when unusual hazards, hazardous materials, hazardous equipment or special conditions are expected. Do not pour chemicals down the drains and do not utilize the sewer for chemical waste disposal. Keep all sink traps and floor drains clean. Laboratory chemical waste can be disposed off in sewer or trash bin if they are non-hazardous materials. Acids and bases are first neutralized followed by sewer disposal. Hazardous waste material is transported to hazardous waste disposal site.

Misuse and mishandling of chemicals may create serious problems for the laboratory workers. A laboratory worker must use the chemicals according to the standard procedures keeping in view the particular hazards and precautions required for the safe use. The chemicals which can create problems for the safety of workers are cleaning agents, disinfectants, solvents, paints, compressed gas cylinders, mineral acids, carcinogenic chemicals etc.

Recognizing hazards which are commonly encountered in the laboratory helps to identify and minimize many of the health and safety problems. Most hazards which we might face while working in the laboratory fall into the following categories.

13.1 Chemical Hazards in the Laboratory

13.1.1 Flammable and Explosive Chemical Hazards

To start working in the laboratory requires great care, responsible behaviour and good attention. It is important to exercise extreme caution while working with delicate instruments, hazardous chemicals and open flames. If flammable and explosive chemicals are not handled in a safe and compliant manner, they can cause acute health problems. These problems may include burns, eye injuries, lung disease and suffocation.

Chemicals that cause a sudden release of pressure, gas and heat when they experience sudden shock are called explosive chemicals. Examples of chemicals which are expected to explode are picric acid, 2,4 -di-nitrophenyl hydrazine, benzoyl peroxide, nitrocellulose etc.

Flammable chemicals or mixtures are those which have a flashpoint around room temperature. Examples of flammable compounds are ethers, methylated spirit, benzene, acetone, petrol etc.

If you ever come across any chemical that you suspect to explode, do not attempt to move the container to avoid shock. Explosives can cause damage to people, windows, tables etc.

Avoid using a chemical that is hazardous. Look for its alternative. If you must use a potentially dangerous chemical, you must follow the underlying safety instructions.

1. Obtain prior approval from your teacher.
2. Always use smallest quantity of the chemicals.
3. Always conduct experiment in fume hood.
4. Remove all other chemicals and apparatus around you.
5. Inform other people working with you.
6. Always wear safety spectacles, gloves and lab. coat.
7. Always keep flammable compounds away from heat source.
8. Pour the flammable liquid very carefully.
9. Properly dispose off any hazardous waste.
10. Do not store flammable liquid in refrigerator.

13.1.2 Corrosive Hazards

Corrosive chemicals attack living tissues when they come in contact with them. They can be in the form of solids, liquids or gases. Such chemicals attack skin, eyes and respiratory tract and in the intestine as well. Whenever you work with corrosive chemicals, wear splash goggles instead of safety glasses and use a face shield.

Safety Precautions

1. Corrosive chemicals must be used in a fume cupboard to avoid breathing corrosive vapours.
2. While mixing concentrated acids with water, always add acid slowly to water and not vice versa.
3. Ensure eye wash and emergency shower is available.
4. Wash the affected area with soap and water and seek medical attention in case of emergency.

Examples of corrosive chemicals are mineral acids including HF, caustic alkalies, acetic acid (glacial) etc.

13.1.3. Toxic Chemical Hazards

A toxic chemical is a poisonous material which is capable of causing serious health problems. Mercury, benzene, chlorine, pesticides, ammonia, hydrogen cyanide are some examples of toxic chemicals. The following safety instructions may be ensured in case you intend to work with toxic chemicals.

1. Wear gloves, masks or other protective devices.
2. Keep the work area well ventilated.
3. Keep the toxic chemicals in original container.
4. Do not work alone.
5. Wash your hands with soap and water after you finished.
6. Always work in fume hood because toxic vapours can be formed during an experiment.
7. Seek immediate medical aid if you think you may have exposed to poisonous substance.

