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Chemical Safety Assessment of Inorganic Chemicals used in an Undergraduate Chemistry Laboratory

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Abstract: ***The identification and assessment of hazards in undergraduate chemistry laboratories is crucial for ensuring the safety of all involved. This report is an effort to collect, organize and create awareness about chemical safety. For the purpose, we need not look far; using MSDS and other easily accessible chemical information sets this report can serve a base for improving laboratory practices in UG-curriculum.***

Keywords: Chemical Safety, Hazard, MSDS, Laboratory practices

1. Introduction

As a part of experiential learning, chemistry students right from the beginning of learning the subject works with substances with varied degree of potential hazard. In doing so, we face the risks of exposure, spillage, explosion and fire like incidents. But, to gain mastery of chemistry, the basic laboratory training plays a vital role. Even with current stages of advancement in computational simulation and calculations, chemistry is still beautiful in a vessel with compounds changing colors, state and form. At this stage, therefore the role of safety regulations, information and knowledge is being recognized by multiple entities. By, accessing the easily understandable info graphic documents, learners should prioritize their safety and be aware of the prospective risks of chemical hazard.

In conversations of green chemistry hazard means the capacity to cause undesirable consequence to humans or the environment [1]. Intrinsic hazards associated with chemicals and process associated can be designed to be insignificant or tolerable. This shall require careful design within chemicals and processes based on the assimilation of the Twelve Principles of Green chemistry facilitated by detailed understanding of available data sets [1]. One of such data sources is the Material Safety Data Sheet (MSDS) [2]. MSDS document provides important information about the physical and chemical states, potential hazards and risks associated with the use of a particular chemical [3]. The use of MSDS is to make sure of safety of the involved ones and the environment. Information available in any MSDS consists of the composition, chemical and physical properties, hazard information, and recommended precautions for handling, use and storage, first aid and emergency protocols.

One such workplace where MSDS needs be an integral part is the Chemistry laboratories of educational institutes of all level [4]. To ensure a healthy generation of young workforce laboratory safety is a must have component of the curriculum. This means development of awareness, skills and responsibility. Each laboratory course needs to be discussed MSDS in hand to cultivate an environment with safety as the primary priority.

The ACS Committee on Chemical Safety has recently published three useful resources that provide guidelines for chemical safety in academic institutions [5] and help in the identification and evaluation of hazards in research laboratories [6], [7]. Chemical safety skills can be developed into basic a part of laboratory skills by working in the following four areas [8].

- Reorganization of Hazards
- Risks Assessment
- Risks minimization
- Preparing for Emergencies

2. Objective and Work Plan

This report is an effort to create awareness among students; teachers and policy makers about the potential hazard of the chemicals used in an undergraduate laboratory of an affiliated college of Gauhati University[9]. The work plan was to list all the inorganic chemicals **(Table 1)** used for three year B.Sc. programs with chemistry, followed by the four steps prescribed above. We systematically analyzed and compiled information from MSDS and hazard classification resources to create a comprehensive database.

Table 1: List of Inorganic compounds used in the undergraduate laboratory of Madhab Choudhury College, Barpeta (Affiliated to Gauhati University)

