



Chemical Safety and Security Officer Training

UAE

September 2011



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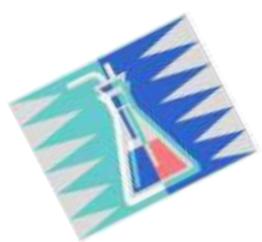
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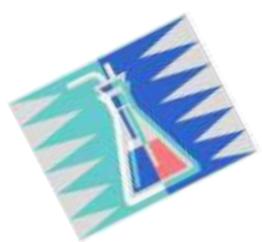
Virtual Exercise – Chemical Dual Use

Hazardous Chemical Properties



Physical property - Boiling point

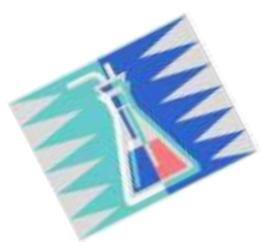
- The ***boiling point*** of a liquid is the temperature at which the vapor pressure of the liquid equals the environmental pressure surrounding the liquid
 - *The temperature at which a liquid transitions into a gas*
 - It is not always necessary to “heat” a substance to initiate boiling
 - Sarin: BP = 158 °C
 - Phosgene (COCl₂): BP = 8.3 °C
 - Water: BP = 100 °C
- What does the boiling point tell us about a chemical?



Vapor pressure and vapor density

- ***Vapor pressure*** is the pressure of a vapor in equilibrium with its non-vapor phases.
 - The equilibrium vapor pressure is an indication of a liquid's evaporation rate or volatility
 - Higher pressure = more likely to explode
 - Higher vapor pressure = lower boiling point
- ***Vapor density*** is the density of a vapor in relation to that of air at a given temperature and pressure

Property	Chlorine (Cl ₂)	Phosgene	HCN	Sarin (GB)
Vapor Pressure (mm Hg at 20 °C)	4,800	1,215	620	2.1
Vapor Density	2.5	3.48	0.94	4.86

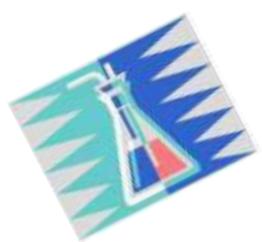


Chemical property – Flash point

- The ***flash point*** of a flammable liquid is the lowest temperature at which it can form an ignitable mixture in air
- At this temperature the vapor still requires an ignition source
- Related to vapor pressure

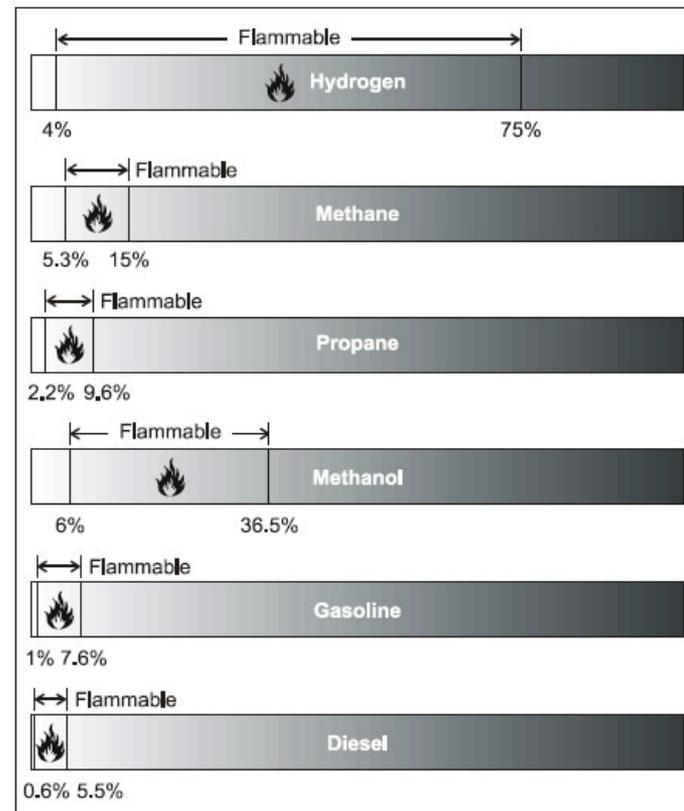
Property	HCN	Phosgene
Flash Point (°C)	-17.78	N/A

Why is flash point important?



Chemical property – Combustion

- **Combustion** or **burning** is a complex sequence of exothermic chemical reactions between a fuel and an oxidant accompanied by the production of heat or both heat and light in the form of either a glow or flames
 - The *flammable range* (explosive range) is the range of a concentration of a gas or vapor that will *burn* (or explode) if an ignition source is introduced

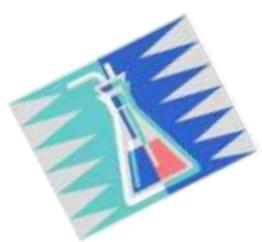


Flammability Range (www.micro-vett.it)



Chemical reaction properties – Air reactive

- A ***pyrophoric*** substance will ignite spontaneously when exposed to air
 - Its autoignition temperature is below room temperature
 - Must be stored in anaerobic (no oxygen) conditions
 - Finely divided metals (calcium, zirconium)
 - Alkali metals (sodium, potassium)
 - Metal hydrides or nonmetal hydrides (germane, diborane, sodium hydride, lithium aluminum hydride)
 - Phosphorus (white)
- **Pyrophoric substances are dangerous**
 - December 2008 – UCLA graduate student dies from severe burns resulting from spill of *tert*-butyllithium, a common laboratory chemical and pyrophore, onto her person.



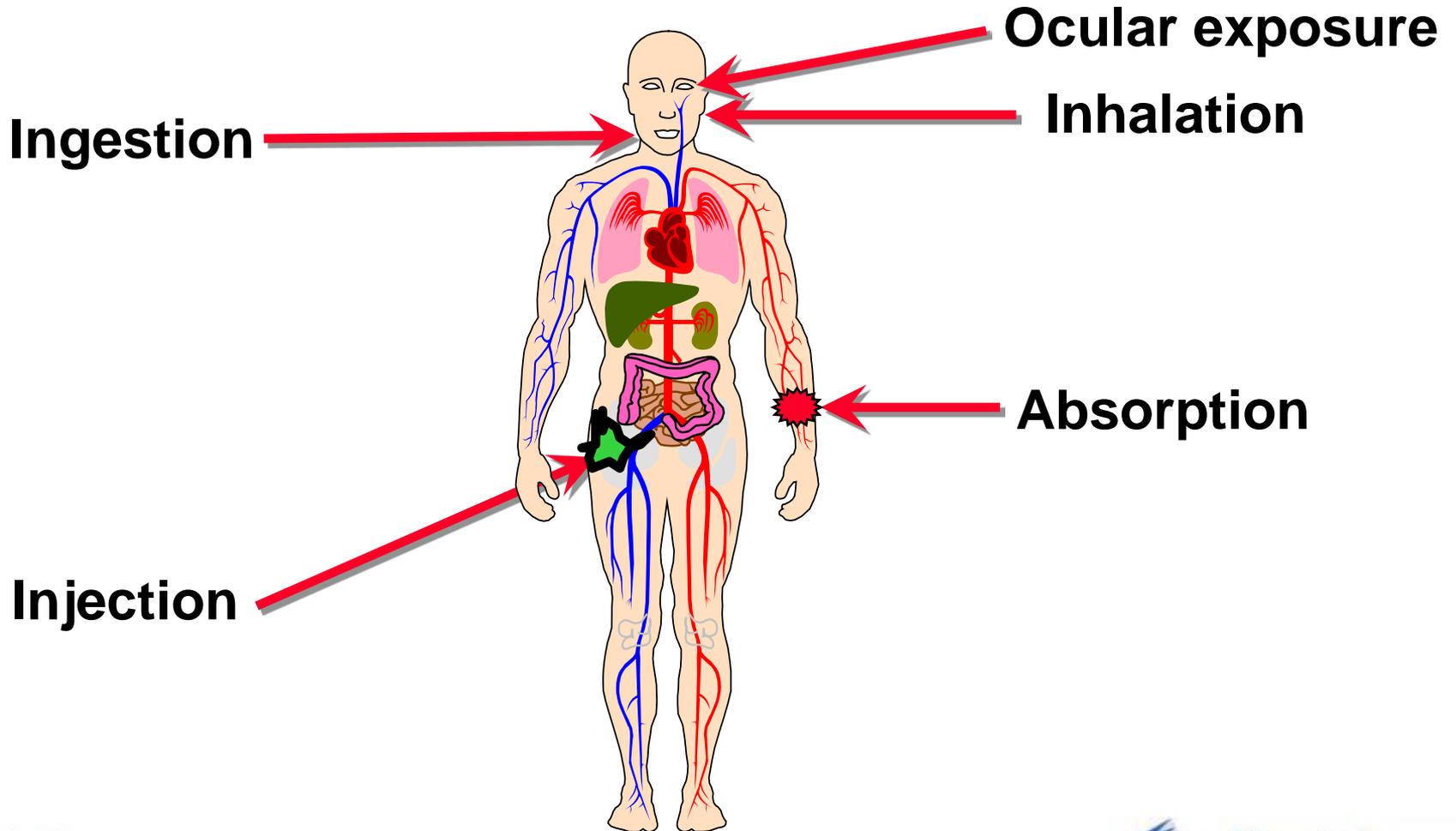
Chemical characteristics for risk assessment