13.1.4. Reactive Chemical Hazards

The reactivity of chemicals is vital for the production of many other chemicals, pharmaceuticals and food products which are in our daily use. When chemical reactions are not properly performed, they may cause fires, explosions as they may evolve dangerous gases. These reactions may result to an extreme damage to life and property. Examples of reactive chemicals are calcium hydride, Na, Li, azides, picric acid, $AlCl_3$, benzoyl peroxide etc.

Safety Instructions

1. Handle reactive chemicals with utmost care. Segregate these from other chemicals while storage.
2. Appropriate measures should be taken before performing reactions with reactive chemicals. Utilize shield and heavy gloves.
3. Minimize the quantity required for experiment.
4. Glass equipment must be shielded by wrapping with tape.
5. After use carefully dispose off every dangerous material.

13.1.5. Radiation Hazards

When a person is exposed to a high dose of radiation, it can damage the functioning of tissues and organs and can cause vomiting, radiation burns, hair loss and radiation syndrome.

Radioactive materials that emit alpha and beta particles inflict extreme damage when inhaled or injected. Gamma rays cause external injuries. Medical x-rays produce ionizing radiation which can affect living tissues.

Safety Instructions

1. Keep radioactive sources shielded.
2. Avoid prolonged exposures to the radiation.
3. Stay inside as walls and ceilings can protect you from radiation fall out.
4. Never operate equipment that produces radiation without sufficient training.
5. Wear protective clothing, wear face mask.
6. Avoid contact of the material with bare skin.
7. Monitor exposure to radiation using badges etc.

13.1.6 Asphyxiation Hazards

It is a type of hazard in which a gas or vapours can cause unconscience or death through suffocation.

A sufficient level of oxygen is essential for normal breathing. If this level falls, it can create very dangerous situation. The exposed person has no warning and cannot realize that oxygen level has become low. If the level of oxygen decreases a person can feel rapid breathing, rapid heart rate, nausea and convulsions.

Examples of chemical asphyxiants are hydrogen cyanide, carbon monoxide, nitrogen, argon, helium, methane and carbon dioxide etc.

Safety Instructions

1. Store and use asphyxiant chemicals in well-ventilated areas with plenty of air.
2. Wear a full lab. coat, wear glasses and standard gloves, long trousers and closed-toed shoes.
3. Dispose off the waste strictly according to the instructions.
4. If exposed to such chemicals wash the exposed part with running water and seek medical attention.
5. When such a chemical is inhaled, remove the patient from the contaminated area and call appropriately trained person.

Exercise

1. Why flammable liquids are not stored in refrigerator?
2. Can you wear contact lenses in the lab.?
3. Under which circumstances explosive chemicals are likely to explode?
4. How will you dispose off acid and alkali waste after the experiment is finished?

13.2 Hazard Signs

A chemistry laboratory is a strict area where rigorous rules must be practised to avoid a chance of a deadly accident. A dangerous situation may arise not only for the individuals working there but for the whole area. In a laboratory there are several hazardous materials, sensitive equipments and specified areas for specific tasks. Proper warning signs ought to be posted on these areas to ensure that every person entering there must understand and act accordingly to maintain laboratory safety.

Several signs and symbols are posted in different areas of the lab. and bottles containing hazardous chemicals. These signs indicate that specific precautions must be observed according to the requirement of the sign posted there. If you see such signs, you must be alert and take extra care to maintain safety in that area, Fig (13.1).

Fig (13.1): Different Hazard Signs

Exercise

1. What does warning sign "caution" convey the message?
2. Name some explosive chemicals.

13.3 Personal Protective Equipment (PPE) in the Laboratory

Personal protective equipment should be made available to students to face any emergency situation which may arise in the lab. They are also useful to reduce exposures to hazardous chemicals. Proper protective equipment include such items as lab coat, protective glasses, face shields, apron, boots and hearing protection.

13.4 Location of Fire Extinguisher

Chemical laboratories using such materials which are likely to catch fire during experiments must have a portable fire extinguisher. This equipment can quickly be used to control a small fire if it is applied by a student individually. For this purpose all students should be well aware of the location where this fire extinguisher is placed. A training session should be held to train all the students to know how to handle and apply this fire extinguisher to extinguish the fire properly without any panic or harm to anybody.