Compounds and reagents	CAS[10] no	Formula	Physical state (rt)	Potential hazard [11]
Sodium acetate	127-09-3	$NaC_2H_3O_2$	Solid	Gastrointestinal irritation or electrolyte imbalances
Potassium acetate	127-08-2	$KC_2H_3O_2$	Solid	Gastrointestinal irritation or electrolyte imbalances
Sodium bicarbonate	144-55-8	$NaHCO_3$	Solid	Metabolic alkalosis, electrolyte imbalances
Potassium bicarbonate	298-14-6	$KHCO_3$	Solid	Gastrointestinal discomfort or alkalosis
Sodium bisulfate	7681-38-1	$NaHSO_4$	Solid	Irritation to the respiratory and digestive systems
Potassium bisulfate	7646-93-7	$KHSO_4$	Solid	Irritation or burns upon skin contact
Sodium bisulfite	7631-90-5	$NaHSO_3$	Solid	Irritation in the respiratory and digestive system and possible neurological effects
Potassium bisulfite	7646-93-7	$KHSO_3$	Solid	Irritation to the skin, eyes and respiratory system
Sodium borate	1303-96-4	$Na_2B_4O_7$	Solid	Irritation or damage to the eyes, skin and respiratory system
Potassium borate	1332-77-0	$K_2B_4O_7$	Solid	Irritation or damage to the eyes, skin and respiratory system
Sodium carbonate	497-19-8	Na_2CO_3	Solid	Irritation and corrosion if it comes into contact with the skin or eyes
Potassium carbonate	584-08-7	K_2CO_3	Solid	Severe irritation or corrosion to the skin, eyes and respiratory system
Sodium chloride	7440-23-5	NaCl	Solid	Excessive intake can lead to negative health effects such as high blood pressure and fluid retention
Potassium chloride	7447-40-7	KCl	Solid	High doses leads to cardiac arrest or other serious health problems
Sodium chromate	10034-82-9	Na_2CrO_4	Solid	Severe health effects such as cancer, reproductive and developmental damage, negative effects on the respiratory and digestive system
Potassium chromate	7789-00-6	K_2CrO_4	Solid	Severe health effects such as cancer, reproductive and developmental damage, negative effects on the respiratory and digestive system
Sodium citrate	68-04-2	$Na_3C_6H_5O_7$	Solid	May cause gastrointestinal upset and may interact with certain medications in excessive amount
Potassium citrate	07-09-7440	$K_3C_6H_5O_7$	Solid	Irregular heartbeat, muscle weakness and breathing difficulties
Sodium cyanide	143-33-9	NaCN	Solid	Inhibiting cellular respiration and causing severe tissue damage
Potassium cyanide	151-50-8	KCN	Solid	Highly toxic and can cause rapidly cause death through interference with cellular respiration
Sodium hydroxide	1310-73-2	NaOH	Solid	Highly toxic and corrosive, causing severe chemical burns and tissue damage upon contact with skin, eyes and other body tissues
Potassium hydroxide	1310-58-3	KOH	Solid	Highly corrosive that can cause burns and tissue damage upon contact with skin and eyes
Sodium nitrate	7631-99-4	$NaNO_3$	Solid	Cancer, methemoglobinemia and reproductive issues
Potassium nitrate	07-09-7440	KNO_3	Solid	Vomitting, diarrhea and methomoglobinemia
Sodium nitrite	7632-00-0	$NaNO_2$	Solid	Methomoglobinemia
Potassium nitrite	7758-09-0	KNO_2	Solid	Methomoglobinemia
Sodium thiosulphate pentahydrate	10102-17-7	$Na_2S_2O_3{\cdot}5H_2O$	Solid	Irritation and burns if it comes into contact with skin or eyes
Potassium thiocyanide	333-20-0	KSCN	Solid	Skin and eye irritation, respiratory issues and other health hazards if ingested or inhaled
Potassium permanganate	7722-64-7	$KMnO_4$	Solid	Irritation or burns to the skin and eyes upon contact, kidney and liver damages and can be fatal in large doses
Barium chloride	10361-37-2	$BaCl_2$	Solid	Severe gastrointestinal, cardiovascular and neurological effects
Barium sulfate	7727-43-7	$BaSO_4$	Solid	Generally, non-toxic and safe for ingestion but high doses may cause gastrointestinal irritation or obstruction
Barium nitrate	10022-31-8	$Ba(NO_3)_2$	Solid	Serious health effects if ingested, inhaled or absorbed through the skin
Barium carbonate	513-77-9	$BaCO_3$	Solid	Serious health effects if ingested or inhaled, including respiratory failure, cardiac arrest and gastrointestinal issues
Barium hydroxide	12230-71-6	$Ba(OH)_2$	Solid	Severe skin and eye irritation, respiratory distress and gastrointestinal if ingested or inhaled
Calcium oxide	1305-78-8	CaO	Solid	Severe burns, respiratory and eyes irritation and other health hazard upon contact with skin, eyes and inhalation
Calcium hydroxide	1305-62-0	$Ca(OH)_2$	Solid	Corrosive to eyes, skin, and mucous membranes, gastrointestinal irritation, pulmonary edema
Calcium chloride	7440-70-2	$CaCl_2$	Solid	Skin irritation, eye irritation, respiratory irritation, gastrointestinal irritation, cardiac arrhythmia

