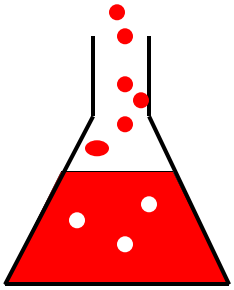
 

# Laboratory Safety Exam Study Materials



## Directions

**In order to insure the safety of all those working in a research laboratory, everyone must have a basic understanding of laboratory safety, prior to having access to the lab.**

1. **Study these materials. Also study the department laboratory safety manual available on the Chemical Engineering safety web page.**
2. **When you are ready, make arrangements with the designated person in the Chemical Engineering office to take the exam.**
3. **The exam has 50 multiple choice questions. You need an 80% grade to pass the exam. The exam is closed book.**
4. **You will be notified by email of your exam grade.**
5. **If you fail to pass the exam, you can take the exam again.**

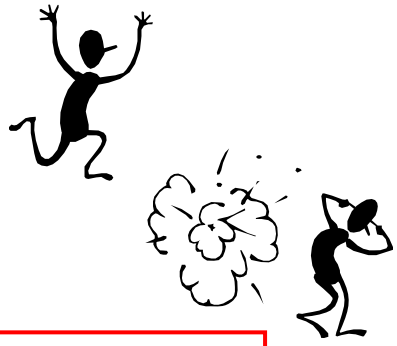
## Legacy of the Past

**Edison Lab at Greenfield Village, Dearborn, MI**

## Potential in the Present

## Hazardous Properties of Chemicals

- Toxic
- Reactive
- Flammable
- Explosive



**Each major group has many sub-groups, i.e. under toxic is carcinogenic**

## Definitions - 1

**Accident:** The occurrence of a sequence of events that produce unintended injury, death or property damage.

**Hazard:** A chemical or physical condition that has the potential for causing damage to people, property or the environment. Hazards from chemicals are always present. Hazards can be created by procedures or equipment.

**Incident:** The loss of containment of material or energy.

## Definitions - 2

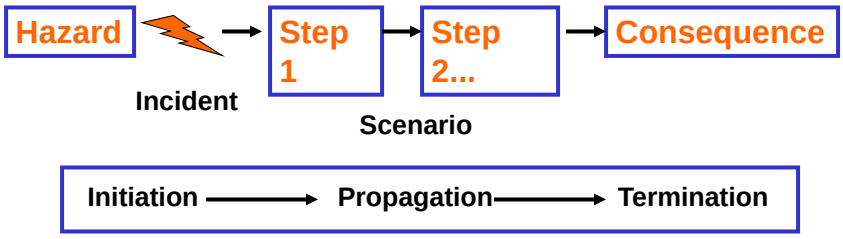
**Consequence:** A measure of the expected effects of an incident. Examples: burns, asphyxiation, cancer, lung failure, etc.

**Scenario:** A description of the events that result in an accident or scenario.

**Risk:** A measure of human injury, environmental damage, or economic loss in terms of both the incident likelihood (probability) and the magnitude of the injury or loss (consequence).

**Risk = f( probability, consequence )**

## Accident Steps




**Safety program wishes to minimize initiation and propagation steps and to maximize termination steps.**
**Accidents typically have multiple root causes, i.e. more than one direct cause.**

## Accident Cause

**Most accidents are due to the loss of control of material or energy.**

**Examples:**

- **Chemical spilling from an overturned beaker. (loss of material control)**
- **Unexpected reaction of a chemical resulting in gas evolution and rupture of container. (loss of energy control)**
- **Sudden disconnection of a hose containing high pressure nitrogen. (loss of material control)**
- **Fire in a beaker. (loss of energy control)**

## Toxicology

**Considers worker exposures**

# Definitions

**Toxicology:** - entry of toxicants into organism
- elimination from organism
- effects on organism

Quantitative

**Industrial hygiene:** prevention or reduction of entry

**Toxicant** - chemical agents
- physical agents: particulates < 5 μm, noise, radiation

**Toxicity:** property related to effect on organism
Problem: organisms respond via a distribution of effects

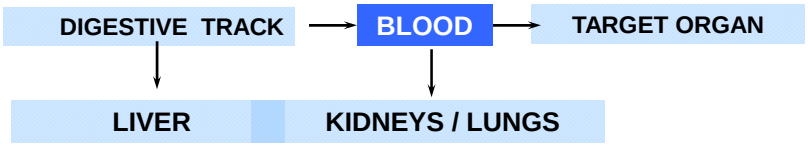
**Toxic hazard:** likelihood of damage based on exposure
reduction by appropriate techniques

# Entry toxicants

| | ROUTE | ENTRY | CONTROL |
|---|---|---|---|
| | Ingestion | mouth, stomach | rules on eating, drinking, smoking |
| * | Inhalation | mouth, nose | ventilation, hoods, protection equipment |
| | Injection | cuts in skin | protective clothing |
| | Dermal Absorption | skin | protective clothing |

* most significant in laboratory

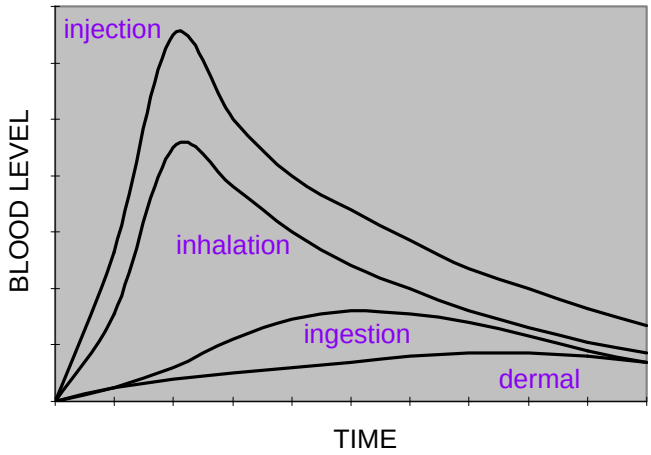
# Routes and elimination



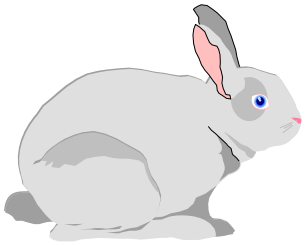

| | |
|---|---|
| EXCRETION | kidneys (urine), liver (bile), lungs |
| DETOXIFICATION | liver |
| STORAGE | fat tissue |
| INACTIVATION | |

# Toxic blood levels

WIDE VARIATIONS EXPECTED



## Toxicology Experiment with Rabbits!



**Start with 50 rabbits.**

**Expose each to a fixed concentration.**

**Get a variety of responses.**

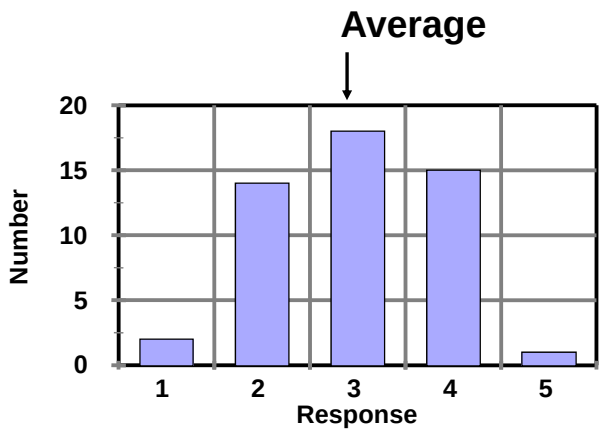
## Determine Response Curve

| Response | | Number | Fraction |
|---|---|---|---|
| Least | 1 | 2 | 0.04 |
| | 2 | 14 | 0.28 |
| | 3 | 18 | 0.36 |
| | 4 | 15 | 0.30 |
| Worst | 5 | 1 | 0.02 |
| | | 50 | 1.00 |

**Average = (1x2+2x14+3x18+4x15+5x1)/50 = 149/50**

**= 2.98**

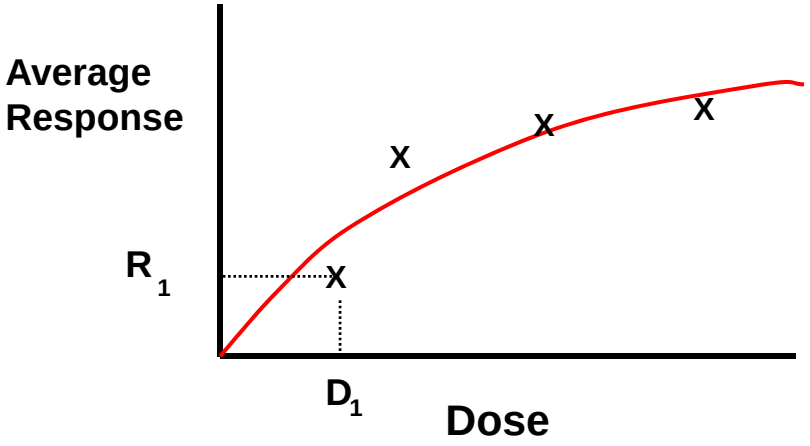
## Plot Bar Chart




## Repeat experiment at different doses.

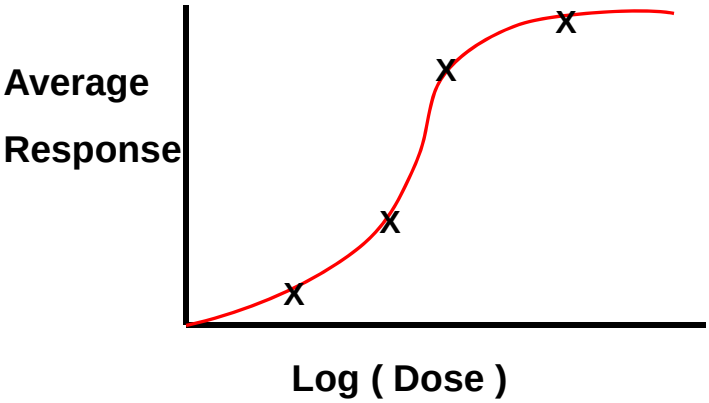
| Dose | Average Response |
|---|---|
| $D_1$ | $R_1$ = 2.98 |
| $D_2$ | $R_2$ |
| $D_3$ | $R_3$ |
| $D_4$ | $R_4$ |

## Plot Response vs. Dose




This form not very useful, particularly at low doses.

## Take the log of the dose.




Get S-shaped curve - better at low dose values

# Threshold Limit Values - 1

**THRESHOLD DOSE: NO DETECTABLE EFFECT**

**Threshold Limit Value TLV: worker's lifetime**
**8 hours per day 40 hours per week**

| | |
|---|---|
| **TLV - TWA *** | **Time weighted average** |
| **TLV - STEL** | **Short term exposure limit** |
| **TLV - C** | **Ceiling limit** |

# Threshold Limit Values - 2

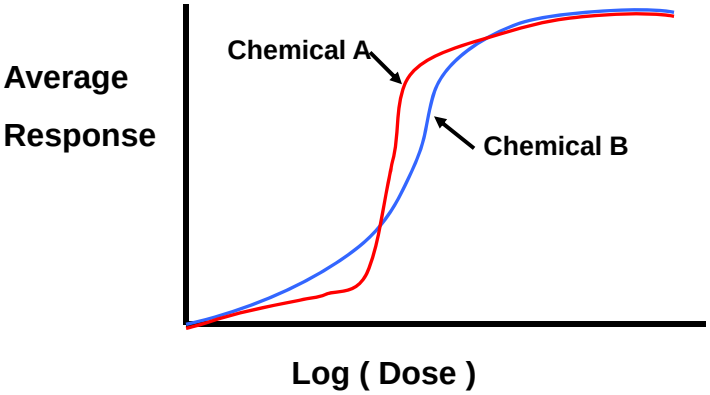
**Published by ACGIH: American Conference of Governmental Industrial Hygienists, a professional organization without legal authority.**

**Cannot be used as indication of relative toxicity.**

**Cannot be used for air pollution exposures.**

**Some toxicants have zero thresholds**

## Problem with Relative Toxicity




## Three Types of TLVs

**TLV-TWA - Time weighted average for normal 8-hour workday, to which nearly all workers can be exposed, day after day, without adverse effects.**

**TLV-STEL - Short-term exposure limit. The max. concentration to which workers can be exposed for a period of up to 15 minutes continuously without suffering (1) intolerable irritation, (2) chronic or irreversible tissue damage, (3) narcosis of sufficient degree to increase accident proneness, impair self rescue, or materially reduce worker efficiency, provided that no more than 4 excursions per day are permitted, with at least 60 minutes between exposure periods, and provided that the daily TLV-TWA is not exceeded**