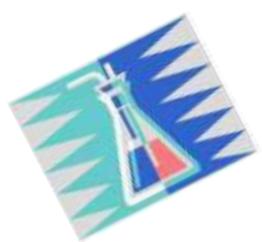
- **Volatility**
- **Persistence**
- **Vapor density**
- **Odor**
- **General Signs and/or Symptoms**
- **Routes of entry**
- **Toxicity**





Chemical hazards - routes of entry





Nerve agents and blister agents are particularly toxic

Nerve agents:

- Tabun (GA), Sarin (GB), Soman (GD), Cyclosarin (GF), Methylphosphonothiolate (VX)
- Routes of entry: Inhalation, Absorption

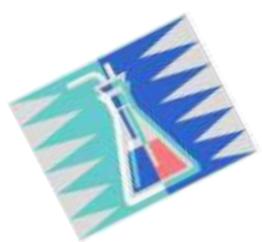
Blister agents (vesicants)

- Sulphur Mustard (HD), Nitrogen Mustard (HN), Lewisite (L), Phosgene Oxime (CX)
- Routes of entry: Inhalation, ingestion or absorption

Nerve and Blister agents

- Vapor density: Heavier than air
- Volatility: Volatile to semivolatile
- Persistent: Some more so
- Dissemination: Liquid
- Availability: Not commercially available





Many industrial chemicals have high toxicity

Choking chemicals –Phosgene, Chlorine (Cl₂)

- Vapor density: Heavier than air
- Dissemination: Liquid or gas
- Legitimate Uses- Plastics, water treatment, paper, paper production
- Routes of entry: Inhalation

Blood active chemicals - Hydrogen cyanide, Cyanogen chloride

- Vapor density: Same as or heavier than air
- Dissemination: Liquid or gas
- Legitimate Uses- Plastics, mining, photography industry
- Routes of entry: Inhalation

Both choking and blood active chemicals

- Volatility: High
- Non-persistent
- Availability: **Commercially available**

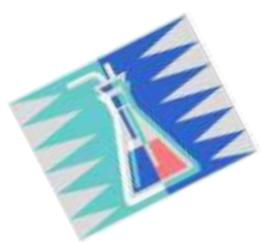


Source: EPA



Source: Wikipedia

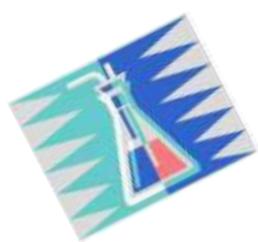




Toxicology of chemical poisons

Important Concepts:

- **LD₅₀** – amount required to kill half of exposed population, usually expressed in grams/individual.
- **LC_{t50}** – can be an inhalation or percutaneous (through skin), the vapor or aerosol dose required to kill half exposed population. Expressed in milligram*minute/m³ or in ppm for given time.
- **AEGL** – Acute Exposure Guideline Levels (airborne conc.)
 - 1: notable discomfort, not disabling, reversible
 - 2: irreversible or serious health effects, impairment
 - 3: life-threatening health effects



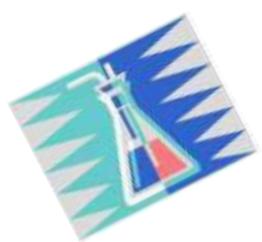
Example : comparison of selected chemical agents

Code	Agent	Volatility (mg/m ³ at 25 °C)	Vapor Density (air = 1.0)	LC ₅₀ (mg min/m ³)	LD ₅₀ (mg/kg)
AC	HCN	1,000,000	0.94-0.99	2500-5000	100-200 (cyanide salts)
CG	Phosgene	- (gas)	3.4-3.5	3200	-
CL	Chlorine	- (gas)	2.5	6000	-
HD	Sulfur mustard	610 (20 °C)	5.4	1500	100
L	Lewisite	4480 (20 °C)	7.1	1200-1500	40-50
GB	Sarin	22,000	4.86	100	24
GD	Soman	3,900	6.3	50	5
GA	Tabun	610	5.6	400	14
VX	VX	10	9.2	10	0.14





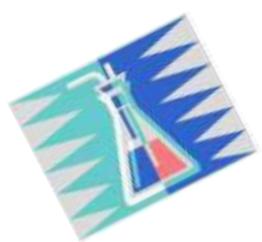
Theft and Diversion



How are chemicals acquired?

- **Access to unprotected facilities**
 - Warehouses
 - Plant storage facilities
 - Analytical laboratories
 - Waste storage/disposal
 - Construction sites
- **No controls or security checks on procurement**
 - Chemical supply companies
 - Shipping & receiving
- **Recruit young chemists**
 - Synthesize chemicals into weapons





Graduate student methamphetamine

Rather than synthesize methamphetamine from the decongestant pseudoephedrine, the starting material popular since the 1980s, he allegedly used phenyl-2-propanone (P2P). The P2P method was common in the 1970s. Historically, meth cooks using the P2P method typically produced relatively impure methamphetamine, but the student was able to produce more than 95% pure drug, a quality similar to that prepared from pseudoephedrine. P2P is regulated by the [Drug Enforcement Administration](#) (DEA)

Before starting graduate studies, the student was convicted of making methamphetamine in his home, using materials stolen from vineyards . Authorities continue to investigating the students actions and plans to review inventory controls and other procedures.

Terrorist group recruits science/engineering students

Tuesday, August 10, 2010 Jakarta Globe

Fighting Back: Roundup of 5 in Bandung exposes plan to target capital Aceh Anti-Terror Sweep Rolls on

Armando Sahaan

The arrest of five terror suspects in West Java at the weekend brought to 102 the number arrested in relation to the Aceh militant network and police are seeking more fugitives, including a French national.

"Of those arrested, 66 are still in custody, while the others have been released," National Police spokesman Insp. Gen. Rdwardi Arifonang said on Monday, adding that all would eventually be tried in Jakarta.

The suspected terrorists are linked to militant groups in the Middle East and the southern Philippines. Police allege they were training for terrorist-style assaults on key government and Western interest targets.

On Saturday, the Denas 88 counterterrorist squad arrested five people believed to be from the Aceh group in four raids in West Java. The raids also unearthed a makeshift laboratory where police claimed the suspects were developing high-powered explosives.

In Cibiru, Bandung, Denas 88 arrested Yakulroti Tanjung, a.k.a. Bayu, and Harnadi, a.k.a. Helmi. In this raid they also seized a car they alleged was being prepared for a bomb attack and uncovered the bomb lab.

Police say the car was listed as belonging to a French national, whose name is not disclosed.

"We're still looking for the person who bought this car and gave it to the group," Edward said. "It's a French national, married to a Moroccan woman." Police were working with Interpol for more information on his background and travel associates.

On the same day in Subang, West Java, Denas 88 arrested a suspect identified as Gopar and



A policeman showing a photo of one of the five terror suspects arrested in Bandung at the weekend. Police believe Kurnia Widodo is a bomb maker. JG Photo/Arifati Hierra

seized 34 cans of 38-caliber ammunition and several tons of chemical compounds.

In a raid in Padalarang, Bandung, the squad arrested Kurnia Widodo, a.k.a. Ujang, a recent university graduate who majored in industrial engineering. "We believe Kurnia was the technician at the bomb lab," Edward said.

The first arrest on Saturday was that of a cleric named Kili

During this raid, Denas 88 confiscated chemical compounds used to make explosives, books on jihad and sketches of targeted buildings.

Edward said the targets included the police Mobile Brigade headquarters in Depok, West Java, as well as the National Police Headquarters, international hotels and embassies in Jakarta.

He said Saturday arrests were

made in anticipation of an attack on President Susilo Bambang Yudhoyono during his visit to the area over the weekend, but said there was no evidence the suspects were planning an attack.

