

SAFETY EDUCATION

Department of Chemistry
Minnesota State University Moorhead

Lecture 2

Overview of Today's Material

- Recognizing Physical Hazards
 - Electrical Hazards
 - Compressed Gases, *Air Lines*
- Recognizing Chemical Hazards
 - Flammability
 - Oxidizing and Reducing Agents
 - Corrosives
 - Water Reactive
 - Toxic Chemicals
 - Sources of Information

Effect of Electrical Current on Humans

Effect	60 Hertz AC Current, mA	
	Men	Women
Slight sensation on hand	0.4	0.3
Perception threshold, median	1.1	0.7
Shock-not painful, muscular control not lost	1.8	1.2
Painful shock-muscular control lost by 0.5%	9	6
Painful shock- let-go threshold, median	16	10.5
Painful and severe shock-breathing difficult, muscular control lost by 99.5%	23	15
Possible ventricular fibrillation		
Three second shocks	675	675
Short shocks(T in seconds)	166/T	116/T

- Reprinted with permission from "Handbook of Laboratory Safety", N.V.Steere, Ed., 1981. CRC Press, Boca Raton, FL
- Note that a normal household or lab circuit is 15 or 20A (15,000/20,000 mA!)

Electrical Hazards

- The current required to blow a standard fuse or circuit breaker can cause serious injury or death.
- Skin has a natural resistance of 100,000 to 500,000 ohms/cm²
- The resistance of wet or punctured skin decreases by 100 to 1000 times.

Ground Fault Circuit Interrupters

- A GFCI can replace normal wall receptacles or replace circuit breakers. Portable models are also available.
- A GFCI compares current flowing to and from the load and trips the circuit if these differ by 5mA for 30 ms.
- Cost is about \$10 - \$20.
- Required in renovated or new bathrooms, outdoor outlets, garages, etc..

Prudent Practices with Electricity

- Be sure all equipment is properly grounded.
- Use GFCI's where necessary.
- Inspect apparatus regularly for worn power cords and defects.
- Don't try to disable electrically interlocked shields.

Prudent Practices with Electricity

- Turn off power at the circuit breaker when working on a circuit and take precautions so that someone else does not turn it on.
- Use insulated tools, rubber mats and rubber gloves when necessary.
- Don't use devices with old two-pronged plugs in which the two prongs are the same size.

Common Electrical Hazards

- Heating mantles, hot plates, mechanical stirrers.
- Some heating devices are meant to be plugged into a variable transformer to control the degree of heating.
- If they are plugged directly into a 120V wall outlet, they will greatly overheat and could cause serious accidents.

Recognizing Physical Hazards

- Electrical Hazards
- Compressed Gases, *Air Lines*

Compressed Gases, *Air Lines*

- Pressure is usually near 30 psi (~2 atm.)
- Never direct air hoses at people.
- Never use air hoses to blow away dirt, dust or residual solvent.
 - Flying particles can cause injury.
 - A contaminating oil film may be left on surfaces.

Recognizing Chemical Hazards

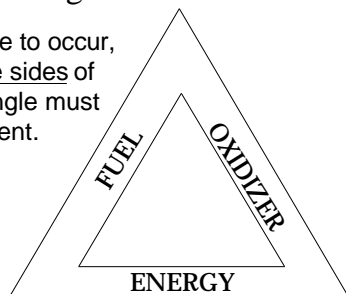
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Flammability

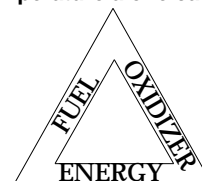
- Almost all organic compounds (those containing C and H) will burn.
- Burning is the rapid oxidation of a fuel by an oxidizer (usually air) with the liberation of heat and (usually) light.
- A fire can only be started when sufficient energy is present to initiate the reaction.

Fire Triangle

- For a fire to occur, all three sides of the triangle must be present.