## Three Types of TLVs

**TLV-C - Ceiling limit. The concentration that should not be exceeded, even instantaneously.**

**Several hundred TLV-TWA values are available for common materials. Less values are available for STEL and C.**

## TLV – Example Values

| | |
|---|---|
| **Acetone** | **500 ppm** |
| **Ammonia** | **25 ppm** |
| **CO** | **25 ppm** |
| **Chlorine** | **0.5 ppm** |
| **Gasoline** | **300 ppm** |
| **Hexane** | **50 ppm** |
| **Phosgene** | **0.1 ppm** |

**For flammables, TLV is ¼ of lower flammable limit.**

## Conversion from mg/m$^3$ to ppm

$$\text{ppm} = \left(\frac{22.4}{M}\right)\left(\frac{T}{273}\right)\left(\frac{1}{P}\right)\left(\text{mg/m}^3\right) = 0.08205\left(\frac{T}{PM}\right)\left(\text{mg/m}^3\right)$$

***T* in K, *P* in atm.**

**For liquid mixtures ppm = mg/m$^3$, but this is not true for vapors!**

## PEL - Permissible Exposure Level

**Published by OSHA, and have legal authority.**

**Defined the same as TLV.**

**Most PELs are same as TLVs.**

**Not updated as regularly as TLVs.**

**Most companies use lowest of the two values.**

**For some chemicals, i.e. benzene, vinyl chloride, a specific OSHA regulation has been published. These are called REGULATED CHEMICALS. Each regulation is unique, but most require EXPLICIT data that workers are not exposed. See OSHA.gov web site for regulations.**

## IDLH

**IDLH – Immediately Dangerous to Life and Health**

**Defined as a condition "that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent adverse health effects or prevent escape from such an environment."**

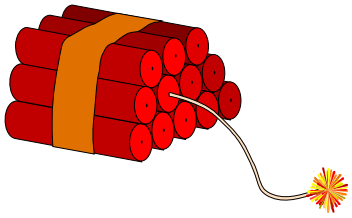
**Published by NIOSH for about 380 chemicals.**

**See NIOSH Pocket Guide on CD.**

## IDLH – Example Values

| | |
|---|---|
| **Acetone** | **2,500 ppm** |
| **Ammonia** | **300 ppm** |
| **CO** | **1,200 ppm** |
| **Chlorine** | **10 ppm** |
| **Hexane** | **1,100 ppm** |
| **Phosgene** | **2 ppm** |

# Fires & Explosions



# Introduction

**FIRE** rapid exothermic, oxidation, with flame

**EXPLOSION** higher energy release rate (mixture)
pressure or shock wave

} may trigger each other

**EFFECTS**

injuries / casualties
property losses
process interruption

} Thermal radiation, asphyxiation, toxic products, blast, fragments

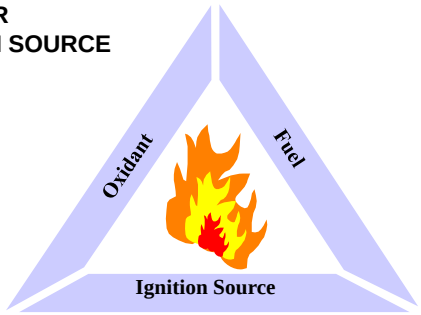
**REQUIRED KNOWLEDGE FOR PREVENTION**

material properties
nature of fire and explosion process
procedures to reduce hazards

# Fire Triangle

**FIRE TRIANGLE**

**FUEL**
**OXIDIZER**
**IGNITION SOURCE**




**Oxidant may not be oxygen, i.e. chlorine.**

# Fire Triangle

| | | |
|---|---|---|
| **FUELS** | **Gases** | **Acetylene, Propane, CO, $H_2$** |
| | **Liquids *** | **Gasoline, Organic Solvents** |
| | **Solids *** | **Plastics, Wood Dust, Fibers, Metal Particles** |
| **OXIDIZERS** | **Gases:** | $O_2$, $F_2$, $Cl_2$ |
| | **Liquids:** | $H_2O_2$, $HNO_3$, $HCl_3O$ |
| | **Solids:** | Peroxides, $NH_4NO_3$ |
| **IGNITION SOURCE** | | **Sparks, Flames, Static Electricity, Heat** |

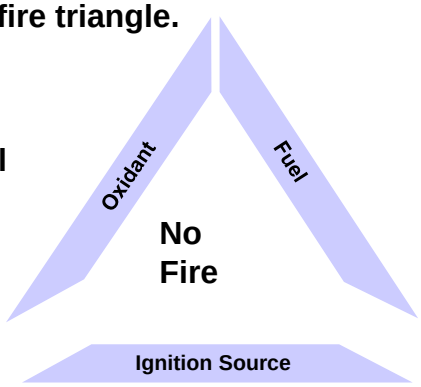
*** Liquids are volatized and solids decomposed prior to their combustion in the vapor phase**

**Sufficient quantity / energy required.**

## Application of the Fire Triangle

**Fires and explosions can be prevented by removing any single leg from the fire triangle.**

**Problem: Ignition sources are so plentiful that it is not a reliable control method.**




**Robust Control: Prevent existence of flammable mixtures.**

## Combustion Behavior – Most Hydrocarbons

**Smoke and fire are very visible!**

**Slide courtesy of Reed Welker.**

## Combustion Behavior – Carbon Disulfide

**No smoke and fire, but heat release rate just as high.**

## Definitions - 1

**LFL:** **Lower Flammability Limit**

**Below LFL, mixture will not burn, it is too lean.**

**UFL:** **Upper Flammability Limit**

**Above UFL, mixture will not burn, it is too rich.**

**Defined only for gas mixtures in air.**

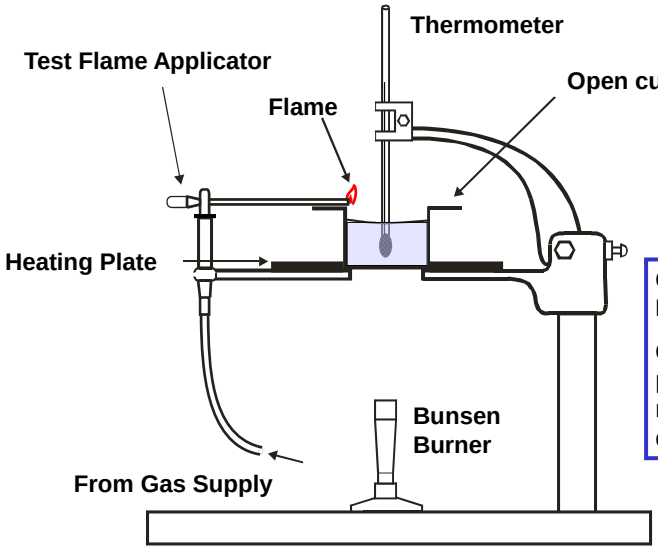
**Both UFL and LFL defined as volume % fuel in air.**

# Definitions - 2

**Flash Point:** **Temperature above which a liquid produces enough vapor to form an ignitable mixture with air. Defined only for liquids at 1 atm. Pressure.**

**Auto-Ignition Temperature (AIT):**
**Temperature above which adequate energy is available in the environment to provide an ignition source.**

## Experimental Determination - Flashpoint




**Cleveland Open Cup Method.**

**Closed cup produces a better result - reduces drafts across cup.**

## Experimental Determination - Flashpoint

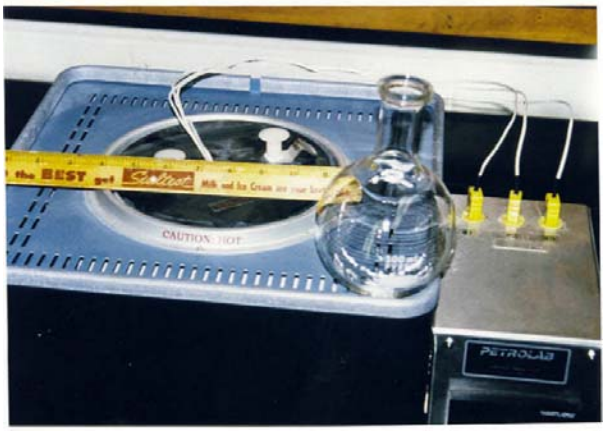
## Setaflash Flashpoint Device

## Setaflash Flashpoint Device – Close-up


## Setaflash Flashpoint Device – Close-up

## Setaflash Flashpoint Device – Close-up


## Auto-Ignition Temperature (AIT) Device



## Typical Values - 1

| | LFL | UFL |
|---|---|---|
| Methane: | 5% | 15% |
| Propane: | 2.1% | 9.5% |
| Butane: | 1.8% | 8.5% |
| Hydrogen: | 4.0% | 75% |

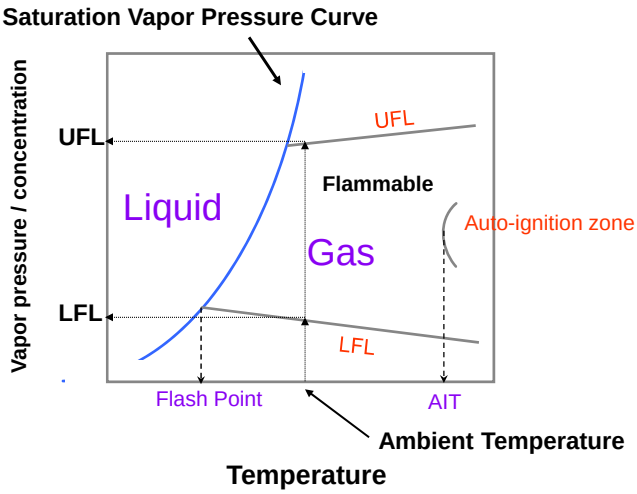
| | Flash Point Temp. (deg F) |
|---|---|
| Methanol: | 52 |
| Benzene: | 12 |
| Gasoline: | -44 |

## Typical Values - 2

| | AIT (deg. F) |
|---|---|
| Methane: | 1112 |
| Methanol: | 865 |
| Toluene: | 997 |

Great variability in reported AIT values! Use lowest value.

# Flammability Relationships




# Chemical Reactivity

**Very difficult to characterize!**

**Can have: Decompositions, reactivity with other chemicals (normal and emergency situations), catalyst effects, contamination of reactants, changes in raw material concentrations, accumulation of unreacted materials, equipment malfunctions (stirrer, cooling, vessel), improper mixing, unintended reactions, reactions occurring elsewhere, ……**

## Reactive Chemical Hazards

**What?**

**Reactive chemicals contain a lot of energy. When this energy is released suddenly and unexpectedly, an accident may result.**

**Why?**

**Reactive chemical accidents are unfortunately, fairly common.**

**Problem?**

**Reactive chemicals are difficult to quantify in a general fashion. Many common materials, when used by themselves, present little hazard. But when mixed with other common materials they present a severe reaction hazard.**

## Reactive Chemical Hazards

**The uncontrolled chemical reaction might be accompanied by:**

- **Temperature increase**
- **Pressure increase**
- **Energy release**
- **Gas evolution**

## Reactive Chemical Hazards

- It need not be explosive to result in serious harm.
- For example, gases evolved from a chemical reaction can be:
  - flammable
  - toxic
  - corrosive
  - hot
  - sufficient to pressurize an enclosure to the point of rupture

## Reactive Hazards Procedure

1. Identify reactive hazards.
2. Characterize reactive hazards.
3. Control reactive hazards

## Chemical Reactivity

**Two major issues:**

1. **Reactivity with other chemicals.**
2. **Reactivity by decomposition of a single pure chemical. The decomp frequently occurs at a higher temperature, but may occur at room temperature.**

**Questions we need to know:**

1. **Does the reaction occur quick or fast?**
2. **Does the reaction generate heat and if so, how much?**
3. **Does the reaction generate gaseous by-products that may lead to a high pressure in the reaction container?**

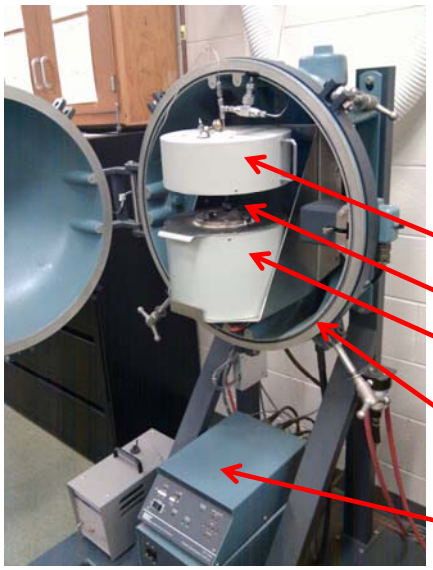
## Chemical Reactivity

**Chemical reactions can result in the very rapid generation of heat, gas, or other chemical products. This can result in a very rapid temperature increase (several 100 deg. C per minute), very rapid pressure increase (several 100 psig per minute), and very rapid generation of flammable and toxic gases or products.**