Yudhoyono declined on Saturday to elaborate on his weekend. West Java was planning to attack him, "I received a security report that some certain elements with bad intentions were lurking

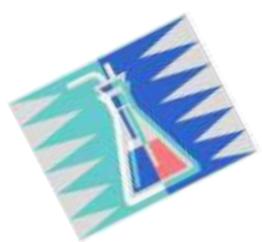
in the Cirebon area to do something against me," he said. Edward said the president was one of the targets of the Aceh group.

Police launched their campaign against the Aceh group after they uncovered a meeting in West Java in February, prompting a nationwide manhunt. A flurry of arrests followed,

stretching from Aceh to Java (Island).

Sidney Jones, from the International Crisis Group, said police were not fighting just one group, but a network of allies. "The network we saw in Aceh was an alliance of several different groups, which are now dispersed," she said. Each group could potentially form new alliances.

...the squad arrested Kurnia Widodo, a.k.a. Ujang, a recent university graduate who majored in chemical engineering. "We believe Kurnia was the technician at the bomb lab," ...



Group discussion

- **What chemicals are of most concern for diversion?**
 - **Common laboratory/industrial chemicals that would be targeted by someone for illegal reasons such as making explosives, illegal drugs, or chemical weapons.**



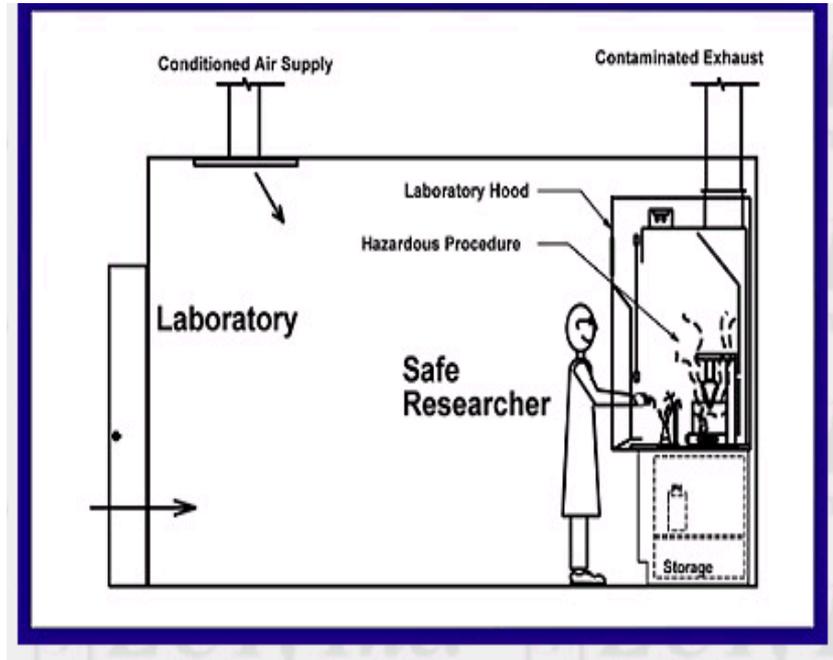
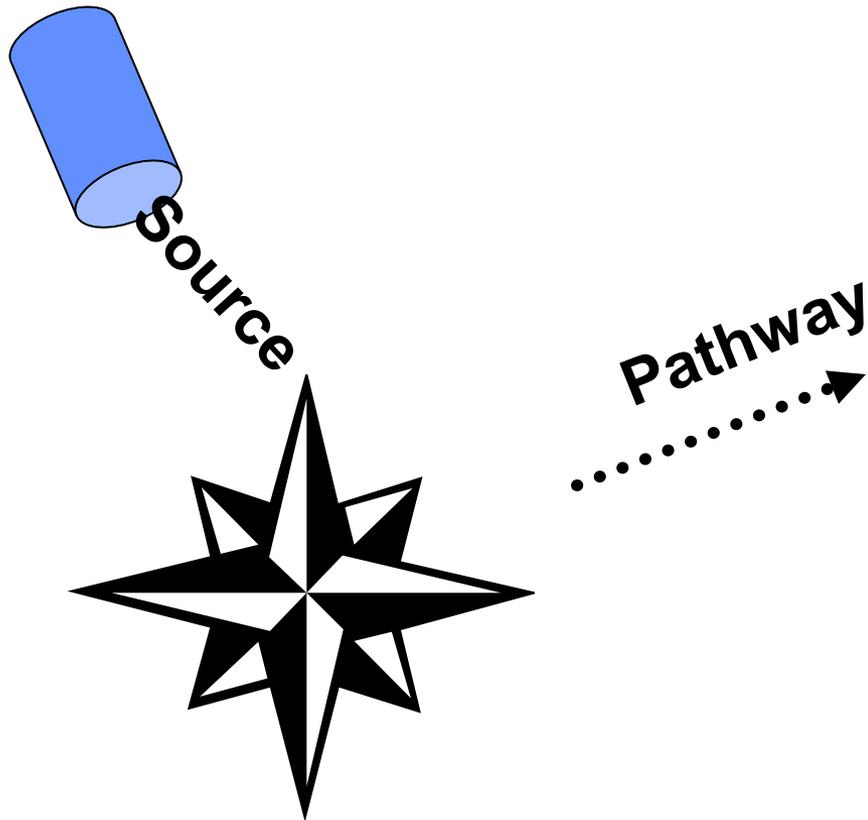


Principles and Concepts of Laboratory Ventilation



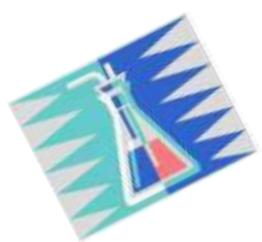


Ventilation



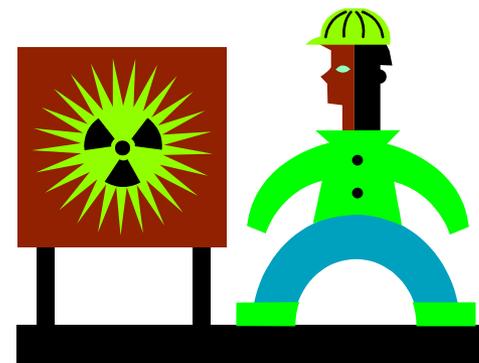
**Safe
Worker**

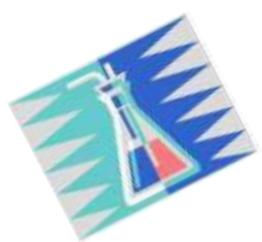
Illustration courtesy, Tom Smith, ECT Technologies, Cary NC USA



Engineering Controls

- **Change the process**
 - Eliminate the hazard
- **Substitution**
 - Non-hazardous substance for hazardous
 - Trichloroethylene for carbon tetrachloride
 - Toluene for benzene
- **Isolate or enclose**
 - Process or worker
 - Barrier
- **Ventilation**
 - Dilution (general ventilation - not good)
 - Local Exhaust Ventilation (LEV)





Definitions

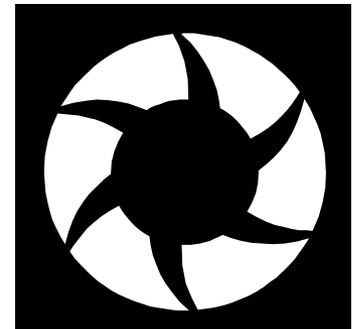
- **Hood** – includes any suction device, regardless of shape, that encloses, captures or removes contaminants.
- **Dilution Ventilation** – moves room air around by a fan that is sometimes exhausted to the outside.
- **Local Ventilation (LEV)** – ventilation system that captures and removes emitted contaminants.