Calcium carbonate	471-34-1	$CaCO_3$	Solid	Generally non-toxic and safe or consumption in appropiate doses
Calcium sulfate	7778-18-9	$CaSO_4$	Solid	Safe for consumption with no significant toxicity reported
Calcium nitrate	13477-34-4	$Ca(NO_3)_2$	Solid	Irritation to the skin and eyes
Calcium phosphate	7758-87-4	$Ca_{3(}PO_4)_2$	Solid	Gastrointestinal irritation, kidney damage, low blood pressure, irregular heartbeat, respiratory irritation, convulsions, coma
Calcium acetate	7440-70-2	$Ca(C_2H_3O_2)_2$	Solid	Gastrointestinal irritation, kidney damage, low blood pressure, irregular heartbeat
Aluminum sulfate	17927-65-0	$Al_2(SO_4)_3$	Solid	Skin and eye irritation, respiratory issues, neurological damage
Aluminum nitrate	7784-27-2	$Al(NO_3)_3$	Solid	Skin and eye irritation, respiratory issues, neurological damage
Aluminum chloride	7446-70-0	$AlCl_3$	Solid	Skin and eye irritation, respiratory issues, neurological damage
Aluminum hydroxide	21645-51-2	$Al(OH)_3$	Solid	Can cause constipation, gastrointestinal issues, bone pain, and muscle weakness
Sodium aluminate	11138-49-1	$NaAlO_2$	Solid	Skin and eye irritation, respiratory issues, neurological damage
Potassium aluminate	12003-63-3	$KAl(OH)_4$	Solid	Skin and eye irritation, respiratory issues, neurological damage
Aluminum phosphate	7784-30-7	$AlPO_4$	Solid	Can cause constipation, gastrointestinal issues, bone pain, and muscle weakness
Sodium aluminum phosphate	10305-76-7	$NaAl(PO_4)_2$	Solid	Respiratory and neurological problems and prolonged exposure may lead to cancer
Aluminum carbonate	14455-29-9	$Al_2(CO_3)_3$	Solid	Neurotoxicity
Basic aluminum carbonate	1339-92-0	$Al_2(OH)_4(CO_3)_2$	Solid	Respiratory and neurological problems
Aluminum acetate	142-03-0	$Al(CH_3COO)_3$	Solid	Nausea, vomitting, abdominal pain and respiratory irritation
Aluminum citrate	31142-56-0	$Al(C_6H_5O_7)$	Solid	Gastrointestinal, neurological and bone health issues
Sodium aluminum tartrate	16828-01-6	$NaAl(C_4H_4O_6)_2$	Solid	Neurotoxicity
Ammonium aluminum sulfate	7784-26-1	$(NH_4)Al(SO_4)_2$	Solid	Gastrointestinal irritation and respiratory issues
Boric acid	10043-35-3	H_3BO_3	Solid	Nausea, vomitting, diarrhea and even death in several cases
Borax	1303-96-4	$Na_2B_4O_7{\cdot}10H_2C$	Solid	Nausea, vomitting, diarrhea and kidney damage
Sodium borohydride	16940-66-2	$NaBH_4$	Solid	Highly toxic if ingested, inhaled or in contact with skin and eyes and cause severe burns, respiratory failure and central nervous system
Iron(II) chloride	7758-94-3	$FeCl_2$	Solid	Corrosive to eyes and skin, can cause gastrointestinal irritation and vomiting
Iron(III) chloride	7705-08-0	$FeCl_3$	Solid	Corrosive to eyes and skin, can cause respiratory irritation and digestive upset
Iron(II) sulfate	7720-78-7	$FeSO_4$	Solid	Can cause gastrointestinal irritation, nausea, vomiting, and diarrhea
Iron(III) sulfate	10028-22-5	$Fe_2(SO_4)_3$	Solid	Can cause skin and eye irritation, respiratory irritation, and digestive upset
Iron(II) nitrate	10101-89-0	$Fe(NO_3)_2$	Solid	Can cause gastrointestinal irritation, nausea, vomiting, and diarrhea
Iron(III) nitrate	10421-48-4	$Fe(NO_3)_3$	Solid	Can cause skin and eye irritation, respiratory irritation, and digestive upset
Iron(II) carbonate	563-71-3	$FeCO_3$	Solid	Can cause gastrointestinal irritation, nausea, vomiting, and diarrhea
Iron(III) oxide	1309-37-1	Fe_2O_3	Solid	Can cause gastrointestinal irritation, nausea, vomiting, and diarrhea
Iron(II) oxide	1317-61-9	FeO	Solid	Can cause skin and eye irritation,respiratory irritation, and digestive upset
Nickel(II) chloride	7718-54-9	$NiCl_2$	Solid	Irritation of the skin, eyes, and respiratory system, allergic reactions
Nickel(II) acetate	6018-89-9	$Ni(CH_3COO)_2$	Solid	Eye and respiratory system irritation
Sodium Hypochlorite	7681-52-9	NaClO	Solid	Poisoning
Iodine	7553-56-2	I_2	Solid	Toxic if ingested or inhaled in large amounts
Nessler's Solution	7783-33-7	K_2HgI_4	Liquid	Toxic, can cause mercury poisoning
Fehling Solution A	7732-18-5	$CuSO_4 \cdot 5H_2O$	Liquid	Irritant, harmful if ingested
Fehling Solution B	6381-59-5	$KNaC_4H_4O_6 \cdot 4H_2O$	Liquid	Irritant, harmful if ingested
Brady's Reagent	119-26-6	2,4,6-tripyridyl-s-triazine (TPTZ)	Liquid	Harmful if ingested
Nessler's Reagent	7783-33-7	K_2HgI_4	Liquid	Toxic, can cause mercury poisoning