**This can lead to fires, explosions or toxic exposures.**

**Can use calorimeters (DSC, ARC, others) to study and characterize.**

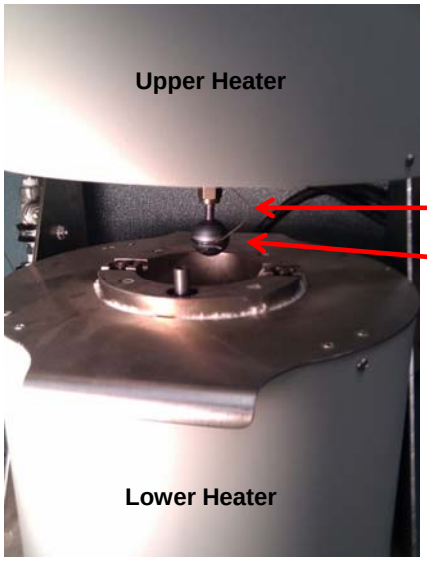
## ARC – Accelerating Rate Calorimeter



**Used to characterize the reactive behavior of chemicals.**

- Upper Heater
- Test Cell
- Lower Heater
- Containment Vessel
- Control Unit

## ARC – Accelerating Rate Calorimeter




- Thermocouple
- Test Cell

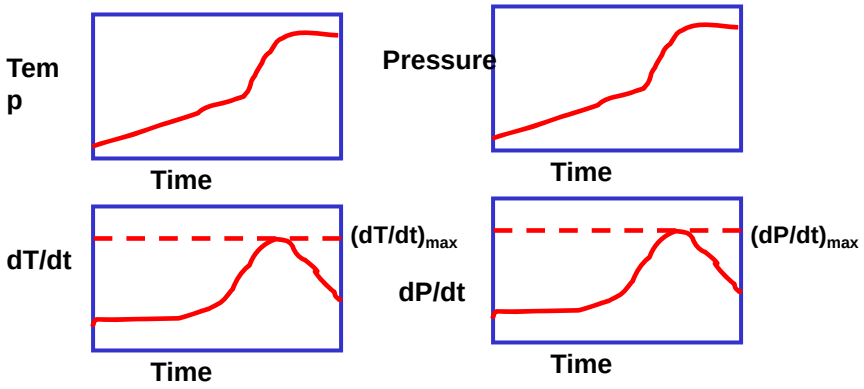
## ARC Test Cell – About 10 ml


## Determining Self Heat Rate

**Heat sample at constant rate.**

**Measure temperature and temperature rate.**

**$(dT/dt)_{max}$ is self heat rate.**



## Summary

- **We must understand the hazardous properties of chemicals prior to their use in the laboratory.**
- **The dominant hazardous properties of chemicals include: toxicity, flammability and reactivity.**
- **We must understand how these properties relate to our use of this chemical, including storage, transport, experimental procedure and disposal.**

# Industrial Hygiene

# Industrial hygiene

**Concerns conditions related to workplace injury and sickness**
**e.g: exposures to toxic vapors, dust, noise, heat, cold, radiation, physical factors, etc.**

| | |
|---|---|
| **ANTICIPATION** | **Expectation of hazard existence** |
| **IDENTIFICATION** | **Presence of workplace exposure** |
| **EVALUATION** | **Magnitude exposure** |
| **CONTROL** | **Reduction to acceptable levels** |

**Chemical labs:** **requires co-operation from industrial hygiene, safety & lab operations people**

# Identification

**Requires study of**

- **CHEMISTRY**
- **OPERATING CONDITIONS**
- **OPERATING PROCEDURES**

⬅

- Operating instructions
- Safety reviews
- Equipment description
- Chemicals description **MSDS's**

**POTENTIAL HAZARDS**

- liquids
- vapors
- dusts
- noise
- radiation
- temperature
- mechanical

**HAZARD DATA**

- physical state / vapor pressure
- TLV's
- temperature sensitivity
- rate and heat of reaction
- by-products
- reactivity with other chemicals
- explosion limits

**RISK ASSESMENT: potential for hazard to result in an accident**

# Evaluating Volatiles

**Monitoring air concentrations** ⬅➡ **Variation in time and place**

**Time Weighted Average**

**Continuous:**

$$TWA = \frac{1}{8}\int_0^{t_w} C(t)dt$$

**ppm or mg/m³**

**Intermittent:**

$$TWA = \frac{1}{8}\sum_1^i C_i T_i$$

# Evaluating Volatiles

**Additive effect multiple toxicants:**

$$\sum_{1}^{i} \frac{C_i}{(TLV - TWA)_i} < 1$$

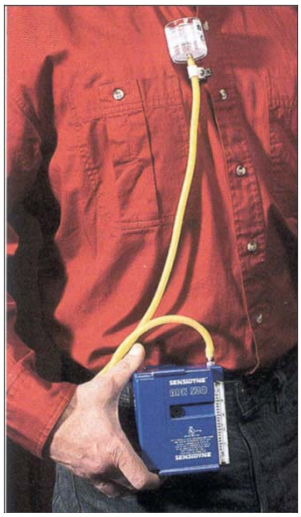
**Mixture:**

Equivalent

$$(TLV - TWA)_{mix} = \frac{\sum_{1}^{i} C_i}{\sum_{1}^{i} \left( \frac{C_i}{TLV - TWA} \right)_i}$$

# Colorimetric Tubes for Volatiles

## Air Sampling Unit for Volatiles

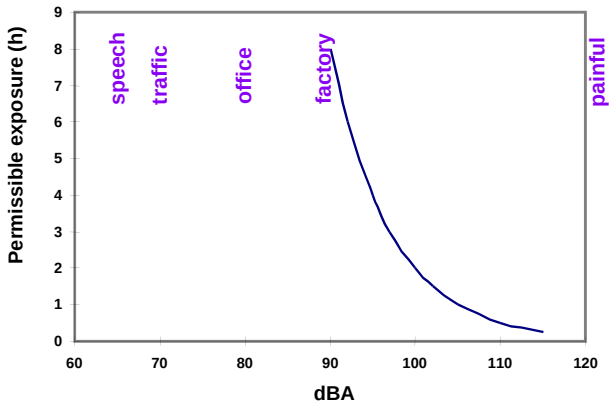


## Badge Units for Volatiles

# Evaluating Noise

**NOISE PROBLEMS ARE COMMON IN CHEMICAL PLANTS**

**Relative Noise Intensity** $= -10 \log \frac{I}{I_0}$ (dB)  $I_0 =$ hearing threshold ➡ (dBA)




**Similar calculations as volatiles**

# Evaluating Noise


**Sound meter for measuring sound levels.**

## Hearing Conservation Program

**Required by OSHA if noise exposure exceeds 90 dba.**

**Worker must have an annual physical.**

**Hearing Protection must be provided.**

**High noise area must be marked with signs.**

## Noise Control - Earplugs

## Noise Control - Ear Muffs

## Noise Reduction Ratio (NRR)

**Used for Personal Protective Equipment:**

**A particular hearing protector has an NRR of 18. If the noise is 95 dba, what is the worker exposure?**

**95 dba - 18 dba = 77 dba**

# Control

## LABORATORY CONTROL TECHNIQUES

**Environmental**

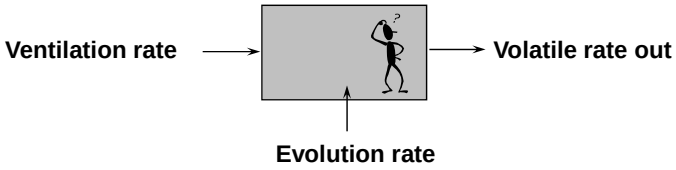
| | |
|---|---|
| Substitution | Less toxic solvents, higher flash points |
| Attenuation | Boiling point reduction by vacuum |
| Isolation | Separate laboratories |
| Intensification | Reduce chemicals, small continuous reactors |
| Enclosures | Contain experiment in hood |
| Local ventilation | Hoods |
| Dilution ventilation | Ventilation in general laboratory |
| Good housekeeping | Keeptoxics contained |

**Personal protection** — Last defense: always compromises workers

# Ventilation

**DILUTION** — Dilution below target concentration

Problems: Requires high air flow, high energy costs and workers always exposed




**LOCAL** — Removes contaminant before workers exposed

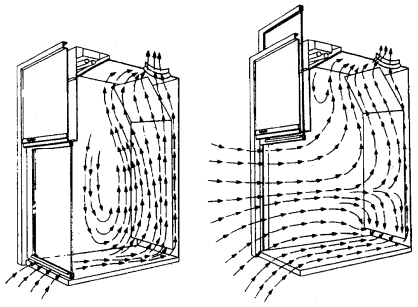
Minimal air flow

# Ventilation - Hoods

**Face Velocity:** **Air velocity through hood opening.**

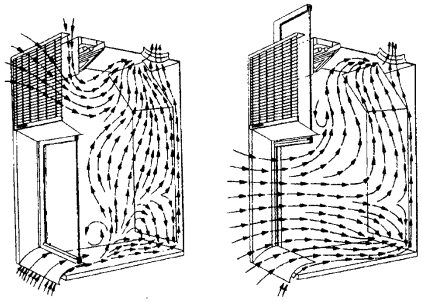
**Use 80 - 125 feet per min (fpm).**

**Standard Hoods**



*** Sash and hood itself can be used to contain process.**
*** Positive indication of hood function required by OSHA.**
*** Hoods should not be used for storage of equipment or chemicals.**

# Ventilation - Hoods



**Bypass Hoods: Air flow is adjusted as sash is moved. Some hoods have dynamic dampers to adjust airflow.**

## Ventilation - Hoods

## Ventilation - Hoods


**Hoods must have positive indication of hood function.**

**This is a manometer type indicator.**

**Colored fluid moves higher as air flow increases.**

# Ventilation - Hoods

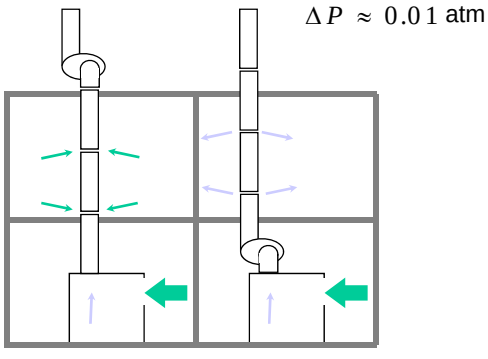

**Hoods must have positive indication of hood function.**

**This is an electronic type indicator.**

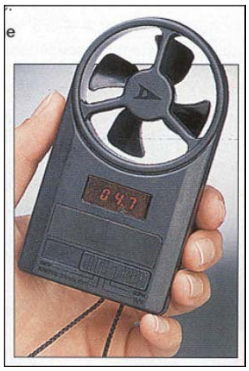
**An alarm sounds if air flow is too low. This can be a problem if Physical Plant turns off hood.**

# Ventilation Systems

**Must use negative pressure to insure no contaminant leakage.**



## Ventilation - Airflow Measurement



**Velometer - can accurately measure air velocity.**

**For hoods, must measure at several locations and with different sash locations.**

## Ventilation – Elephant Trunks


**Provides a movable ventilation source that can be located very close to emission sources.**

## Safety Showers / Eyewashes

Useful for fires and chemical spills.

For chemical spills, clothing must be removed.

Must be used, with assistance, for 15 min.
Minimum flows: Eyewash: 4 gpm
Shower: 30 gpm

Both must be tested regularly.

Area around unit must be unobstructed.

Required within the lab if chemicals are used.

## Safety Showers / Eyewashes

Water must continue to flow once handle is released.

Current OSHA standard requires water temperature control.