Similarly the facility of a shower should also be made available in the lab whose location and working must be told to everybody working in the lab. In case of fire or any other emergency students should know how to face that emergency situation.

Exercise

1. Should emergency drills be compulsory or optional?

13.5 Emergency Situation in the Lab.

Students should make themselves aware of the actions that need to be taken in case of an emergency in a laboratory or if a person is affected. For this purpose periodic drills should be held with compulsory participation. Students should not only been given lectures but involve them practically to handle the emergency situations. During drill firefighting and other equipments must be checked whether they are in proper working order or not.

The following points should be kept in mind to cope with the emergency situation.

1. Stay calm and do not panic.
2. Alert people in the area to evacuate.
3. In case of fire, close doors to confine fire. Use fire extinguisher to put down the fire.
4. In case of chemical emergency adopt safety procedures as mentioned in article 13.1.
5. Call and assist emergency staff.

Key Points

1. Working in the laboratory requires care and responsible behaviour. Hazardous chemicals and open flames if not handled properly can cause health problems.
2. Chemicals can suddenly explode due to shock and heat. They require handling them with care.
3. Safety instructions should be followed strictly to avoid any damage due to flammable and explosive chemicals.
4. Corrosive chemicals affect skin, eyes and respiratory tract. To avoid such health problems corrosive chemicals must be handled in fume cupboard.
5. Chemicals are poisonous and cause great harm if not handled according to instructions.
6. Some chemicals are so reactive that they require special care in the laboratory.
7. Radioactive materials can affect living tissues and organs and cause other health problems. It is important to avoid longer exposure to radiation to stay healthy.
8. Asphyxiant chemicals are extremely lethal because they can cause suffocation. They must be used in well-ventilated places with protected dress.
9. Signs and symbols should be posted in the lab. and chemical bottles to let the people know their hazardous nature
10. Personal protection equipment are mandatory before you enter the lab.
11. Students shall know the location and operation of fire extinguisher and shower in the lab.

Exercise

1. Tick (✓) the correct answer.

(i) Safety in the chemistry laboratory is:

(a) the responsibility of the students only
(b) the responsibility of the professor only
(c) the responsibility of the lab. incharge only
(d) a shared responsibility

(ii) Accidents often result from:

(a) making mistakes
(b) failure to use common sense
(c) failure to follow instructions
(d) all of the above

(iii) The label "Warning" on a chemical bottle signifies:

(a) that the chemical can cause less serious injury
(b) that the chemical can cause serious injury
(c) that user should be careful when using chemical
(d) that user should open it only in the presence of a teacher

(iv) The label "Corrosive" on a chemical bottle indicates:

(a) that the material is an oxidizing agent
(b) that the material can degrade rapidly upon exposure
(c) that its contact destroys living tissue
(d) that the chemical can explode

(v) Example of highly toxic chemical:

(a) Ethanol (b) Acetic acid
(c) Potassium cyanide (d) Potassium permanganate

(vi) Example of self-reactive chemical:

(a) Potassium (b) Phenol
(c) Picric acid (d) n-Hexane

(vii) When diluting an acid with water:

(a) do it quickly

(b) do not stir the container

(c) always add acid to water

(d) always add water to acid

(viii) What should you do in case of a fire drill in the lab.?

(a) run to safety shower

(b) climb into the fume cupboard

(c) close gas valves and turn off all equipments

(d) carry chemicals out of the lab.

2. Questions for Short Answers

i. Name some corrosive chemicals.

ii. What type of safety precautions are adopted to avoid damage due to explosive chemicals?

iii. What type of damages can reactive chemicals cause?

iv. Indicate two such safety instructions which are required to avoid radiation.

v. Which chemicals can cause suffocation?

vi. Why signs and symbols are posted on lab. and chemical bottles?

vii. How fire caused by chemicals should be handled?

viii. Why emergency drills are important to face emergency situations?