- Fuel and oxidizer must be present in a high enough concentration to form a combustible mixture.
- The ignition source must supply enough energy to initiate combustion. It need not be a spark or flame; temperature alone can supply the energy.



Examples of Flammable Solvents

- Acetone
- Ethanol
- Methanol
- Hexane
- Ether
- Toluene
- Gasoline



Flammability - Flash Point

- A flammable liquid usually does not itself burn; it is the mixture of the vapor from the liquid and the oxygen in the air that burns.
- The flash point is the minimum temperature necessary to produce sufficient vapor to support combustion.

Flash Points, examples

Compound	Flash Point, °C	Boiling Point, °C
Acetone	-17.0	56.5
Diethylether	-40	34.6
Ethyl Alcohol	8	78
<i>p</i> -xylene	77	138

Flammability Limits

- Once the liquid molecules have vaporized, they need the proper amount of air in order to burn.
- Flammability limits are the upper and lower percentages (by volume) of fuel in air that will support combustion.
 - Acronyms: UFL, LFL

Flammability Limits

- If the % of fuel in air exceeds the UFL, the mixture is said to be too fuel rich and it will not burn.
- If the % of fuel in air is lower than the LFL, the mixture is said to be too lean and, again, it will not burn.

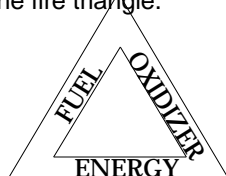
Flammability Limits, examples

Compound	LFL	UFL
Acetone	2.6	12.8
Diethylether	1.9	36.0
Ethyl Alcohol	3.3	19.0
<i>n</i> -hexane	1.1	7.5

- Data from "Prudent Practices for Handling Hazardous Chemicals in Laboratories", National Academy Press, 1981.

Fire Control and Flammable Solvent Safety

- The key to safety is removing, or otherwise making inaccessible, at least one side of the fire triangle.



Removing the fuel may be the easiest approach

- Store flammable solvents in areas isolated from reactive substances, such as oxidizers, e.g., nitric acid.
- Storage areas should be well-ventilated to prevent build up of vapors.
- When using or dispensing flammable solvents, use a working fume hood.

Removing the fuel side of triangle

- Approved metal safety cans cannot break easily and thus, fuel will not be spilled.
- When transporting solvents that are stored in glass bottles, use an approved safety over-container to eliminate breakage.

Removing the oxidizer (keeping the fuel and oxidizer apart)

- For reactions that involve heating flammable solvents, an over layer of an inert gas, such as nitrogen, may be used to prevent fires.

Removing the ignition source

- This can be very difficult as there are many possible energy sources.
 - Electrical heaters, sparking electrical motors, stirrers, fans, etc.
 - Thermostat switches in refrigerators
 - Bunsen Burners
 - Static electricity can be generated by clothing or by the motion of a solvent being poured out of a container.

Insidious Hazards of Solvents

- Liquid Density
 - If a solvent is less dense than water, you will not be able to put out a fire with water since the solvent will float on the water.
- Vapor Density
 - The vapors of most solvents are more dense than air and can travel long distances to an ignition source.
 - The vapor “wick” can then permit a flash back to the source.

Insidious Hazards of Solvents

- Water Solubility
 - A water soluble organic solvent (such as ethyl alcohol) may give off sufficient solvent vapor to burn even when diluted with water.
 - Water would not be efficient for extinguishing a fire of such a liquid.

Pyrophoric Materials

- A pyrophoric material is one that, even in a small quantity, without an ignition source, can ignite within 5 min. after coming in contact with air.
 - Finely divided metals: calcium (Ca), lead (Pb), titanium (Ti), zirconium (Zr), etc.
 - Alkali metals: sodium (Na), potassium (K)
 - Metal and nonmetal hydrides: diborane (B_2H_4), sodium hydride (NaH), Lithium aluminum hydride ($LiAlH_4$)
 - White phosphorus (P_4)

Preventing Fires and Explosions, review

- Know the flammability of the chemicals you use.
- Keep the fire triangle in mind.
- Store and transport solvents safely.
- Beware of ignition sources.
- Electrically ground flammable liquid containers before making transfers.