Problems with:

- Dirty water
- Rust from pipes
- Water temperature

## Flammable Storage Cabinets


**Offers protection from external fire.**

**Must be electrically grounded to prevent static accumulation.**

**Vent hole is left closed, unless stored materials have an odor, in which case the vent is connected to the ventilation system.**

**Do not store anything on the top.**

**Store only flammables, nothing else.**

## Corrosive Storage Cabinets


**Used to store acids and other corrosives.**

**Do not store anything on top of cabinet.**

## Safety Cans


**Use to store bulk flammable solvents.**

**Container provides protection from external fire.**

**Difficult to pour into and out of.**

## Eye Protection

**Provide eye protection against flying objects, liquid chemicals, light radiation, etc.**

**Safety glasses must be ANSI rated (ANSI Z87).**

**Must include permanently affixed side shields.**

**Must be worn at all times in the lab.**

**Contact lens usage is unclear.**

## Eye Protection - Goggles

**These provide additional protection over safety glasses.**

**Can be worn over safety glasses.**

**Come in vented and unvented styles.**

## Eye Protection - Face Shield

**Provides additional, full face protection.**

**Can wear over safety glasses or goggles for additional protection.**

## Eye Protection - Accessibility


**This storage rack is mounted near the door of the laboratory. It provides access to safety glasses for all who enter.**

## Skin Protection - Gloves

**Gloves protect the hands against chemical, mechanical, electrical and thermal hazards.**

**Come in many styles, shapes and materials.**

**Must be compatible with chemical used. See chart in Safety Manual.**

## Spill Kits


**Provide materials to clean up chemical spills. Required if you use chemicals in the laboratory.**

## Spill Kits


**Usually includes:**
*** Absorbent spill blankets**
*** Spill dams or pigs.**
*** PPE for cleanup.**
*** Disposal materials.**

# Fire Extinguishers


**Several Types:**

- **A: Wood, cloth, paper.**
- **B: Gas, liquid, grease**
- **C: Electrical fires**

**Our labs have type ABC.**

**Must be sized correctly for lab area**

**Must be inspected monthly.**

**Must be free of obstructions.**

# Fire Extinguisher Usage

**Must direct fire extinguisher discharge at base of flames, not at the flames.**

**PASS: Pull, Aim, Squeeze, Sweep**

## Broken Glass Disposal


**The box is disposed of directly so that the janitor is protected from the broken glass contents.**

**Get box from Chemical Stores.**

## Glass Storage

## Labeling of All Power Boxes



## MSDS Library


**Required by regulation.**

**Must be available to workers at all times.**

## Labeling of All Chemical Storage

## Student Responsibilities

- **Responsible for safety of their own actions and coworkers.**
- **Must attend all training and meetings for safety.**
- **Must follow proper work procedures.**
- **Must wear assigned personal protective equip.**
- **Must report all hazardous situations.**

**Safety is a requirement for employment!**

## Faculty / Staff Responsibilities

1. **Integrate safety, health, and environmental protection into the daily activities of students, employees, and any other persons they supervise.**
2. **Provide training and information to students, employees, and all others they supervise as requested by department administration and as required under University programs and policies.**
3. **Review new equipment and procedures for recognized safety, health, and environmental hazards and take appropriate precautions before they are used or implemented.**

## Faculty / Staff Responsibilities

4. **Investigate all incidents resulting in injury or property damage and report them to their department administrator and Occupational Safety and Health Services, OSHS. Close calls must also be investigated and reported if they are found to have had the potential for personal injury or property damage. All employee fatalities must be reported immediately to OSHS regardless of cause.**
5. **Enforce safety rules and review work areas daily.**
6. **Maintain a written record of the content of each training session and the identification of the trainer and all attendees.**

## Chemical Hygiene Officer-CHO

**Responsibilities of CHO include:**

- **Coordinate and update dept. safety manual annually.**
- **Act as a technical resource.**
- **Meet with dept. Space and Safety Committee on issues related to safety.**
- **Work with MTU Occupational Safety and Health Department.**

**Current CHO: David Zei**

**Manager of Laboratory Facilities: Dave Caspary**

## Prior Approval for Hazardous Operations

**Operations involving special approval:**

- **Use or storage of regulated chemicals.**
- **Temperatures exceeding 1000°C or equipment design specs.**
- **Pressures exceeding 35 atm (515 psi) or equipment design specs.**
- **Class 3b or 4 lasers.**

**Need to obtain approval from CHO and Dave Caspary prior to any hazardous operation.**

## Medical Consultations

**Medical exams are required if:**

- **Respirators are used (annual physical).**
- **Documented exposures have occurred.**
- **Signs or symptoms of exposures have occurred.**
- **Exposures due to spills, leaks, or explosions.**

**See Safety Manual for more details.**

## Unattended Operation

**Unattended operation is discouraged. If necessary, complete the form in the Safety Manual and post on outside of laboratory door.**

## Laboratory Work Late at Night

**Laboratory work late at night is highly discouraged. If a problem arises, no one is in the building to assist!**

## Laboratory Clothing

- **Long pants required, no shorts.**
- **No neckties, dangling clothes or dangling jewelry.**
- **Long sleeve shirts recommended.**
- **Tie-up long hair to prevent from entanglement.**
- **Non-porous shoes, no sandals.**

## Electrical Safety

- **Do not work on electrically activated equipment.**
- **All outlets near sinks must be Ground Fault Circuit Interrupter (GFCI) plugs.**
- **Do not use excessive extension cords.**
- **No frayed power or extension cords.**
- **Use three-prong plugs on all units. Make sure they are wired properly.**

## GFCI

**Circuit trips open when current on ground detected by GFCI.**

## Plugs and Adapters

**Should not be used in laboratory.**

**Three prong plugs are recommended.**

**Hot**

**Neutral or ground**

**Safety ground**

## Outlets / Extension Cords

**Do not overload outlets.**

**Do not use home-made extension cords.**

**Minimize extension cord use.**

## Drying Ovens

**Two types of ovens:**

1. **Natural convection or direct drying – heating element is exposed and within the drying chamber. These types require approval from CHO for use.**
2. **Indirect drying – a fan moves heat from an external heating source.**

**All drying ovens require an operating log book.**
**See Safety Manual.**

## Drying Ovens


## Gas Cylinders

- **Transport using a cylinder cart. Cylinder cap must be in place for transport.**
- **All cylinders must be secured prior to use.**
- **All cylinders must have a regulator and a shut-off valve downstream of the regulator.**
- **Cylinder fittings depend on material in cylinder – these fittings cannot be mixed!**

## Gas Cylinders


## Gas Cylinders

- **Common gases such as nitrogen, oxygen, and helium are supplied at pressures of around 3,000 psi (pounds per square inch) when full.**
- **Enough internal energy to kill.**
- **Should a cylinder valve sheer off accidentally, the net force is approximately 3,000 lbs – more than enough to accelerate a 150 lb cylinder very rapidly.**
- **A torpedo!**

## Case History

## Case History

## Many "gases" are liquids stored under their vapor pressure

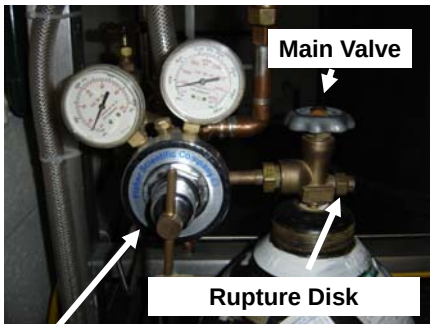
- Carbon Dioxide ($CO_2$) is the most common and is used for beverage dispensers around the world.
- Propane ($C_3H_8$)
- Liquefied Petroleum Gas (LPG)
  - A mixture of propane and butane
- Butane ($C_4H_{10}$)
  - Take a look at a butane lighter for example


## Gases stored as liquids

- These cylinders will reach their vapor pressure at ambient temperature
- Should filled cylinders be exposed to heat, hydrostating (complete liquid filling) can occur – most large cylinders have relief systems built into the valve to prevent explosion
- Another heating outcome is a BLEVE: Boiling Liquid Expanding Vapor Explosion
  - Many lives have been lost to this phenomena – propane and LPG cylinders are the most common

# Cylinders have a Rupture Disk Near Main Valve

**Should pressure exceed a certain limit, rupture disk will pop. This prevents the cylinder from rupturing which can cause great damage**




**Two Stage Regulator for Nitrogen**

# The Gas Cylinder Regulator

- **Often 2 stage**
- **Not a flow regulator**
- **Maintains constant outlet pressure**
- **Fittings are standardized to the gas being metered**
- **Brass regulators cannot be used with corrosive gases**

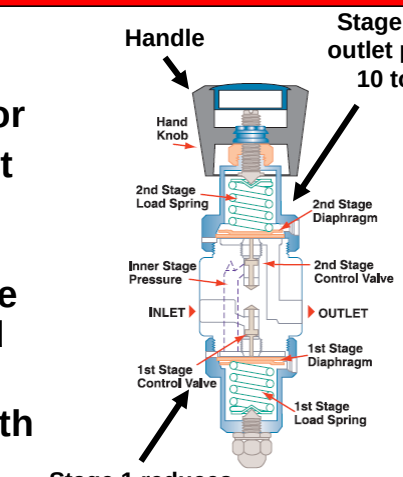
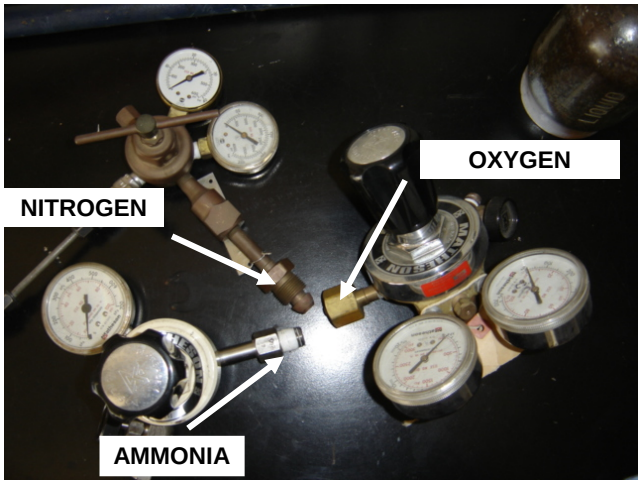



Diagram source: *www.mathesongas.com*

## Regulators have special fittings for the gas they service




**Some fittings are left handed threads and some are right handed! Cannot mix regulator in oxygen service with regulator in fuel service.**

## CYLINDER RENTALS

- **Typically, cylinders are *owned* by a gas manufacturer/supplier**
- **When the customer's cylinder is depleted or use is discontinued, the remaining contents, and the cylinder, are not considered a waste under RCRA, Resource Conservation and Recovery Act, at the your site**

## Cylinder Rentals (cont.)

- **This is because the cylinder is the property of the gas manufacturer/supplier and the reason for the return shipment is to return the manufacturer's/ supplier's property, NOT to discard the cylinder or it's contents (residual gases)**

## Gas Cylinders

**Cylinders must be secured during usage.**

## Gas Cylinders


**Must have a shut-off valve after regulator.**

## Refrigerators in Labs

- **Food or drink must never be stored in a refrigerator containing chemicals.**
- **Refrigerators storing flammable materials must be specially designed for this purpose – a regular refrigerator cannot be modified for this.**

**"Flammable Material" – vapor on inside only, no sparks on inside**

**"Explosion-proof" - flammable vapors on inside and outside.**

## Refrigerators in Labs


## Laser Safety


**Laser Classes:**

**1:** **Incapable of producing damaging radiation.**

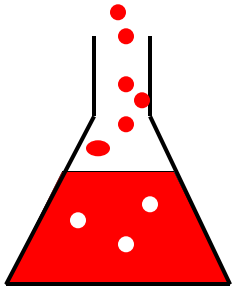
**2:** **Emits accessible, visible radiation at levels where damage from chronic exposure is possible.**

**3:** **Biological damage to human tissue is possible from acute exposure. Two subclasses: a, b.**

**4:** **Significant human tissue damage possible.**

**See Safety Manual for protection requirements.**

# Chemical Handling



## Most Important Fact

**"A commitment to purchase a chemical is a commitment to handle and store the chemical safely and to dispose of the chemical in an environmentally acceptable fashion."**

**The technology and management systems exist to handle all chemicals safely.**

## Steps in Chemical Handling

1. What are the hazardous properties of the chemical?
2. How much to purchase?
3. How do I keep track of the chemical?
4. How do I store the chemical?
5. How do I handle the chemical?
6. How do I dispose of the chemical?
7. What do I do if a chemical spill occurs?

## Step 1: What are the hazardous properties of the chemical?

**Sources of information:**

- MSDS sheets, either on-line, from manufacturer or other.
- What do these hazardous properties mean?
- Can we handle this chemical safely?
- Is the chemical regulated?