Bromine Water	7726-95-6	Br_2 (H_2O)	Liquid	Toxic, corrosive
Chlorine Water	7782-50-5	Cl_2 (H_2O)	Liquid	Toxic, corrosive
Copper Sulfate	7758-98-7	$CuSO_4 \cdot 5H_2O$	Liquid	Irritant, harmful if ingested
Hydrogen Peroxide	7722-84-1	H_2O_2	Liquid	Irritant, harmful if ingested
Iodine Solution	7553-56-2	I_2 and KI	Liquid	Harmful if ingested
Magnesium Sulfate	7487-88-9	$MgSO_4$ $7H_2O$	Liquid	Irritant, harmful if ingested
Manganese Dioxide	1313-13-9	MnO_2	Liquid	Irritant, harmful if ingested

During their three year of UG program, students learn qualitative and quantitative detection, identification and estimation of inorganic samples. Experimental techniques like acid base titration, gravimetric estimation, spectroscopic, electrochemical and chromatographic analysis, mixing, heating, derivatization, fusion, filtration, crystallization, centrifugation, extraction are employed for various experiments.

Techniques and compounds can be handled better with prior preparation.

3. Classification based on toxicity

The listed Inorganic compounds can be classified based on their potential toxicity levels as carcinogenic, irritant, flammable, or corrosive [12].