Fire Extinguishers - Fire Types

- Extinguishers are based on the area of coverage and the type of fire.
 - Type A: Wood, paper rubber, plastic
 - Water or water/foam, dry chemical, carbon dioxide
 - Type B: Flammable liquids and greases
 - Foam (non-water), carbon dioxide, dry chemical
 - Type C: Electrical equipment
 - Carbon dioxide, dry chemical
 - Type D: Active/combustible metals
 - Sand and special powders

Fire Extinguishers

- Many common extinguishers are ABC type which means they will work on types A, B, and C fires, but not on type D fires
- Carbon dioxide extinguishers must not be used to try to put out type D (metal) fires. CO₂ will actually increase the intensity of metal fires because the metal reacts with CO₂



What To Do When a Fire Occurs

- If the fire is
 - large or
 - compressed gases are nearby or
 - toxic fumes are present,
- you should LEAVE immediately!
- Your first concerns should be:
 - Sound an alarm
 - Evacuate the area
 - Summon assistance

What To Do When a Fire Occurs

- Fighting a fire with a fire extinguisher requires:
 - training and practice at using extinguishers.
 - the proper extinguisher.
- If a person's clothing is on fire, use the safety shower. If this is not available, wrap the person in a fire blanket.
 - Caution: Blankets can force flames toward the face and neck.
 - Clothing with chemical contamination should be removed.
- Place clean, wet, cold cloths on burned areas. Wrap the person to avoid shock.
- Get medical attention promptly.

Flammable Liquids video

Recognizing Chemical Hazards

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Oxidizing and Reducing Agents

- The flammability of organic solvents in air is an example of the more general case of oxidizing and reducing agents.
- Oxygen is the oxidizing agent and the organic material (fuel) is the reducing agent.
- Very vigorous reactions or even explosions can occur when oxidizing and reducing agents are combined.

Common oxidizing agents

- A more general definition of an oxidizing agent is a chemical substance in which one of the elements has a tendency to gain electrons. The following common materials are oxidizing agents by this definition:

- O₂, Halogens: F₂, Cl₂, Br₂
- Peroxides, H₂O₂, Na₂O₂, etc.
- Nitric acid, HNO₃; Nitrate Salts, e.g., NaNO₃
- Hypochlorous Acid, HClO; Hypochlorite salts, e.g., NaClO
- Chlorous Acid, HClO₂; Chlorite Salts, e.g. NaClO₂
- Chloric Acid, HClO₃; Chlorate salts, e.g., KClO₃
- Perchloric Acid, HClO₄; Perchlorates salts, e.g. KClO₄
- Chromic acid, H₂CrO₄; Chromate salts, e.g., K₂CrO₄
- Permanganates, e.g. KMnO₄

Common Reducing Agents

- A more general definition of a reducing agent is any chemical substance which has atoms with a tendency to lose electrons. The following are common examples:

- H₂(g), hydrocarbons, e.g.C₂H₆, and their derivatives including alcohols, e.g.,C₂H₅OH, oils, greases, organic acids (CH₃COOH)
- Metals and many metal salts,e.g., Na, LiH
- Ammonia, NH₃ and ammonium salts, (with NH₄⁺ ion)
- Carbon

Incompatibilities, examples

- Nitric acid(ox.agent) and alcohol(red.agent)
- Ammonia soln.(red.agent) and bleach(sodium hypochlorite,ox. agent)
 - This is a very common household error. toxic chloramines are given off
- Do not store incompatibles together

Heat & Shock Sensitive Compounds (explosives)