## MSDS

**Provide critical safety data.**

**Manufacturer of chemical is required by law to provide an MSDS.**

**Data on MSDS is not confirmed.**

**Many times data fields are blank.**

**I would recommend reviewing data from a number of different sources.**

## MSDS


**MSDS library must be in the lab in an easily accessible and visible location.**

**In my lab, I also include department Safety Manual and JSA sheets for procedures in laboratory.**

## MSDS

**Parts of a typical MSDS:**

- **Physical / Chemical Characteristics: Boiling point, vapor pressure, specific gravity, appearance.**
- **Fire and Explosion hazard data: Flash point, flammable limits, fire fighting procedures, explosion hazards.**
- **Reactivity data: stability, incompatibility, decomposition by-products.**
- **Health Hazard Data: Routes of entry, signs and symptoms of exposure**

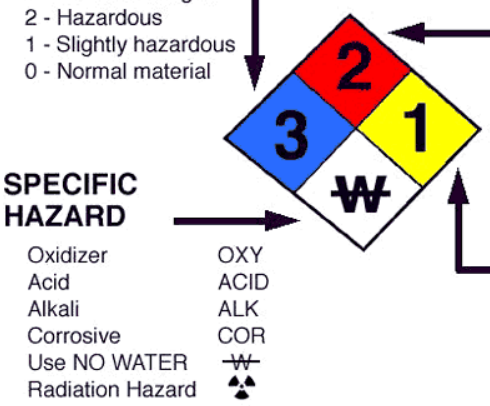
## MSDS

- **Precautions for safe handling and use: waste disposal, storage**
- **Control Measures: Personal Protective Equipment (PPE)**

## NFPA Diamond

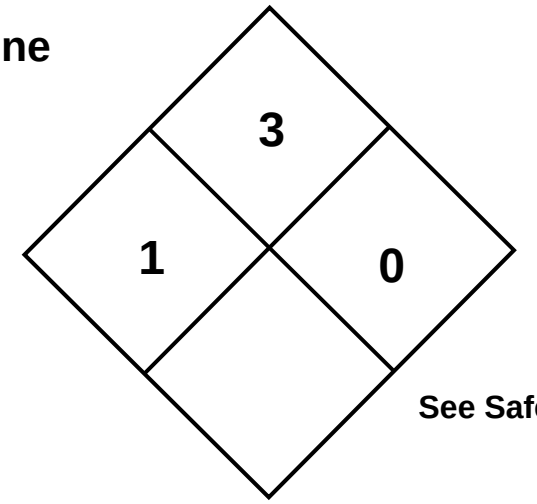
**Ratings: 0-4**
**0 : no hazard**
**4: max. haz.**

**Used for firefighters**




## NFPA Diamond

**Acetone**




**See Safety Manual**

## Can we handle the chemical safely?

**Depends on your capability, the condition of your laboratory facility, the equipment available, and the confidence in managing the chemical properly.**

**Some chemicals I will not handle: phosgene, ethylene oxide, regulated chemicals, others.**

## Regulated Chemicals

**OSHA publishes a list of about 30 regulated chemicals.**

- **Each chemical has a standard (see OSHA.gov)**
- **Most require explicit measurement of exposure concentrations.**
- **Most require annual medical physicals for workers potentially exposed.**

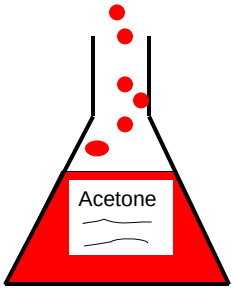
**Common chemicals on list: benzene, benzidene, ethyleneimine, acrylonitrile, formaldehyde, 1,3 butadiene, methylene chloride**

## Step 2: How much to purchase?

**Order only what you need! Keep inventories to a minimum. Remember, what you don't have can't hurt you!**

## Step 3: How do I keep track of the chemical?

- **Chemical Inventory**




- **Labeling of container**

# Chemical Inventory

**Not required by regulation but an excellent idea.**

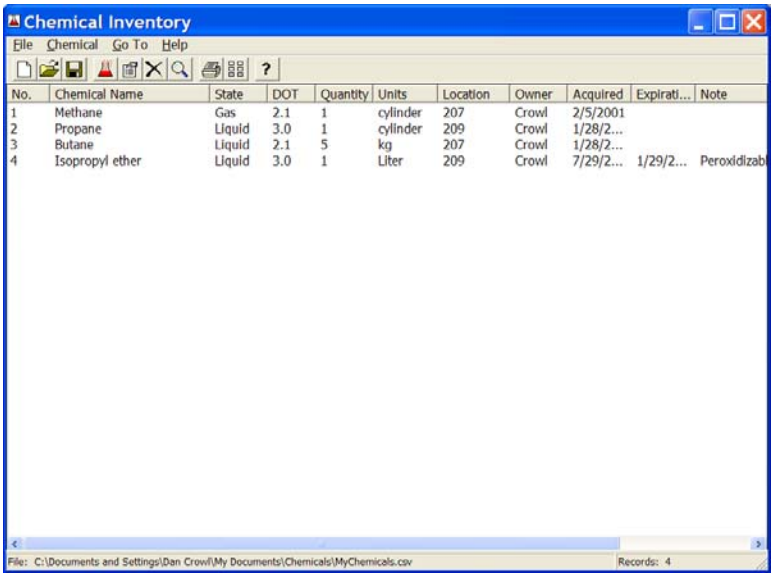
**Software programs are available (one is on your CD).**

**Laboratory user must take ownership of the inventory.**

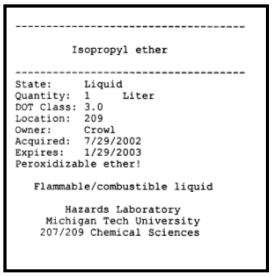
**Should track chemicals from acquisition to disposal.**

**Should include same information as chemical label.**

# Chemical Inventory Program



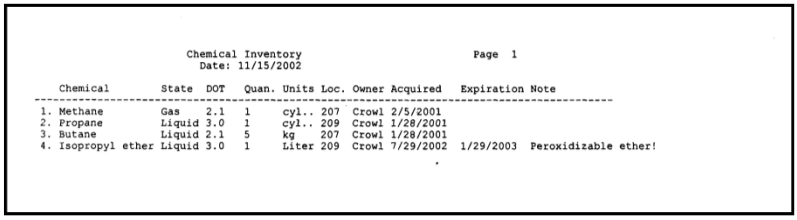
# Chemical Inventory Program



```
-------------------------------------

        Isopropyl ether

-------------------------------------
State:      Liquid
Quantity:   1      Liter
DOT Class:  3.0
Location:   209
Owner:      Crowl
Acquired:   7/29/2002
Expires:    1/29/2003
Peroxidizable ether!

   Flammable/combustible liquid

       Hazards Laboratory
    Michigan Tech University
   207/209 Chemical Sciences
```

**Label printed by program**

# Chemical Inventory Program



```
                    Chemical Inventory                          Page  1
                      Date: 11/15/2002

    Chemical        State  DOT   Quan. Units Loc. Owner Acquired   Expiration Note
-------------------------------------------------------------------------------------
1. Methane          Gas    2.1   1     cyl.. 207  Crowl 2/5/2001
2. Propane          Liquid 3.0   1     cyl.. 209  Crowl 1/28/2001
3. Butane           Liquid 2.1   5     kg    207  Crowl 1/28/2001
4. Isopropyl ether  Liquid 3.0   1     Liter 209  Crowl 7/29/2002  1/29/2003  Peroxidizable ether!
```

**Inventory printed by program.**

## Chemical Labeling

**A chemical label is required for any chemical or sample that will not be in your physical possession at any time.**

**Parts of the label:**

- **Identity of contents**
- **Date chemical was acquired**
- **Disposal date (for unstable chemicals)**
- **Responsible person**
- **Hazardous characteristics**
- **Other pertinent safety information.**

## Chemical Labeling

- **Label container prior to use.**
- **Chemical label must be legible, in English.**
- **Must have actual chemical name, not a number.**
- **Must not obscure existing labels or safety information.**

# Chemical Labeling

Hazards Laboratory

Chemical Name:_____

Date Rec'd:__/__/__ Disposal Date:__/__/__

Dept:_____ Location:_____

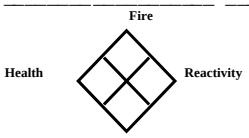
Responsible Party:_____

Safety Info:_____ Remarks:_____

_____ _____

_____ _____

_____ _____




## Step 4: How do I store the chemical?

- **MSDS sheets must be available for all chemicals.**
- **All chemicals must be properly labeled and inventoried.**
- **Do not store chemicals on top of lab benches, out in open, or above eye level.**
- **Storage in hoods is not recommended.**
- **Keep incompatible chemicals separated (see table in safety manual).**
- **Flammables stored in flammable storage cabinet.**
- **All cabinets containing chemicals must be labeled.**

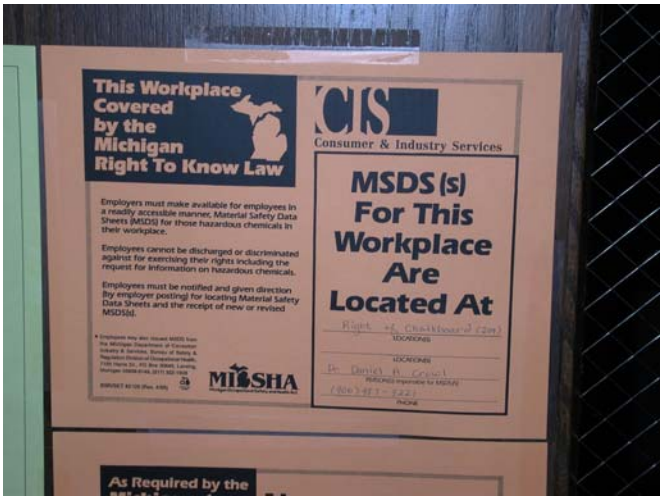
## Chemical Storage – Acids and Bases


## Chemical Storage - Flammables

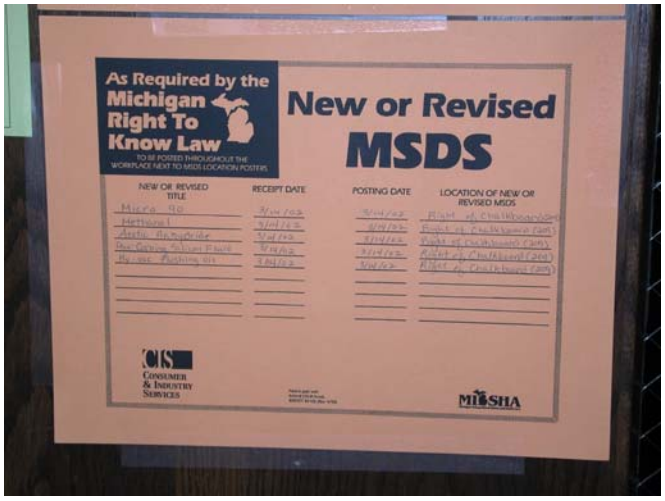

## Chemical Storage

**Identify locations in lab where chemicals are stored.**

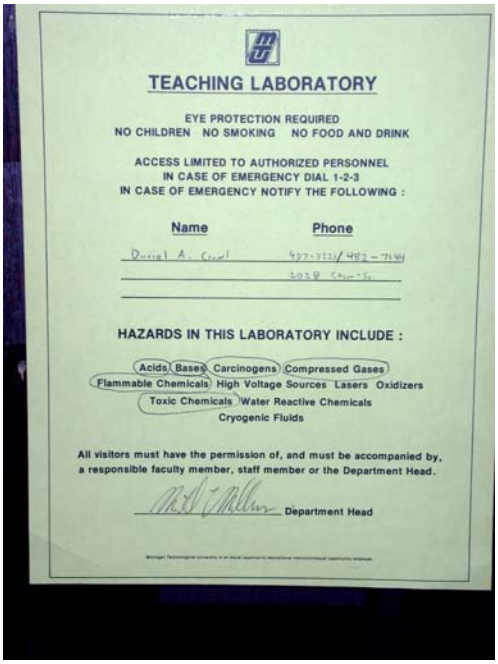
## Chemical Storage - Signs



## Chemical Storage - Signs




## Chemical Storage - Signs



## Step 5: How do I handle the chemical?

- Depends on properties of chemical.
- Usually involves personal protective equipment.
  - Gloves (see compatibility chart in Safety Manual)
  - Aprons
  - Others
- Try to minimize exposure by minimizing transport and handling.

## Chemical Transport

This method provides stability and containment.