3. Constructed Response Questions

i. How will you handle an emergency situation caused by fire due to short circuiting?

ii. What type of reactions should be carried out in fume cupboard?

iii. Put forward at least two suggestions to improve safety in the lab.

iv. Can you identify warning symbols posted for radiation and asphyxiant chemicals?

v. Why sudden shock can cause some chemicals to explode?

4. Descriptive Questions

i. Explain hazards due to explosive and toxic chemicals.

ii. Write down five such common safety instructions which are used to avoid all types of hazards.

iii. Explain the importance of warning signs and symbols to avoid any accident in the lab.

iv. Name some toxic chemicals. Describe the effects of spreading toxic gas in the lab.

v. A student has spilled over a corrosive and explosive chemical due to an accident. Which emergency measures you will take to tackle the situation.

5. Investigative Question

i. A few decades ago, a tanker carrying poisonous chlorine gas leaked and the gas spread over a large area in Lahore. The accident killed a few persons as well as animals. Give some concrete proposals to avoid such an accident in future.

Glossary

$2n^2$ Formula: Formula used for filling the electrons in shells.

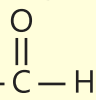
Accuracy: It refers to how close a measurement is to the true value.

Acid Rain: Pollutant gases mixed with rain water come down as acid rain.

Activation Energy: Energy absorbed by the reactants and product molecules in order to be converted into the transition state.

Aerobic Respiration: The process of respiration in the presence of oxygen.

Aldehydes: organic compounds containing the aldehydic functional group



(— C — H).

Aliphatic Compound: (Acyclic compounds) Compounds containing open chain of carbon atoms.

Alkanes or Saturated Hydrocarbons: Hydrocarbons in which all the four valencies are fully utilized or they contain single bonds only.

Alkenes: Compounds containing a double bond between two carbons atoms.

Alkyl Amine: Organic compounds containing amino group ($-NH_2$) as a functional group.

Alkyl Halides: A family of organic compounds containing halogen atom as a functional group.

Alkyl Radical: When an alkyl molecule drops one of its many hydrogen atoms.

Alkynes: Compounds containing a triple bond between two carbons atoms.

Anaerobic Respiration: Respiration without oxygen.

Aromatic Compounds: Compounds containing at least one benzene ring.

Arrhenius Acid: A chemical which gives proton (H^+) in water.

Arrhenius Base: A chemical compound which gives hydroxide ion (O^-H) in water.

Astrochemistry: It is the study of molecules and ions occurring in stars and interstellar space.

Atomic Mass: The mass of an atom of an element relative to the unit mass, which is 1/12th of the mass of C-12.

Atomic Number: The number of positively charged particles (protons) present in the nucleus of an atom.

Atomic Size: Average distance between the nucleus of an atom and its outermost electronic shell. Its units are m or pm.

Avogadro's Number: The huge number 6.022×10^{23} is called Avogadro's number.

Biochemistry: Which deals with the study of chemical compounds present in the living things.

Bronsted Acid: A compound which can donate proton.

Bronsted Base: A compound which can accept proton.

Carboxylic Acids: Organic compounds containing carboxyl group

as a functional group.

Catalytic Converter: It is a device used in the exhaust of an automobile which converts harmful gases produced in the engine.

Catenation: The self-linking property of carbon.

Chemistry: It deals with the composition and changes in matter and the laws which govern these changes.

Colloidal Solution: A solution in which solute particles are bigger than those present in a true solution and which cannot be filtered.

Combustion: Burning of an organic compound in an excess of oxygen.

Concentrated Solution: A solution that contains a relatively large amount of a dissolved solute.

Concentration of a Solution: The amount of a solute which has been dissolved in a particular amount of solvent.

Coordinate Covalent Bond: When the shared pair of electrons is provided by one of the bonded atoms, a coordinate covalent bond is formed.

Covalent Bond: It is the force of attraction that arises between two atoms due to mutual sharing of an electron pair.

Crystal Lattice: Three-dimensional arrangement of ions.