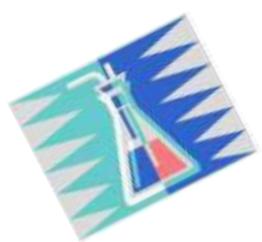


Uses of Ventilation

- **Keep gas / vapor concentration below OEL**
- **Air movement to reduce heat stress**
- **Keep toxic contaminants below OEL**
- **Confined space entry**
- **Limit CO₂ buildup**
- **Control clean room or hospital environments**

OEL = Occupational Exposure Limit



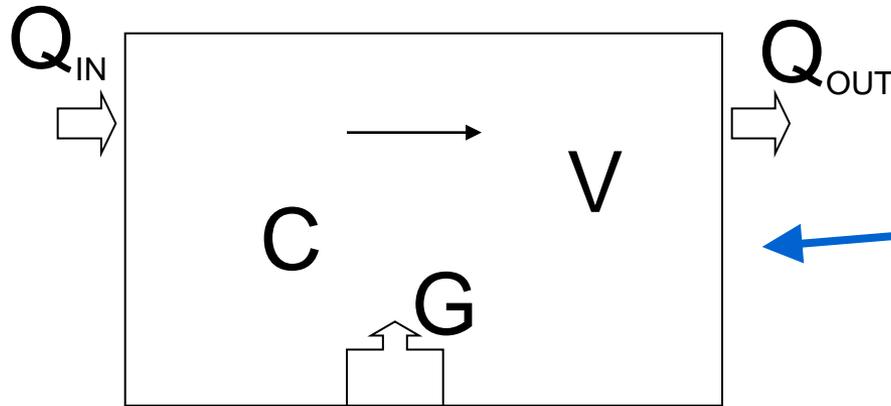


Limitations of Ventilation

- **May require large amounts of air (expensive)**
- **Outdoor air may create problems**
 - Need tempering
 - Heat, cool, dehumidify, humidify
 - May be “contaminated”
- **System design**
 - Remove contaminate from breathing zone
 - Insufficient air velocity or volume
- **Contaminant cleanup or discharge**
- **Users need training**



Engineering Controls



**Dilution (general)
ventilation**

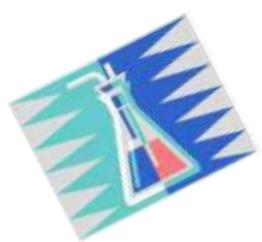
not good

**Local exhaust
ventilation**

preferred

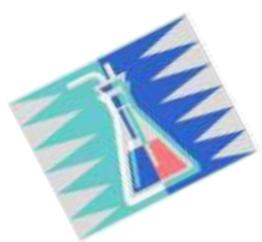


Q = flux, C = contaminant conc.
V = velocity, G = generation rate



Use Local Exhaust Ventilation (LEV)

- To enclose and contain
- When contaminant is toxic
- Employee works near the contamination
- When complete containment/enclosure is not feasible



LEV Principles

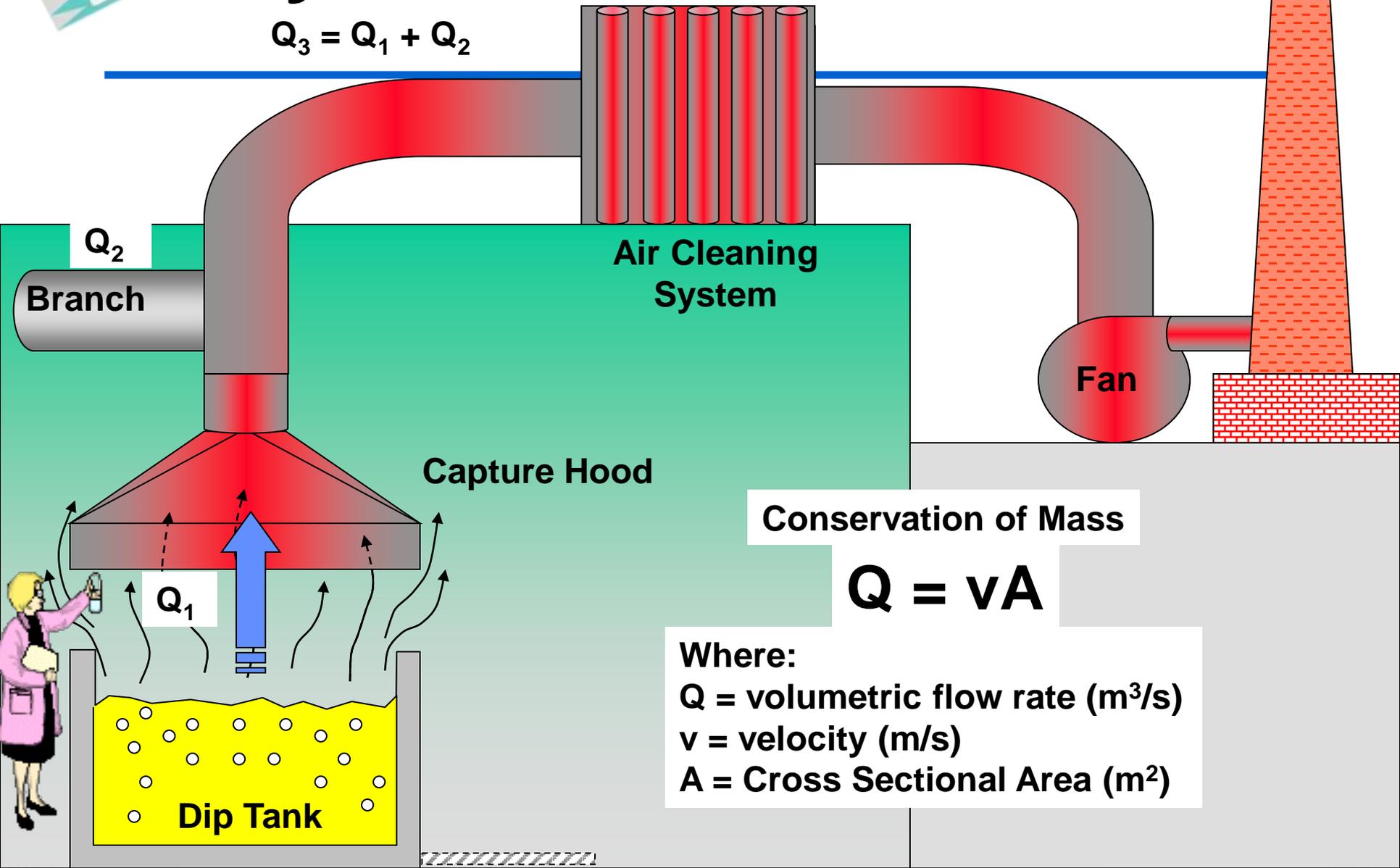
- **Enclose source**
- **Capture contaminant near source**
- **Keep contaminant out of breathing zone**
- **Provide adequate make-up air**
- **Discharge away from air intake**





System Characteristics

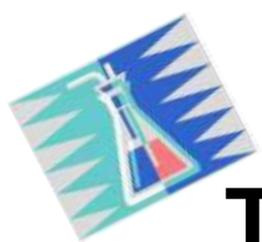
$$Q_3 = Q_1 + Q_2$$



Conservation of Mass

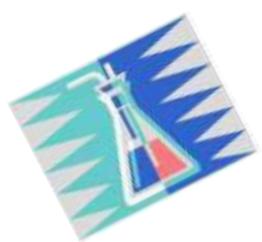
$$Q = vA$$

Where:
Q = volumetric flow rate (m³/s)
v = velocity (m/s)
A = Cross Sectional Area (m²)