## Step 6: How do I dispose of the chemical?

**Michigan Tech has a waste disposal program, however, they collect and dispose of chemicals on an infrequent basis, dependent on volume. The user must pay for the service. This service is very costly if the material is unknown (factor of ten).**

**See Chemical Engineering Waste Disposal Manual.**

**This will be discussed later.**

## Step 7: What do I do if a chemical spill occurs?

**If spill is minor, you may be capable of clean-up or response - see Safety Manual. Spill kits are very valuable here.**

**If spill is major, leave spill site immediately and call Public Safety at 9-1-1.**

## Legal Requirements

- **MTU is a State institution, so we do not come under Federal OSHA authority.**
- **However, we are under Michigan OSHA authority.**
- **Michigan is an OSHA certified state, meaning that all regulations are consistent with Federal regulations.**
- **Two major regulations:**
  - *** Hazard Communication**
  - *** Hazardous Work in Laboratories**

## Hazard Communication

**Designed to make information about hazardous chemicals available to exposed employees.**

**Applies to any business that uses hazardous chemicals.**

**Does not depend on number of employees.**

## Part 42: Hazard Communication

**The program must include a written hazard communication document, which addresses:**

1. **Container labeling.**
2. **Employee training.**
3. **MSDSs library development and maintenance.**
4. **A list of hazardous chemicals.**
5. **Informing employees about the hazards of non-routine tasks, such as maintenance or repair.**
6. **Information exchange between employees, sites and contractors.**

## Part 42: Hazard Communication

**In addition, the program must address:**

1. **Employee training in the identification, use, and hazards of chemicals they may work with.**
2. **MSDS sheets must be maintained in an orderly fashion.**
3. **Containers and pipes must be labeled.**

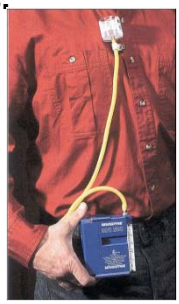
## Part 431: Hazardous Work in Laboratories

**Major Parts:**

1. **Exposure Monitoring**
2. **Chemical Hygiene Plan**
3. **Employee Information and Training**
4. **Medical Surveillance**
5. **Hazard Identification**
6. **Respiratory Protection**
7. **Record keeping**

## 1. Exposure Monitoring

**Must measure exposure to any regulated chemicals and notify the employee within 15 working days of results.**



## 2. Chemical Hygiene Plan

**Chemical hygiene plan must:**

1. **provide the means of protecting employees from chemical exposures.**
2. **provide methods to keep exposures below limits.**
3. **be readily accessible.**
4. **have the following elements:**
   a. **Standard Operating Procedures (SOP)**
   b. **Criteria for control measures**
   c. **methods to insure lab hood functions**

## 2. Chemical Hygiene Plan (cont'd)

   d. **employee information and training.**
   e. **prior approval for hazardous operations.**
   f. **provisions for medical consultations.**
   g. **assignment of chemical hygiene officer.**
   h. **provisions for working with particularly hazardous substances.**
   i. **designation of exposure areas, including usage of hoods, waste removal and decontamination procedures.**

5. **Must review and update plan annually.**

## 3. Employee Information and Training

1. Employee must know and understand the hazards of chemicals in the workplace.
2. Information and training must be provided prior to chemical use and must be updated for new exposure situations.
3. Employees shall be informed of the following:
   a. The chemical hygiene plan.
   b. The PEL's for workplace chemicals
   c. Signs and symptoms of exposure.
   d. The availability of reference materials.

## 3. Employee Information and Training (cont'd)

4. Employee training must include the following:
   a. Methods used to detect chemicals in workplace.
   b. Physical and health hazards of chemicals.
   c. Protection methods.
5. The employee must be trained on the employer's chemical hygiene plan.

## 4. Medical Surveillance

1. **Employers must provide the following medical services:**

   **a. appropriate medical examination after exposures.**

   **b. if exposures are above required levels for regulated chemicals, then medical surveillance must be established.**

2. **Medical examinations must be provided without cost to the employee.**

3. **The employer must provide to the physician:**

   **a. the identity of the chemical**

## 4. Medical Surveillance (cont'd)

   **b. a description of the conditions under which the exposure occurred.**

   **c. a description of the signs and symptoms of exposure.**

4. **Employer must obtain a written report of the examining physician.**

## 5. Hazard Identification

1. **Existing labels on containers must not be defaced or removed.**
2. **MSDS sheets must be maintained and available to employees.**
3. **Unknown chemicals must be treated as hazardous until proper determinations are made.**

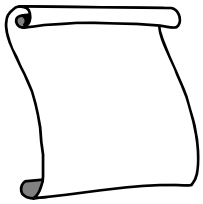
## 6. Use of Respiratory Equipment

**Respiratory equipment must be provided at no cost to employee.**

**This also applies to any safety equipment required for the job.**

## 7. Record Keeping

1. **Employers must maintain accurate records of exposure measurements, medical consultations, and medical tests.**
2. **Must be protected from unauthorized disclosure.**



# Laboratory Inspections

# Laboratory Inspections

**In the Department of Chemical Engineering, we have mandatory annual inspections of all laboratories in the department. The purpose of this inspection is to assess the safety program - not to correct problems in the lab. Inspection of the laboratory on a day-to-day basis is the responsibility of the laboratory user.**

**The results of the inspections are documented, signed by the department head, and distributed throughout the department.**

## Laboratory Inspections

**If a laboratory has very serious safety problems, the laboratory may be shut and locked.**

**The department chemical hygiene officer and laboratory manager may inspect a lab at any time, and recommend corrective action.**

**Normal, annual inspections are done by Chemical Engineering faculty.**

## Lab Inspections

**I do a laboratory inspection every time I walk into a lab (even if it is someone else's lab). If I find a problem in my lab, I usually take immediate corrective action.**

**Lab inspections require skills in hazard identification.**

**Annual lab inspections in our department use an inspection form (which changes from year to year).**

**I consider the inspection form to be a minimum requirement for safety, and we can all do much better.**

**It is easier to keep the lab safe on a day-to-day basis than it is to "fix it up" once a year for the annual inspection.**

# Hazards Identification

**Best done with more than one person.**

**Requires awareness, attention to detail, and technical understanding.**

**There is always something that can be improved!**

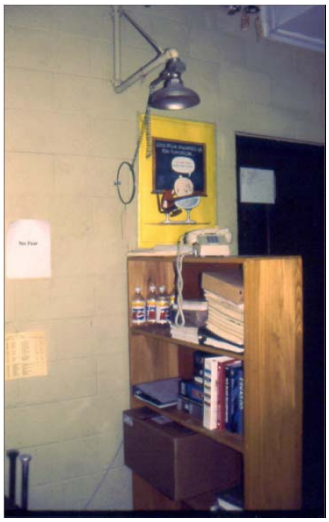
**<u>Some Usual Places to Look:</u>**

- **Look in every cabinet and drawer.**
- **Look at chemical storage.**
- **Look at a few chemical labels.**
- **Look at MSDS library for a few chemicals.**
- **Look at general housekeeping and organization.**

# Hazards Identification

**Example of an unknown chemical that has corroded the container and is spilling out into the lab.**

## Hazards Identification



**A safety shower that cannot be used since a bookshelf is in the way.**

## Hazards Identification

**A fire extinguisher and fire blanket that cannot be used since they are obstructed by wires.**

## Hazards Identification

**A chair obstructing a fire extinguisher.**

## Hazards Identification

**Lots of things here!**

- **Flammables not stored in flammable storage cabinet.**
- **Improper waste disposal.**
- **Incompatible chemicals stored together.**

# Inspection Checklist

**The inspection checklist includes a number of mandatory items. These items are shown in red on the following slides and are identified as "Mandatory" on the inspection checklist.**

**The mandatory items must be corrected immediately, otherwise the laboratory will be closed. All other items on the list become mandatory at the next inspection.**

# Inspection Checklist

**A.Emergency:**

1. Completed emergency information labels posted outside room
2. Exits not blocked
3. Window on laboratory door not covered
4. Emergency Exit route posted on inside of door
5. Fire Extinguisher: Available within laboratory
   Clearly visible
   Not blocked
   Annual inspection is up-to-date
   Correct for flammables present

## Inspection Checklist

6. Safety shower: Available within laboratory
Clearly visible
Not blocked
Annual inspection is up-to-date
7. Eye wash: Available within laboratory
Clearly visible
Not blocked
Annual inspection is up-to-date
8. Spill kits: Available within laboratory if chemicals present
Clearly visible
Not blocked
Appropriate for chemicals present (includes mercury)

## Inspection Checklist

**B. Housekeeping**
Counters and floor clear of clutter
No food or evidence for food
**C. Compressed Gas**
Manual shutoff valves provided at all points of supply and use
Corrosive gases stored no more than 6-months
All cylinders secured in place
Pressure gauges in place
**D. Mechanical Guarding**
Machine guarding in place
Sharps disposal container available if hypodermic needles present in lab

# Inspection Checklist

**E. Electrical**

- Electrical cords - not pinched, broken, cracked, or covered up
- Circuits feeding potentially wet areas protected by GFCI
- No exposed and energized electrical parts
- Electrical panels are not blocked
- Electrical panels labeled, even when not in service

# Inspection Checklist

**F. Ventilation**

- Laboratory hood sash is in working order - not stuck, broken, or removed
- Equipment or materials do not obstruct air flow
- Hood interior is clean, uncluttered, and not used as storage
- Air flow rate is posted or flow gauge is present (between 80 - 120 fpm)
- Air flow indicator on hood shows positive indication of hood function

# Inspection Checklist

**G. Personal Protective Equipment**

- Appropriate safety eye wear is worn
- Appropriate shoes worn
- Necessary PPE available

# Inspection Checklist

**H. Chemical Storage**

- Chemicals in open kept to a minimum
- Flammable/combustible liquids stored in safety cans or flammable storage cabinets
- Flammable storage cabinets grounded
- Incompatible chemicals, i.e. acids and bases, stored separately
- Chemical containers are properly labeled
- Chemical storage cabinets labeled

# Inspection Checklist

**I. Chemical Waste Management**

Chemical wastes stored in proper containers and location

All chemical wastes in labeled containers

All chemical wastes in compatible groups

Chemical waste disposal done regularly

# Inspection Checklist

**J. Hazard Communication**

MSDS sheets available for all non-R&D chemicals in lab

Safety Manual accessible

Emergency response phone numbers permanently marked on the phone

Chemical inventory is up-to-date and available

Standard operating procedures are available

# Inspection Checklist

**K. Glassware**

- Properly stored
- Chipped, broken, or scratched glassware is disposed of
- Broken glass container provided

**L. Drying Ovens**

- JSA's for use are on file and followed.
- A logbook is used to document use.
- Direct-heated ovens are not used to dry flammables.
- Mercury thermometers are not used in ovens.
- Ovens used to dry materials that off-gas toxic or noxious vapors are located in a hood.

# Waste Disposal

## General Concepts – Waste Disposal

1. Return unused chemicals to Chem Stores, if possible.
2. Keep all chemicals unmixed and labeled.
3. Keep waste storage to a minimum.
4. Do not dispose by evaporation in the hood.
5. A few chemicals can be dumped down the drain (need to be absolutely sure!)
6. Special waste code required on storage container.