3.1 Carcinogenic inorganic compounds: These are inorganic compounds that have the potential to cause cancer in humans. Compounds of this potential can be identified by the sign shown in its packaging [13].
Examples: Arsenic trioxide (As_2O_3), Potassium dichromate ($K_2Cr_2O_7$), Nickel sulfate ($NiSO_4$) etc.

3.2 Irritant inorganic compounds: These inorganic compounds can cause irritation or inflammation of the skin, eyes, or respiratory system.
Examples: Ammonium hydroxide (NH_4OH), Copper sulfate ($CuSO_4$), Potassium permanganate ($KMnO_4$), Silver nitrate ($AgNO_3$) etc.

3.3 Flammable inorganic compounds: These compounds can ignite or explode in the presence of heat or flames or excess oxygen.
Examples: Magnesium (Mg), Potassium (K), Sodium (Na), Calcium carbide (CaC_2) etc.

3.4 Corrosive inorganic compounds: These inorganic chemicals can cause severe damage to the skin, eyes, or respiratory system upon contact. Examples: Hydrochloric acid (HCl), Sulfuric acid (H_2SO_4), Nitric acid (HNO_3), Sodium hydroxide (NaOH), Potassium hydroxide (KOH) etc.

Figure 1: Hazard Symbol and their meanings

4. Safety Interpretations [14]

Clearly, laboratory work needs precautions. Some practices that should become general habits in the undergraduate laboratory to avoid accidents are therefore:

4.1 Knowing with the laboratory whereabouts: Prior to any laboratory work, it is important to be familiar with the laboratory environment, including the location of safety equipment such as fire extinguishers and first aid kits. It is essential to be aware of the emergency procedures.

4.2 To be dressed in appropriate personal protective equipment (PPE): Lab coats, safety goggles, gloves, and closed-toe shoes must be worn at all times when working in the laboratory. PPE provides a physical barrier between the laboratory worker and hazardous substances and protects against potential harm.

4.3 Following proper handling and storage procedures: Chemicals should be properly labeled and stored according to their compatibility and flammability. All chemicals and equipment should be handled with care and caution to prevent spills, leaks, or breakage.

4.4 Be aware of hazards and risks associated with chemicals: It is important to be aware of the hazards and risks associated with chemicals, including toxic, corrosive, flammable, and explosive properties. Always read the Material Safety Data Sheet (MSDS) before using any chemical and follow the recommended safety precautions.

4.5 Using equipment and machinery properly: Equipment and machinery such as centrifuges, hot plates, and microscopes should be used properly and according to manufacturer instructions. Be aware of potential hazards associated with the equipment, including electrical shocks and burns.

4.6 To avoid distractions and focus on the task at hand: Laboratory work requires focus and attention to detail. Avoid distractions such as phone calls, social media, or conversations with colleagues while working with hazardous materials or equipment.

4.7 Dispose of waste properly: Proper disposal of hazardous waste is important to minimize the risk of contamination and pollution. Follow the proper disposal procedures for all hazardous waste generated in the laboratory.

Figure 2: Type of awareness posters available in our departmental laboratory

5. Conclusion

The survey found that most inorganic compounds used in undergraduate chemistry laboratories have been classified as hazardous substances based on their physicochemical properties, toxicity, and environmental impact. The majority of these compounds are classified as irritants, corrosives, or toxic substances, which can cause skin and eye irritation, respiratory problems, and other health effects.

In addition, the work highlighted the importance of using MSDS as a tool for identifying and managing hazards in the laboratory. MSDS provides information on the physical and chemical properties of the compounds, as well as their hazards and suggested safety measures. The survey found that many undergraduate chemistry students are not adequately trained on the proper use of MSDS, which can increase the risk of accidents and injuries in the laboratory. The laboratory instructors must be leaders in safety; teaching safety to students, continuously promoting safety, indicating the importance of safety through their actions, and accepting responsibility for safety. The Safety Ethic is, above all, a value, stated as: I value safety, work safely, prevent any risk-behavior, promote safety, and accept responsibility for safety.

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