- Some compounds have reducing atoms or groups and oxidizing atoms or groups in the same molecule or ion. These tend to be heat and shock sensitive. Examples:
 - Chlorites, chlorates, perchlorates, nitrates, e.g. NH₄NO₃. The NO₃⁻ is the oxidizing agent; the NH₄⁺ is the reducing agent.
 - Organic nitrates and nitro compounds, (e.g., TNT, trinitrotoluene, CH₂C₆H₂(NO₂)₃). The nitro groups are oxidizing agents; the carbon atoms are reducing agents

Peroxide Formers

- Peroxides are shock sensitive compounds that often form in the following compounds as a result of partial decomposition or oxidation of these compounds.
 - Compounds that form peroxides
 - Ethers, -O-
 - Vinyl compounds, CH₂=CH- (styrene, vinyl acetate)
 - Aldehydes, -CH=O and ketones, >C=O (especially cyclic ketones)
 - Allylic compounds, CH₂=CHCH₂-
 - Alkenes, >C=C< (cyclohexene)
 - Compounds containing benzylic C₆H₅CH₂- hydrogen atoms
 - Precautions when using these compounds
 - Keep only small amounts stored for use
 - Do not distill these compounds unless known to be peroxide free.
 - Follow precautions on MSDS's

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Corrosives

- Living tissue as well as equipment is destroyed on contact with corrosives. The following are common laboratory reagents that are corrosive:
 - Ammonia soln., NH_4OH Hydrochloric acid, HCl
 - Nitric acid, HNO_3 Hydrogen fluoride, HF
 - Phosphoric acid, H_3PO_4 Sulfuric Acid, H_2SO_4
 - Sodium hydroxide, NaOH
 - Potassium Hydroxide, KOH
 - Glacial acetic acid, CH_3COOH
 - Potassium chromate, K_2CrO_4

Acid and Base safety

- Always use proper personal protective equipment including proper goggles when working with concentrated acids and bases.
- Store acids and bases separately.
- Know how to handle acid/base spills.

Acid and Base safety

- When diluting a concentrated acid: Add the acid to water! Why?
 - Lots of heat is generated when acids and bases are diluted. If you add water to the concentrated acid or base, the heat may be enough to boil the water and splash the concentrated solution on you.
 - If you add the acid or base to water, the bulk of the water can absorb the heat fairly quickly without getting hot enough to boil. (That is if you don't add too much too fast.)

Precautions with Corrosives

- Do not breathe chemical vapors.
- Avoid contact with skin, eyes, and clothing (Safety Goggles).
- Carefully clean equipment that comes in contact with corrosives.
- Use suitable protective equipment.
- Use secondary containment devices when storing, transporting, or dispensing corrosives.

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Water Reactive Compounds

- Materials that by contact with water become spontaneously flammable or give off a flammable or toxic gas presenting a health hazard.
 - Alkali metals, e.g., Li, Na, K (detonation, heat, hydroxide formation, H_2 liberated)
 - Alkaline earths, e.g. Be, Mg, Ca, Ba (detonation, $\text{H}_2(g)$ liberated)
 - Hydrides, e.g., LiH , LiAlH_4 (hydroxide formation, $\text{H}_2(g)$ liberated)
 - NaOH , KOH , H_2SO_4 (gives off lots of heat, splash hazard)
 - Metallic peroxides, e.g., Na_2O_2 , K_2O_2 ($\text{O}_2(g)$ liberated and heat)
 - Chlorides of group III metals, transition metals, non-metals, e.g., AlCl_3 , FeCl_3 , PCl_5 ($\text{HCl}(g)$ liberated)
 - Phosphides and Nitrides, e.g., Mg_3P_2 , Mg_3N_2 (liberate phosphine gas, PH_3 and ammonia gas, NH_3 respectively)
 - Carbides e.g., CaC_2 , MgC_2 (liberate acetylene $\text{C}_2\text{H}_2(g)$)

Laboratory Safety Instruction

- Remember:
 - Take responsibility for your own safety.
 - Be informed about the chemicals you use and come in contact with.
- Read through section III of “Safety in Academic Chemistry Laboratories”.