## Waste Disposal

**A waste is any solid, liquid, or contained gaseous material that you no longer use, and either recycle, throw away, store, treat, dispose of or abandon.**

**Regardless of whether it is liquid, solid, or compressed gas, these wastes are known as solid wastes.**

**Generators of solid waste are required to immediately determine if their wastes are hazardous waste. If you fail to determine that your waste is hazardous, then the waste may be managed or accumulated improperly. This is one of the most common generator mistakes found.**

## Waste Disposal

**Hazardous waste must be accumulated and stored at the point of generation until removed by OSHS and must be:**

1. **Collected in a container that is compatible with its contents under all conditions it might be subjected to during accumulation, storage, and shipment.**
2. **Kept tightly sealed except when adding waste to the container.**

## Waste Disposal

3. **Handled only by personnel trained in the requirements of the hazardous waste rules for satellite accumulation of hazardous waste.**

4. **Removed from the accumulation area within three days if the quantity of any one waste exceeds 55 gallons (from a safety perspective, no more than 5 gallons should be accumulated in a laboratory or shop).**

## Waste Disposal - Labeling

**Labeled properly according to the following:**

1. **Each container must have a label. The label should be attached to the container when it is initially used for waste. The label must contain the words "hazardous waste," the waste identification number (see Section 3), the accumulation start date, the name of the responsible person, room number and building, and a chemical description of the waste. The label must also contain the date the container becomes full.**

## Waste Disposal - Labeling

2. **Wastes that are commingled must list all components in the contents section, including water and all trace materials.**

3. **Aqueous wastes should have the pH of the solution recorded.**

4. **All used oils must also be marked with the words, "used oil."**

## Waste Disposal - Labeling

**HAZARDOUS WASTE** **HAZARDOUS WASTE**

Dept: _____
Rm/Bldg:_____
Name: _____
Date: _____

**Waste Code**

-Complete Label in Pencil-

**Labeling must always be done in English!**

**These labels are what I use in my lab!**

## Waste Disposal - Labeling

*HAZARDOUS WASTE* Complete Label in Pencil

Dept.: _____ Date: _____

Room: _____ Name: _____

| Contents | % | | |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | pH If Aqueous | |

## Waste Codes

**Hazardous wastes are defined by the United States Environmental Protection Agency (USEPA) as either listed (meaning that it is listed on a table) or defined based on a particular characteristic of the material.**

## Waste Codes – K Listed

**K-Listed Hazardous Wastes:** **K-listed hazardous wastes are source-specific wastes that are generated by specific industries such as iron and steel production facilities. K-listed hazardous wastes are not likely to be found in a laboratory and are not discussed in detail here.**

## Waste Codes – F Listed

**F-Listed Hazardous Wastes:** **F-listed hazardous wastes are non-specific source wastes that are generated by particular industrial processes that can occur in various industries. Industrial processes that generate F-listed hazardous wastes include wood preservation, electroplating and other metal finishing processes, and processes that generate waste solvents.**

## Waste Codes – F Listed

**F-listed wastes that may be found in laboratories include the following solvents or mixtures containing 10 percent or more of the solvent (before use) when spent:**

**Acetone**
**Benzene**
**Carbon tetrachloride**
**Cyclohexanone**
**Ethyl acetate**
**Ethyl ether**
**Isobutanol**
**Methanol**
**Methyl ethyl ketone**
**Methylene chloride**
**Toluene**
**Xylene**

**See complete table in Hazardous Waste Manual!**

## Waste Codes – U Listed

**U-Listed Wastes are wastes regulated because they are a discarded chemical product or are spill-debris that contains a specific chemical compound which is considered toxic.**

**There are over 300 U-listed hazardous wastes. Please see Appendix VII in the Hazardous Waste Manual for the complete list.**

## Waste Codes – U Listed

**U-listed hazardous wastes most commonly found in laboratories include the following:**

Acetaldehyde
Acetone
Acetonitrile
Acrylonitrile
Aniline
Benzene
1-Butanol
Carbon tetrachloride
Cyclohexane
Ethanol
Ethyl ether
Formaldehyde
Mercury
Methanol
Toluene

**See complete table in Hazardous Waste Manual!**

## Waste Codes – P Listed

**P-Listed Wastes are also wastes regulated because they are a discarded product or are spill-debris that contains a specific chemical compound which is considered acutely toxic. P listed wastes are dangerous, even in small amounts, and are regulated the same way as larger amounts of other hazardous wastes. Dieldrin, endrin, epinephrine, and sodium cyanide are examples of P-listed wastes. Even the containers that hold these wastes are regulated as hazardous waste until they have been emptied and triple rinsed.**

## Waste Codes – P Listed

**There are over 100 P-listed hazardous wastes. Please see Appendix VI in the Hazardous Waste Manual for the complete list.**

**The P-listed hazardous wastes most commonly found in laboratories include the following:**

Acrolein
Arsenic acid
Carbon disulfide
Chloroacetaldehyde
Cyanides
Phosgene
Potassium cyanide
Sodium azide
Sodium cyanide

## Waste Codes – Michigan Specific

**Michigan Specific Wastes are listed in Appendix VIII of the Hazardous Waste Manual. These wastes are specifically listed for Michigan.**

## Characteristic Wastes

**Even if a waste does not appear on the EPA lists, it is considered hazardous if it exhibits one or more of the following characteristics:**

**Ignitability - Waste Class Number D001**

**Corrosivity - Waste Class Number D002**

**Reactivity - Waste Class Number D003**

**Toxicity - Waste Class Number D003 thru D043.**

## Characteristic Wastes - Ignitibility

**Ignitability - Waste Class Number D001**

**A waste exhibits the characteristic of ignitability and is identified by the hazardous waste number D001 if a representative sample of the waste has any of the following properties:**

**It is a liquid and has a flash point less than 60 degrees Centigrade (140 degrees Fahrenheit).**

**Plus other special circumstances (see Hazardous Waste Manual).**

## Characteristic Wastes - Corrosivity

### Corrosivity - Waste Class Number D002

**A waste exhibits the characteristic of corrosivity and is identified by the hazardous waste number D002 if a representative sample of the waste has either of the following properties:**

- **It is aqueous and has a pH less than or equal to 2 or greater than or equal to 12.5.**
- **It is a liquid and corrodes steel (SAE 1020) at a rate of more than 6.35 mm (0.250 inch) per year at a test temperature of 55 degrees Centigrade (130 degrees Fahrenheit) as determined by the test method specified in the National Association of Corrosion Engineers (NACE) standard TM -01-69.**

## Characteristic Wastes - Reactivity

### Reactivity - Waste Class Number D003

**A waste exhibits the characteristic of reactivity and is identified by the hazardous waste number D003 if a representative sample of the waste has any of the following properties:**

- **It is normally unstable and readily undergoes violent change without detonating.**
- **It reacts violently with water.**
- **It forms potentially explosive mixtures with water.**
- **When mixed with water, it generates toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment.**

## Characteristic Wastes - Reactivity

- **It is a cyanide or sulfide-bearing waste that, when exposed to pH conditions between 2 and 12.5, can generate toxic gases, vapors, or fumes in a quantity sufficient to present a danger to human health or the environment.**
- **It is capable of detonation or explosive reaction if it is subjected to a strong initiating source or if heated under confinement.**
- **It is readily capable of detonation or explosive decomposition or reaction at standard temperature and pressure.**
- **It is a forbidden explosive.**

## Characteristic Wastes - Toxicity

**Toxicity - Waste Class Number D003 thru D043.**

**See Tables 1 and in Appendix IV in Hazardous Waste Manual**

**A waste exhibits the toxicity characteristic if, using the toxicity characteristic leaching procedure, the extract from a representative sample of the waste contains any of the contaminants listed in Table 1 at a concentration equal to or greater than the respective values given in the table. If the waste contains less than 0.5% filterable solids, then the waste itself, is considered to be the extract for the purposes of this rule.**

**A waste exhibits the characteristic of severe toxicity if the waste contains l part per million or more of a severely toxic substance listed in Table 2.**

MichiganTech

**Request for Collection of Waste Chemicals**

Requested by _____ Date _____

Department/Office/Division _____ Telephone number _____

Location of Waste Chemicals _____

Disposal Approved by _____ Date _____

| Item No. | Chemical Name/Description | EPA Waste ID No.* | Physical State ** | Quantity | Container Size |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | | | | | |
| 4 | | | | | |
| 5 | | | | | |
| 6 | | | | | |
| 7 | | | | | |
| 8 | | | | | |
| 9 | | | | | |
| 10 | | | | | |
| 11 | | | | | |
| 12 | | | | | |
| 13 | | | | | |
| 14 | | | | | |
| 15 | | | | | |

* Refer to EPA hazardous waste tables or contact OSHS
** Indicate whether waste is solid, liquid, gas, or sludge

**Form used to request pick-up of hazardous waste.**

**Lab wastes are picked up on a very irregular basis at MTU (normally 2x per year).**

**Notify OSHS as soon as possible.**

## Procedure – Chemical Waste Labeling

1. **See if chemical is on one of the lists. Some chemicals appear on more than one list – select the list that best matches what you are doing with the chemical.**
2. **If not on the list, see if the chemical can be classified according to the characteristic of the chemical.**
3. **Put waste code on label.**

# Job Safety Assessment

- **Used to determine hazards associated with a particular experiment / procedure and to control the hazards.**
- **Side benefit: excellent method to organize experiment and procedure prior to operation.**
- **Can be used as an appendix in thesis.**

**Need:**

1. **Complete diagram of lab, showing location of safety equipment, chemical storage and experiment.**
2. **Complete flow diagram of apparatus, including numbered valves.**
3. **MSDS sheets for all chemicals attached.**

# JSA – Page 1

Job Safety Assessment Form
Department of Chemical Engineering
Michigan Technological University

| | |
|---|---|
| Equipment Name: | JSA Author: |
| Room Number/Building: | Faculty Supervisor: |
| Revision #: | Revision Date: |

**Used to identify location of experiment.**

## JSA – Page 1

**Purpose of Experiment / Equipment:** Briefly describe what this experiment is designed to achieve and the types of data collected.

**Provide a brief verbal description of what this experiment is supposed to do.**

## JSA – Page 1

**Personal Protective Equipment (PPE)** – Check all PPE worn during the entire experiment. Do not list these in the procedure section.

| | | | |
|---|---|---|---|
| ☐ Long Pants | ☐ Safety Glasses | ☐ Hard Hat | ☐ Apron |
| ☐ Long Sleeves | ☐ Splash Goggles | ☐ Insulated Gloves | ☐ Ear Protection |
| ☐ Non-porous Shoes | ☐ Face Shield | ☐ Chemical Gloves | ☐ Other: |

**This should summarize all the personal protective equipment required normally in the laboratory and PPE required for this particular experiment. Equipment that is required all the time (such as safety glasses) does not need to be listed on each step of the JSA.**

# JSA – Page 1

**Hazard Summary** – Check all general hazards that are likely to be encountered during this experiment and list the major source of the hazard.

| Hazard | Major Source of Hazard |
|---|---|
| ☐ Toxicity | |
| ☐ Fire/Flammability | |
| ☐ Reactivity | |
| ☐ Pressure Hazard | |
| ☐ Electrical Shock | |
| ☐ Mechanical Hazard | |
| ☐ Hot Surfaces/ High Temp > 150 F | |
| ☐ Biohazard | |
| ☐ Laser Radiation | |
| ☐ Ionizing radiation | |
| ☐ Other: _____ | |
| ☐ Other: _____ | |

**Check all hazards that result due to this experiment. Identify the one major source of the hazard.**

# JSA – Page 1

**Expected Operating Conditions** –

| Temperature | Pressure |
|---|---|
| Normal: | Normal: |
| Minimum: | Minimum: |
| Maximum: | Maximum: |

**List the expected normal, minimum and maximum values for the temperature and pressure.**

# JSA – Page 2

**Special Operating Conditions** - Check all that apply and consult department Safety Manual.

| | |
|---|---|
| Unattended Operation: ☐ | Drying Oven: ☐ |
| Regulated Chemicals: ☐ | Class 3b or 4 Lasers: ☐ |
| Pressures Exceeding 35 atm (515 psia) or Equipment Specifications: ☐ | |
| Temperatures Exceeding 1000°C or Equipment Specifications: ☐ | |

**Check all special operating conditions. If any of these are checked, need to consult with Dave Caspary, Manager of Laboratory Facilities.**

# JSA – Page 2

**Available Safety Equipment** – Provide the location of each item shown below. Show the location of this equipment on the attached floor plan. If not available, type "NA" in the field.

| Item | Location |
|---|---|
| Fire Extinguisher: | |
| Eyewash: | |
| Safety Shower: | |
| Telephone: | |
| First Aid Kit: | |
| Other: | |
| Other: | |

**List all equipment available within the laboratory and their location. Show the locations on the attached floor plan.**

# JSA – Page 2

**Spill Response Supplies** - Provide the location of each item shown below. Show the location of this equipment on the attached floor plan. If not available, type "NA" in the field.

| Item | Location |
|---|---|
| Spill Kit: | |
| Floor-Dri: | |
| Spill Dikes: | |
| Sodium Bicarbonate: | |
| Drain Plugs: | |
| Spill Pillows: | |
| Mercury Spill Kit: | |
| Other: | |
| Other: | |

**List the location of the spill response equipment. Show location on an attached laboratory diagram.**

# JSA – Page 2

**Required Attachments:**

| |
|---|
| ☐ Diagram of process or equipment<br>Label all valves and identify all equipment for reference in procedure. |
| ☐ Laboratory Floor Plan<br>Identify the location of your experiment and all safety and spill response equipment. |
| ☐ Equipment Specifications<br>Include materials of construction, maximum temperature and pressure, standard operating values, and any other specifications important to the safe operation. |
| ☐ Material Safety Data Sheets (MSDS)<br>Include for all reactants, products and any intermediate or other chemicals which may occur. |

**Additional Attachments:** As necessary.

| | |
|---|---|
| ☐ | ☐ |
| ☐ | ☐ |

**Provide all the attachments shown, and list any additional attachments provided.**

# JSA – Page 3

**Chemical Information Page**

Fill in as much data below as available. If data are not available, leave the field blank.
List all chemicals, including reactants, products, intermediates, solvents, and any others used.