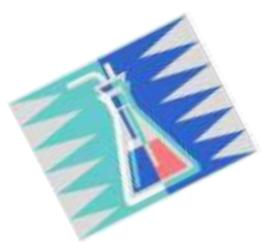
Traditional Laboratory Chemical Hood





Special Purpose Hoods Vented to the Outside

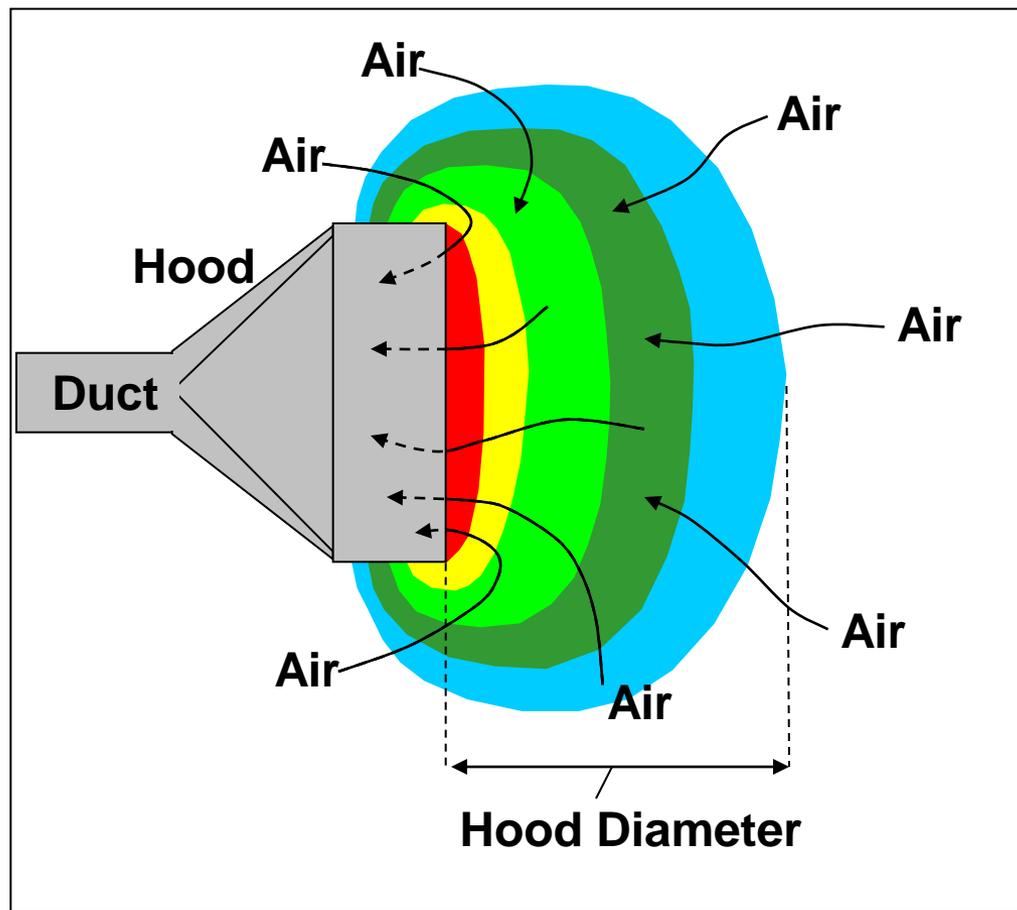


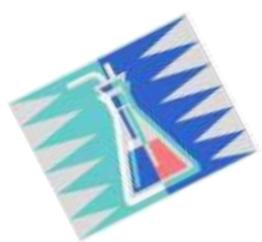


Hood Capture Velocities

Equal Velocity Zones

% Hood Capture Velocity	
	~100%
	~60%
	~30%
	~15%
	~7.5%





Hood Exhaust

- **Height**
- **Discharge velocity**
- **Configuration**



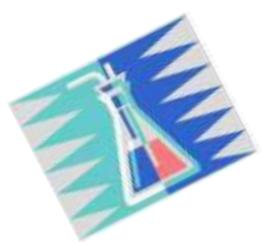


Engineering Controls: Avoid Exhaust Recirculation

Hood
Exhaust

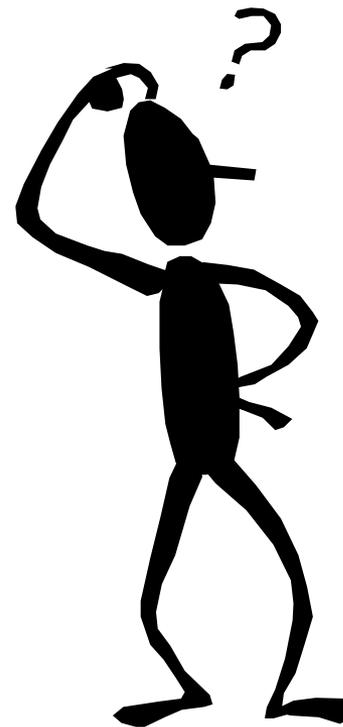


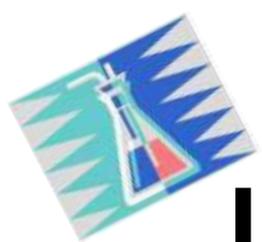
Air Intake



Potential Issues

- Insufficient air volume
- Too much air flow
- Wrong location
- Wrong configuration
- Bad hood design
- Duct velocity too low
- Insufficient make up air
- Clogged system
- Noise

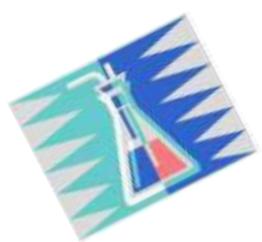




Laboratory Chemical Hoods:

How they work & when they don't.



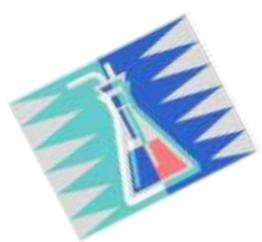


Laboratory Hoods

Laboratory hoods and ventilation are the basis of engineering controls.

But they must be properly: *selected, located, used, and maintained.*



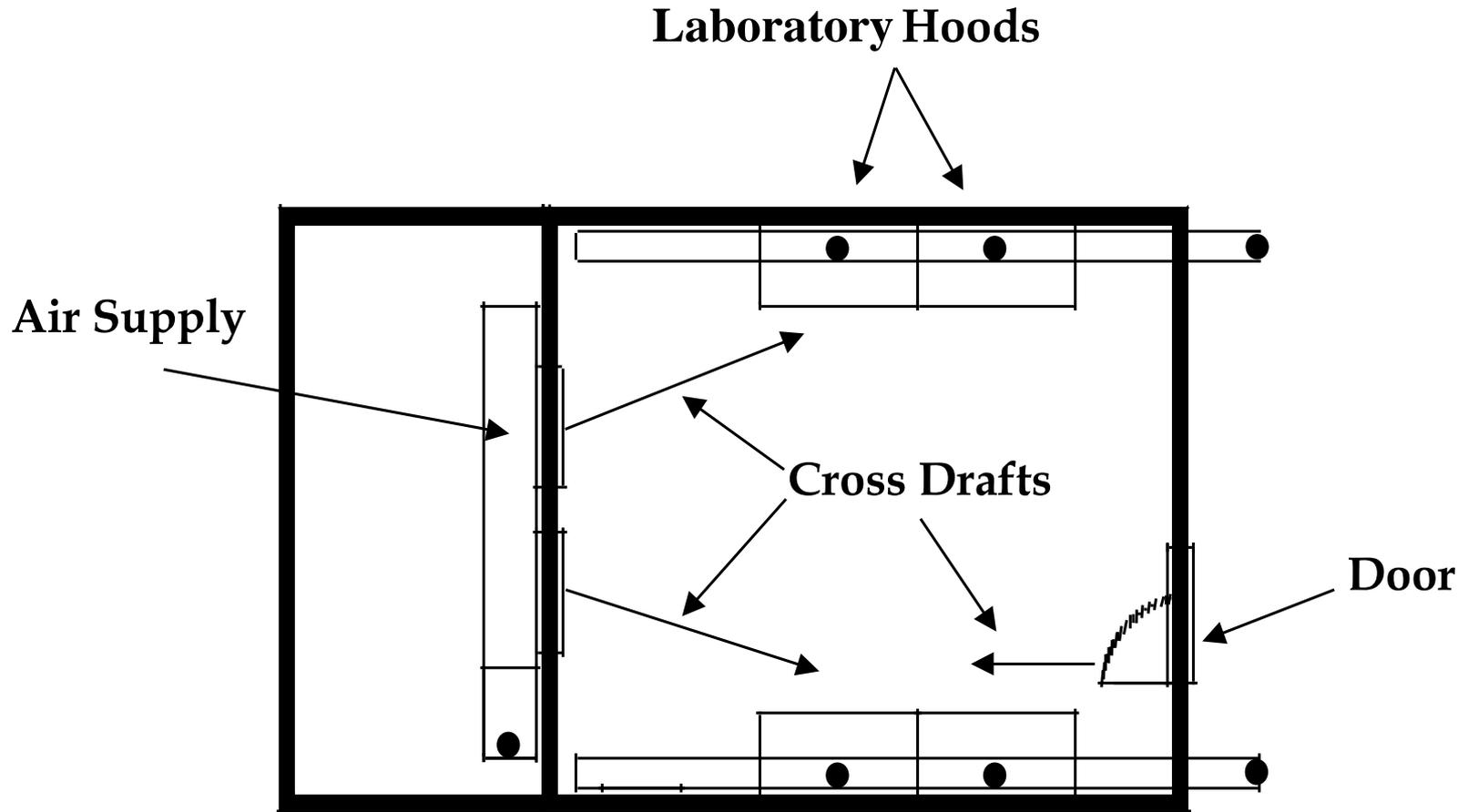


Hood Location Requirements

- **As near to contamination source as possible**
- **So contamination moves away from operator**
- **Minimize cross-drafts**
- **Don't place near windows and doors**
- **Don't place near air conditioning/heater diffuser**
- **Doesn't interfere with other workers**
- **Locate out of traffic flow**
- **Place near rear of laboratory**