Cyclic or Ring Compounds: Compounds in which carbon atoms are linked together to give a ring.

Dilute solution: A solution that contains a relatively small amount of dissolved solute.

Discharge Tube: A glass tube containing a gas at a very low pressure and provided with electrodes to study the passage of electricity through the gas.

Dynamic Chemical Equilibrium: When the rate of forward reaction becomes equal to the rate of reverse reaction, at this stage the reaction is said to be in a state of dynamic chemical equilibrium.

Electron: It is the smallest negatively charged particle present in all kinds of atoms. Its mass is 9.1095×10^{-31} kg and carries a charge -1.602×10^{-19} C.

Electronegativity: It is the power of an atom to attract the shared pair of electrons.

Empirical Formula: The formula of a compound, which shows the minimum ratio present between its atoms.

Endothermic Reactions: Those chemical reactions during which heat is absorbed.

Enthalpy of Reaction: Heat of reaction which takes place at constant pressure.

Enthalpy: It is the measurement of energy in a thermodynamic system.

Environmental Chemistry: In this branch, we study the chemicals and other pollutants present in the environment. It also covers the effects of these pollutants on living and non-living things.

Error: The difference between the measured value and the actual value.

Exothermic Reactions: Those chemical reactions during which heat is evolved.

Exotic states of Matter: These are not commonly encountered states of matter, for example, dark matter.

Extranuclear Portion: Area surrounding the nucleus of an atom.

First Ionization Energy: The minimum amount of energy required to remove an electron from the outermost electronic shell of an isolated gaseous atom. Its unit are kJ mol^{-1}.

Formula Mass: Formula mass is the mass of a compound relative to the unit mass which is 1/12th of the mass of C-12.

Functional Group: An atom or group of atoms or a bond whose presence imparts characteristic properties to the organic compounds.

Geochemistry: It covers the study of chemical composition of rocks and minerals.

Global Warming: The progressive warming of the Earth's surface due to the blanketing effect of CO_2, CH_4 and the water vapour present in the atmosphere.

Heat content: The total amount of heat energy present in a molecule under standard conditions.

Heat of neutralization: The heat given out during a neutralization reaction when one mole water is formed from an acid and base is called the heat of neutralization.

Heat of Reaction: Heat evolved or absorbed during a chemical reaction which takes place at any pressure.

Hydrated Salt: A salt with water molecular of crystallization.

Hydrocarbons: Compound of carbon and hydrogen only.

Inorganic Chemistry: The study of all other elements and their compounds except carbon and its compounds.

Inorganic Compounds: Compounds obtained form non-living things or mineral sources or synthesized in the laboratory by reacting metals with non-metals.

Intermolecular Forces: Forces between two separate molecules.

Ionic Bond: A bond formed due to the electrostatic force of attraction between oppositely charged ions.

Irreversible Reaction: Reaction which moves in one direction only; the reactants react to give the product.

Isomerism: The phenomenon shown by the organic compounds having the same molecular formula but different structural formula.

Isotopes: Atoms of an element having the same atomic number but different mass number.

Isotopic Abundance: The natural abundance of an isotope.

Ketones: Organic compounds containing the ketonic functional group

$$(R-\overset{\overset{O}{\|}}{C}-R).$$

Lipids: A group of organic compounds which serve as an energy reserve.

Liquid crystals: It is a state of matter whose properties are between those of liquids and solids.

Mass number: The total number of protons and neutrons present in the nucleus of an atom.

Medicinal Chemistry: Designing and synthesizing medicines or drugs which are useful to mankind.

Metallic Bond: When positively charged metal ions are held together by freely moving electrons, the bond formed is called a metallic bond.

Metallic Lustre: Shine present on metallic surfaces.

Modern Periodic Table: A table in which elements are arranged in ascending order of their atomic numbers.

Molar Mass: The mass of an element or a compound which contains Avogadro's number of particles.

Molecular Formula: The formula of an element or a compound which tells the actual number of atoms present in the molecule of that element or a compound.