**Chemical Properties and Hazards**

| Chemical Name | Physical State S, L, G | NFPA Ratings* | | | | Incompatible Chemicals List chemicals present within the laboratory, and any others that may come in contact. | Flash Point Temp. | Flammability Limits | |
|---|---|---|---|---|---|---|---|---|---|
| | | H | F | S | Sp. | | | LFL | UFL |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

*NFPA Ratings: **H** – Health, **F** – Flammability, **S** – Stability, **Sp.** – Special

**List all chemicals (including reactants and products) used for this experiment / procedure, and additional information requested.**

# JSA – Page 3

**Chemical Toxicology, Regulation and Disposal:** List the same chemicals that appear above, in the same order.

| Chemical Name | Toxicology | | | Hazardous Waste Number# | Regulated? See Safety Manual | Personal Protective Equipment Specific to this Chemical |
|---|---|---|---|---|---|---|
| | TWA | PEL | Other | | | |
| | | | | | ☐ | |
| | | | | | ☐ | |
| | | | | | ☐ | |
| | | | | | ☐ | |
| | | | | | ☐ | |
| | | | | | ☐ | |
| | | | | | ☐ | |
| | | | | | ☐ | |

#See Chemical Engineering Hazardous Waste Manual.

**Provide information on the chemical toxicology, regulation and disposal. List personal protective equipment specific to this chemical.**

# JSA – Page 3

**Chemical Reactions:** Provide details below on any chemical reaction(s) that occur in your process. Please show the species involved, the stoichiometry and the heat of reaction, if available. Also list side reactions and any other reactions that may impact safety. You cannot type subscripts in the form field provided – use the names for the species and the stoichiometric coefficients.

**Provide information on the chemical reactions. Include the stoichiometric equation, heat of reaction, and any other information.**

# JSA – Page 4

Job Safety Assessment Form
Safe Operating Procedures Page

| Sequence of Steps | Potential Hazards | Procedure to Control Hazard | PPE or Equipment Required |
|---|---|---|---|
| Emergency Shutdown | | | |
| | | | |
| Start-up Procedure | | | |
| | | | |
| Run Time Procedure | | | |
| | | | |
| Shutdown Procedure | | | |
| | | | |
| Cleanup / Waste Disposal | | | |
| | | | |

**Need to be as detailed as possible. Refer to flow diagram of equipment and floor layout. Safety procedure should be as detailed as possible, not just "be safe" or "be careful".**

## JSA – Page 4

**Emergency Shutdown:**

**List a few things you can do prior to evacuating the laboratory.**

**Start-Up Procedure:**

**List the steps to get ready to operate the experiment.**

**Run Time Procedure:**

**Steps required to operate the experiment.**

**Shut-down Procedure:**

**Steps required to normally terminate the experiment.**

**Clean-up / Waste Disposal:**

**Steps required to clean the equipment and dispose of all chemical wastes.**

## JSA – Example

**Need to charge 10 ml of acetic anhydride into a test cell. Acetic anhydride is stored in the flammable storage cabinet in a 1-liter container.**

**First step → get MSDS sheet!**

# Acetic Anhydride MSDS

**OSHA PEL:** 5 PPM **OSHA PEL Code:** M
**OSHA STEL: OSHA STEL Code:**
**ACGIH TLV:** 5 PPM **ACGIH TLV Code:** M
**ACGIH STEL:** N/P **ACGIH STEL Code:**
**EPA Reporting Quantity:** 5000 LBS
**DOT Reporting Quantity:** 5000 LBS
**Ozone Depleting Chemical:** N

# Acetic Anhydride MSDS

**Health Hazards Acute & Chronic:** ACUTE:INHAL:IRRITATION OF NOSE & THROAT, SEVERE IRRITATION OF RESPIRATORY SYSTEM, COUGHING, DIFFICULT BREATHING, CHEST PAINS, PULMONARY EDEMA. SKIN/EYE CONTACT:BURNS. SKIN ABSORPTION:NONE IDENTIFIED. INGEST:SEVERE BURNS TO MOUTH, THROAT & STOMACH, NAUSEA, VOMITING, SHOCK. CHRONIC:NONE IDENTIFIED. (EFTS OF OVEREXP)

**Signs & Symptoms of Overexposure:**
HLTH HAZ:TARGET ORGANS:RESPIRATORY SYSTEM, LUNGS, EYES, SKIN.

**Medical Conditions Aggravated by Exposure:**
NONE IDENTIFIED.

# Acetic Anhydride MSDS

**Route of Entry Indicators:**
- **Inhalation:** YES
- **Skin:** YES
- **Ingestion:** YES

**Repiratory Protection:**
RESP PROT REQUIRED IF AIRBORNE CONC EXCEEDS TLV. AT CONCS UP TO 250 PPM, A NIOSH/MSHA APPRVD CHEM CARTRIDGE RESP W/ACID/ORGANIC CARTRIDGE IS REC. ABOVE THIS LEVEL, A NIOSH/MSHA APPRVD SCBA IS ADVISED.
**Ventilation:**
USE GENERAL OR LOCAL EXHAUST VENTILATION TO MEET TLV REQUIREMENTS. VENT HOOD.

# Acetic Anhydride MSDS

**Protective Gloves:**
NEOPRENE GLOVES.
**Eye Protection:** SAFETY GOGGLES & FACE SHIELD.
**Other Protective Equipment:** UNIFORM & PROTECTIVE SUIT ARE RECOMMENDED. LAB COAT & APRON.
**Work Hygenic Practices:** WASH THOROUGHLY AFTER HANDLING.

**Flash Point: Flash Point Text:** 118F,48C

**Autoignition Temperature:**
- **Autoignition Temperature Text:** N/A
- **Lower Limit(s):** 2.7%
- **Upper Limit(s):** 10.3%

## Conclusions from MSDS

1. **Perform all open bottle transfer operations in hood.**
2. **Wear Neoprene gloves for all operations.**
3. **Wear face shield and safety goggles.**
4. **Use lab coat.**
5. **Wash hands thoroughly after all transfers.**

## JSA Steps

| Step | Hazard | Safety Proc. | PPE |
|---|---|---|---|
| 1. Remove acetic anhydride from storage cabinet and place in tub on cart. | Spill | Tub to contain<br>Spill kit in lab<br>Safety Shower in lab | Face Shield<br>Neoprene Gloves<br>Lab Coat |
| | Fire and Explosion | Fire Extinguisher on wall near door.<br>Safety Shower in NE corner of lab. | |
| 2. Move cart to hood | " | " | " |
| 3. Move acetic anhydride from cart to tub in hood. | " | " | " |

# JSA Steps

| Step | Hazard | Safety Proc. | PPE |
|---|---|---|---|
| 4. Remove cap from bottle and pour 10 ml into measuring flask. | | | |
| | " | " | " |
| 5. Pour into test cell. | " | " | " |
| 6. Place cap on bottle, return to cart, transport to storage cabinet. | | | |

# Biosafety

## Considers infectious exposures

# What is Biosafety?

- **Principles and practices employed to protect laboratory personnel and the environment from exposure or infection while working with living organisms, biological materials, or agents.**
  - **Included are any materials that may be potentially infectious.**
  - **Includes recombinant DNA research**

## Laboratory Acquired Infections (LAI)

**Bacterial:** 76% from clinical labs, 8% from research labs

**Exposure:** 60% acquired from inhalation

Other exposures include:
digestion,
inoculation (i.e. sharps),
splashes,
direct and indirect contact

What not to do! →

## Biological Risk

Need to Understand:

- the biology of the agent
- susceptibility and transmission within the host
- hazards associated with equipment and procedures
- Goal:
  - *Provide the highest practical protection and the lowest practical exposure*

## World Health Organization - WHO

### Assigned Risk Groups for Biological Agents

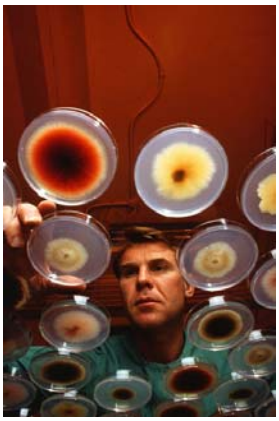
- RG-1 Unlikely to cause disease in humans or animals
  - low individual or community risk
- RG-2 May cause disease but typically not serious
  - individual risk, low community risk, treatable
- RG-3 May cause serious disease, usually treatable
  - High individual but low community risk, serious respiratory agents
- RG-4 Serious or fatal, often not treatable,
  - Easy transmission, high individual and community risk

## Biosafety Levels (BSL)

- Different concept than the Risk Groups!
  - Risk groups used in risk assessment
  - BSL's are used in risk management
- BSL are ways to control the agent
  - facilities, safety equipment, practices, PPE, etc.
- Once risk is assessed then the appropriate BSL is determined

  RG1 → BSL 1 but does not always correspond directly!

# BioSafety Level 1



- **RG1: Well characterized, non-pathogenic organisms or agents**
- **Open bench- no containment**
- **Use good laboratory practices, waste disposal, and aseptic techniques**
- **Example: E. coli**

## *Biosafety Level 1*

Facility Design (Secondary Barrier)

**Requirements:**

- *Laboratories have doors*
- *Sink for hand washing*
- *Work surfaces easily cleaned*
- *Bench tops are impervious to water*
- *Sturdy furniture*
- *Windows fitted with flyscreens*

## Biosafety Level 1

Standard Microbiological Practices

- Minimize splashes and aerosols
- Decontaminate work surfaces daily
- Decontaminate wastes
- Maintain insect & rodent control program

## Biosafety Level 1

Safety Equipment (Primary Barriers)

Protective clothing

- *Lab coat*
- *Gloves*

# BioSafety Level 2

- RG2: Agents of moderate hazard to personnel or environment
- Basic lab, but restricted access, containment during certain processes (i.e. aerosols, large volumes, etc.)
- Autoclave and Biological Safety Cabinet desired
- Use good laboratory practices, waste disposal, and aseptic techniques
- Example: most non-respiratory, non lethal, agents

## *Biosafety Level 2*

### Safety Equipment (Primary Barriers)

**In addition to BSL-1:**

- *Use biosafety cabinets (class II) for work with infectious agents involving:*
  - Aerosols and splashes
  - Large volumes
  - High concentrations

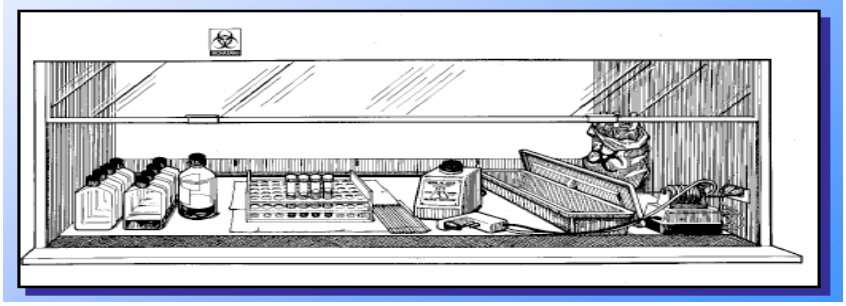
2.4

# BioSafety Level 2 Equipment

## Class II Biosafety Cabinet

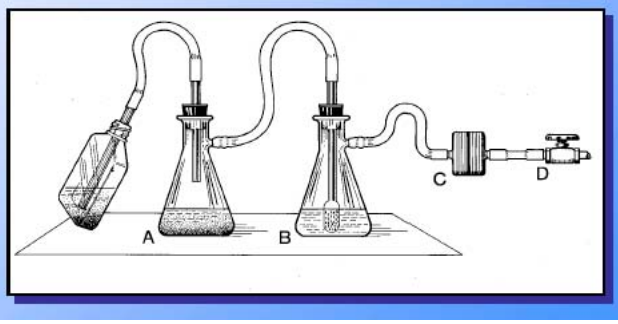
- *Equipment layout*



http://www.cdc.gov/od/ohs/pdffiles/ Module%202%20-%20Biosafety.pdf

# BioSafety Level 2 Equipment

- *Vacuum lines protected with liquid disinfectant traps or HEPA filters*



# BioSafety Level 3

**FORGET ABOUT IT AT MTU!**

- **RG3: Agents of high hazard to personnel or environment**
- **Respiratory exotic or indigenous agents which are easily transmissible causing serious or lethal disease**
- **All work is contained, engineering controls and controlled environments we currently do not have the facilities to handle.**

**Example: Mycobacterium tuberculosis, SARS, etc.**

# BioSafety Level 4

**FORGET ABOUT IT!!!**

- **RG4: Hemorrhagic fever, deadly viruses, etc.**
- **Total containment, airtight labs, "submarine" doors, air pumps, water treatment, HEPA filtration, etc.**
- **Positive pressure "moonsuits"**