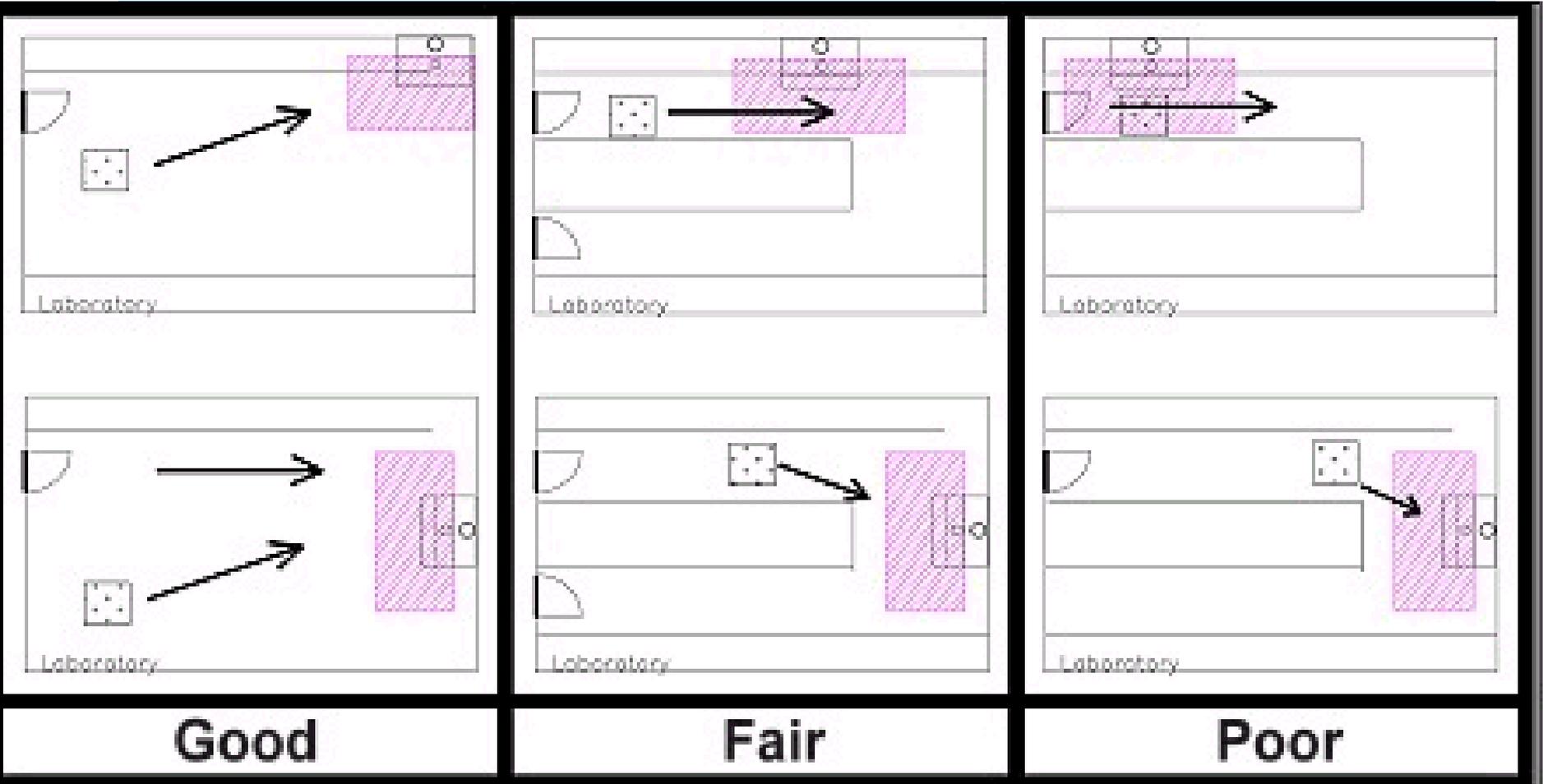


Problem Cross-drafts

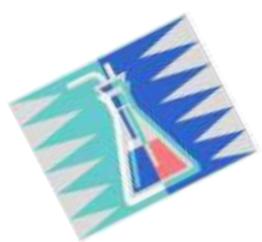




A person walking at 2-3 mph (0.9-1.3 m/s) generates cross drafts of 250 fpm (1.3 m/s) that can interfere with hood capture

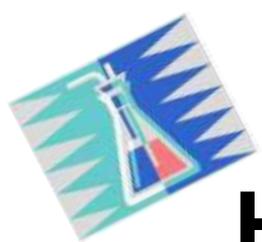


Air current or draft caused by door, traffic, air diffuser or other source.



Principles of Hood Design and Operation

- **Enclose as much of the operation as possible**
- **Place utility controls (gas, electric) outside or as near hood front as possible**
- **Hood lights should be vapor tight**
- **Mount hood motor *outside building and away from building air intakes***
- **Don't use hoods for uses not intended (e.g., perchloric acid digestion, radioisotopes)**
- **Ensure duct material compatible with exhausts**
- **Don't use without indication it is working properly**



Hood Design & Operation, cont'd.

- Don't put your head in the hood.
- Use proper PPE (gloves, eyewear, etc)
- Place large equipment above surface on 5 cm blocks to allow uniform air flow
- Lower sash height to 30 - 50 cm during operation
- Keep sash fully closed when not in use
- Use liner or tray inside hood to contain spills





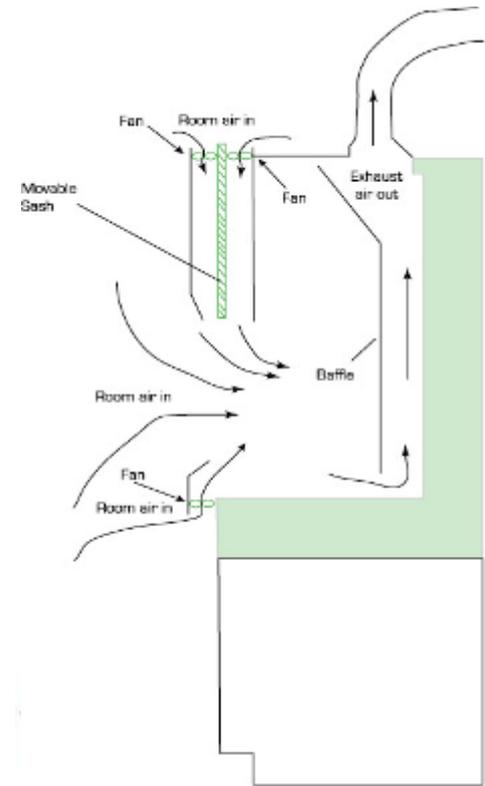
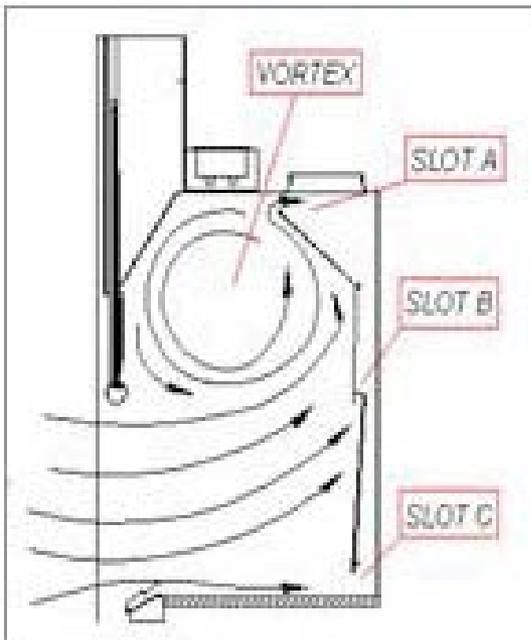
Hood Design & Operation, cont'd.

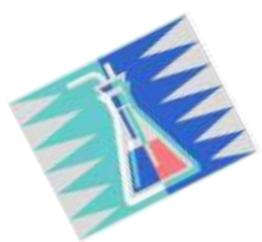
- **Work in the center of hood and 15 cm in from hood sash.**
- **Don't store chemicals or equipment in hood.**
- **Don't block baffles (slots).**
- **Maintain hood regularly (check fan belt, lubricate motor).**
- **Regularly evaluate hood (flow rate, mark operating sash height).**
- **Reports problems, concerns, malfunctions immediately.**



Traditional Constant Volume Hood

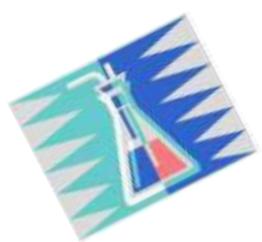
- All make up air enters through hood face.
- Air exhausted is constant regardless of size of face opening or sash height.
- Volume of air movement is constant but velocity varies with sash height.