Molecular Mass: Molecular mass is the mass of the molecule of an element or a compound relative to the unit mass, which is 1/12th of the mass of C-12.

Neutralization: Acids and bases react together to form salts and water and, in this way, they neutralize the properties of each other. This reaction is called neutralization reaction.

Neutron: It is the smallest neutral particle present in the nucleus of atoms. Its mass is slightly more than that of a proton.

Nuclear Chemistry: This branch deals with the reactions taking place in the nucleus of an atom.

Nucleus: Central part of an atom where most of its mass is concentrated. Its size is very small as compared to the size of the atom.

Octet Rule: When an atom has eight electrons in its outer most shell, it is said to be stable and does not combine with other atoms to reduce its energy. This is called octet rule.

Orbit: the circular path of an electron around the nucleus.

Organic Chemistry: The branch of chemistry in which we study the compounds of carbon.

Organic Compounds: Compounds obtained from living or plant and animal sources and which can be synthesized in the laboratory. All the organic compounds contain carbon as an essential element.

Oxidation: A process in which an electron or electrons are lost.

Oxidising Agent: A substance which accepts an electron or electrons.

Parts per Million: One part per million parts of the solid, liquid and gas mixture in which pollutant is formed.

Physical Chemistry: This branch investigates how substances behave on an atomic or molecular level and how physical laws govern the specific characteristics of atoms and molecules.

Plasma: It is the fourth state of matter. It is composed of particles with very high kinetic energy.

Pollutant: Any solid, liquid or gaseous substance present in such concentration as may be injurious to health.

Polymer Chemistry: It focuses on the properties, structure and synthesis of polymers and macromolecules.

Precision: It refers to how close measurements of the same item are to each other.

Proton: It is the smallest positively charged particle present in all kind of atoms. The mass of this particle is equal to the mass of hydrogen nucleus (H^+).

Radioactive rays: Rays emitted from radioactive elements or their compounds, which can cause fogging of the photographic plates.

Radioactive Isotopes: Isotopes of elements which throw out excess energy in the form of radiation.

Radiocarbon Dating: A method for finding out the age of a historical object containing organic material with the help of ${}^{14}_{6}C$.

Random Error: Error which a student commits during measurement.

Reducing Agent: A substance which loses an electron or electrons.

Reduction: A process in which an electron or electrons are gained.

Reversible Reaction: A chemical reaction, which takes place in both directions, forward as well as backward.

Saturated Solution: A solution, which contains the maximum amount of a solute at a particular temperature and which is unable to dissolve further amount of solute in it.

SI Units: A common system of units based on metric system.

Solubility: The amount of a solute in grams which has been dissolved in 100g of a solvent at a particular temperature to prepare a saturated solution.

Strong Acid: An acid which ionizes completely in water.

Strong Base: A base which can ionize completely in water giving excess of hydroxide ions.

Structural Formula: The formula which shows the arrangement of atoms in a compound.

Substitution Reaction: A reaction which occurs when an atom or a group of atoms from the reagent displaces an atom or group of atoms from the organic reactant.

Supercritical Fluids: They are highly compressed gases which show the properties of both gases and Liquids.

Surrounding: Everything else which does not fall in the system.

System: Anything under consideration for the purpose of study.

Systematic Error: Error which naturally occurs when we use tools for measurement.

Transition Elements: Elements having incomplete penultimate (next inner to the outermost) electronic shell.

Transition State: A state of molecules when they are undergoing breakage or formation of bonds.

Unified Atomic Mass Unit: Unit of a new scale, which is equal to 1/12th of the mass of C-12.

Unsaturated Hydrocarbons: Hydrocarbons containing double or triple bonds.

Unsaturated Solution: A solution, which can dissolve further amount of a solute at a particular temperature.

Vital Force: The imaginary supernatural force which was supposed to be present in all those compounds which were obtained from living things.

Water of Crystallization: The number of water molecules present in the crystals of a solid.

Weak Acid: An acid which ionizes partially in water.

Weak Base: A base which ionizes partially in water.

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