Specialized Hoods

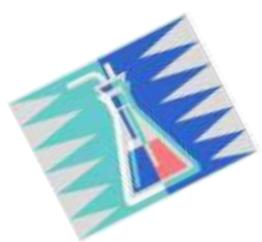
- **Perchloric acid (with water wash down)**
- **Radiological (with special filters)**
- **Floor level (improperly called walk-in)**
- **Distillation/California hoods (~1.5 ft or 0.5m above floor)**
- **Canopy hoods (not suitable for most lab operations)**
- **Slot hoods**
- **Ductless fume hoods**
- **Vented enclosures or special purpose hoods**
- **Glove Boxes (complete enclosure)**
- **Biological Safety Cabinets (BSC)**



Ventilation System Evaluation

- Smoke sources
 - Visualize air movement
 - Assess capture effectiveness
- Smoke tubes
- Smoke candles
- Theatrical smoke generators
- Incense sticks

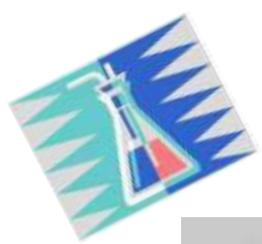




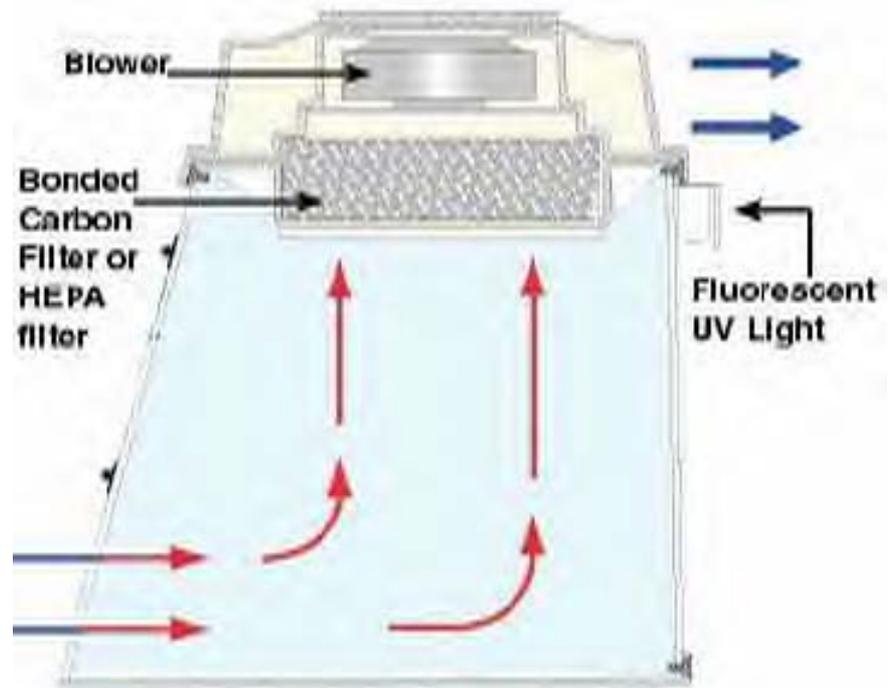
Ventilation System Evaluation

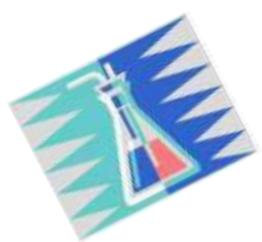
- Velocity measurements
 - Anemometers (m/s)
 - Directional
 - Hot-wire anemometer (m/s)
 - Non-directional





Ductless Hoods

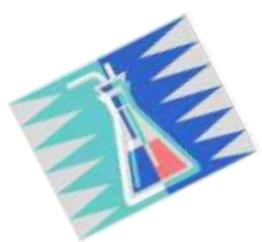




Ductless Hoods

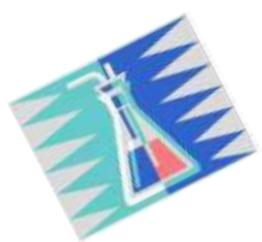
Should only be used in laboratories with:

- Small quantities of known non-volatile substances.
- Only with HEPA filters
- Never with volatile substances
- Unless breakthrough time for the specific chemical being used is known, carbon filters are unreliable.

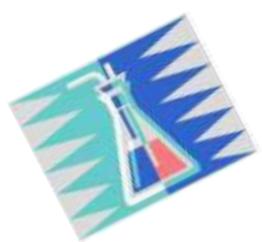


Conclusions

- **Ensuring laboratory hood safety depends on many factors including:**
 - Hood design
 - Hood use
 - Lab design
 - System operation



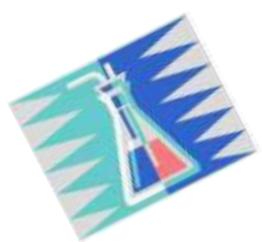
Fire Protection and Prevention in Chemical Laboratories



Fires

- **Preventable**
- **Caused by unsafe practices**
 - **Electrical safety violations**
 - **Uncontrolled use of flammable and combustible materials**
- **Control**
 - **Inspect, inspect, inspect**
Educate, educate, educate!



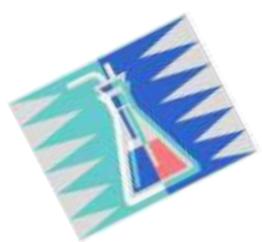


Home Fires

1 million fires and 8,000 deaths annually in the US



Leading causes:
Cigarettes
Heating/cooling equipment
Electrical
Matches, lighters, candles



Key Elements of Fire Safety

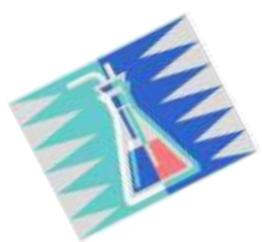


Get occupants out
Minimize property loss and interruption
Fire Containment/Suppression



It's the Smoke...

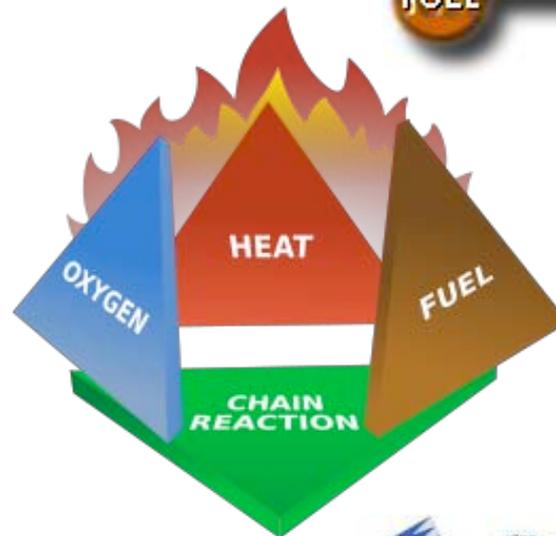


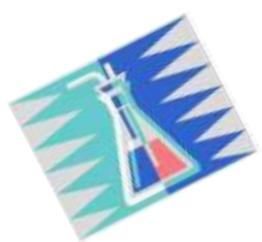


Fire

• A fire must have four things to ignite and maintain combustion:

- Fuel
- Heat
- Oxygen
- Chain reaction





Flash Point

- **Flash point:**

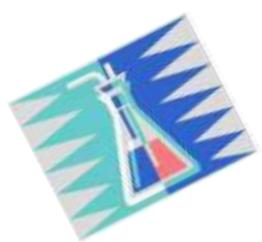
- The minimum temperature at which a liquid gives off enough vapor to form an ignitable mixture.
- In general, **the lower the flash point, the greater the hazard.**

- **Flammable liquids:**

- have flash points below 38°C
- are more dangerous than combustible liquids
- may be ignited at room temperature

- **Combustible liquids:**

- have flash points at or above 38°C
- Can pose serious fire and/or explosion hazards when heated



Flammability/Explosive Limits

Above UFL/UEL, mixture is too rich to burn

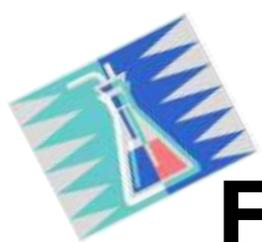
Upper Flammability/Explosive Limit (UFL/UEL)



Flammability/Explosive Range

Lower Flammability/ Explosive Limit (LFL/LEL)

Below LFL/LEL, mixture is too lean to burn

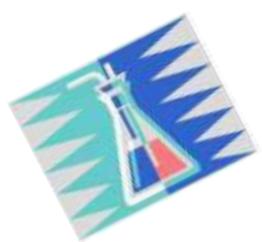


Fire Safety Program Components

A good plan for safe use of flammable and combustible liquids contains at least these components:

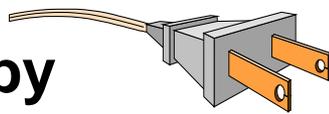
- **Control of ignition sources**
- **Proper storage**
- **Fire control**
- **Safe handling**

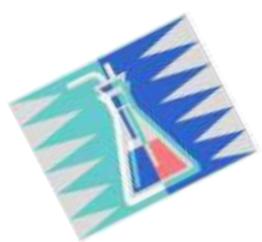
OSHA Office of Training and Education



Classification of Fires

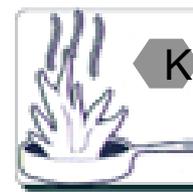
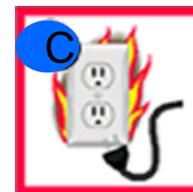
With recommended extinguisher distances

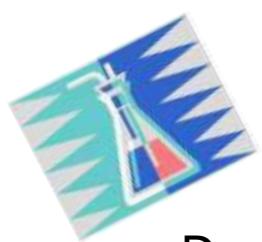
- **A** Ordinary combustibles – cloth, paper, wood, coal ~23 m 
- **B** Flammable/combustible liquids, gases, greases and oils - gasoline, diesel fuel ~15 m 
- **C** Energized Electrical equipment cables, motors nearby 
- **D** Combustible metals - sodium, magnesium, titanium ~23 m 
- **K** Restaurant grease fires associated with cooking nearby 



Classification of Fires

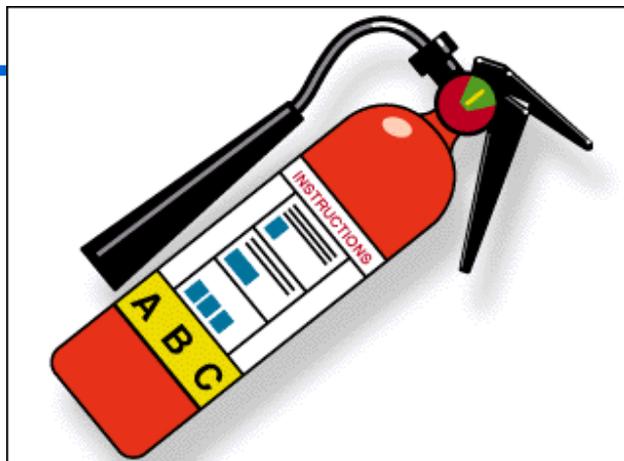
- **A** Extinguish by cooling or smothering.
(water)
- **B** Extinguish by inhibiting release of combustible vapors or interfering with the chemical reaction-release of OH radicals.
(CO₂ or dry powder: monoammonium phosphate)
- **C** Extinguishing agent must ***not*** be conductive.
(CO₂ or dry powder)
- **D** Extinguishing agents must absorb heat and not react with the metal.
(special dry powder, sand)
- **K** (Special liquid chemicals)





Fire Extinguishers

Dry Chemical



Placed within ~15-25 m

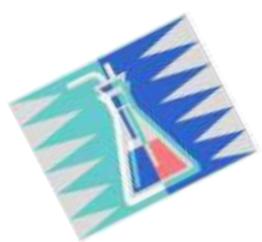
Water



Annual & Monthly inspections

CO₂

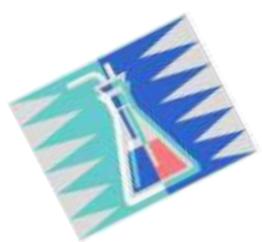




Fire Alarm Systems

- **Will it be recognized and followed?**
 - Audible, visual, public address systems...
- **What about deaf or blind employees?**
 - Are there “dead spaces”...
- **System reliability**
 - System failure may not be obvious
 - Supervised systems (built-in monitoring)
 - Testing, maintenance and backup systems





Fire Detection & Alarms

- **Thermal**

- **Heat**

- Fixed temp
- Rate of rise
 - ~6 to 8 C/min (12 to 15°F/min)



Issues:

Testing

Dust, corrosion, hot processes, weather, mechanical damage



- **Smoke**

- Photoelectric
 - IR from smoke
- Ionization
 - Ionize smoke

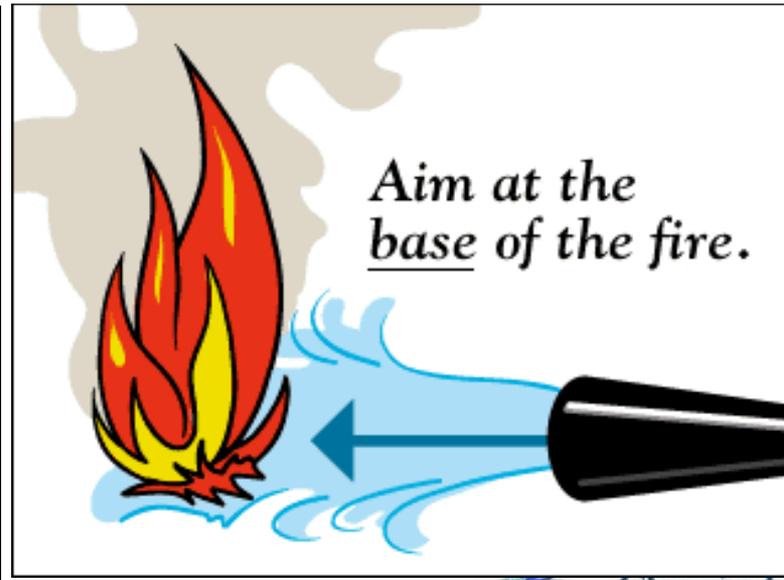
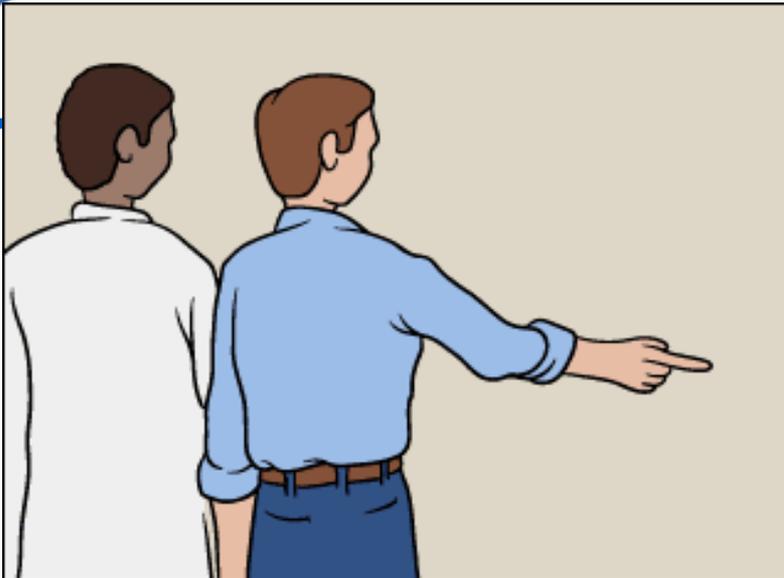
- **Flame Detectors**

- Flames – IR or UV

- **Gas Sensors**



Responding To A Fire





Employee Training

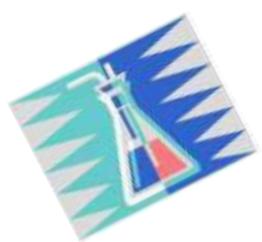


Few employees know how to *effectively* use extinguishers!

Need for training:

- Upon initial employment
- Annual refresher

Emergency Response (phone numbers)



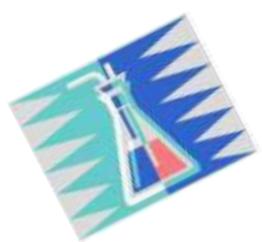
Using a Fire Extinguisher



- P** Pull
- A** Aim
- S** Squeeze
- S** Sweep



Video Courtesy of Washington State Emergency Management Division, Public Education Program



Electrical Fires



Pull the plug out or switch off the power at the fuse box. This may stop the fire immediately.



Smother the fire with a fire blanket, or use a dry powder.



Never use water on it.





WHAT TO DO IF SOMEONE CATCHES ON FIRE

If **you** should catch on fire:

STOP - where you are

DROP - to the floor

ROLL - around on the floor

This smothers the flames, possibly saving your life.

Remember **STOP, DROP and ROLL**

If a **co-worker** catches on fire:

Smother flames by grabbing a blanket or rug
Wrap them in it.

Could save them from serious burns or death.





WHEN NOT TO FIGHT A FIRE

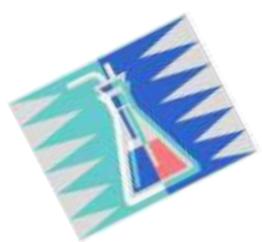
Don't fight a fire, when:

- It is bigger than a waste paper bin
- One extinguisher is not enough
- The fire is spreading beyond the spot where it started
- Smoke is affecting your breathing
- You can't fight the fire with your back to an escape exit
- The fire can block your only escape
- You don't have adequate fire-fighting equipment



DON'T FIGHT THE FIRE YOURSELF

CALL FOR HELP



Remember

When...

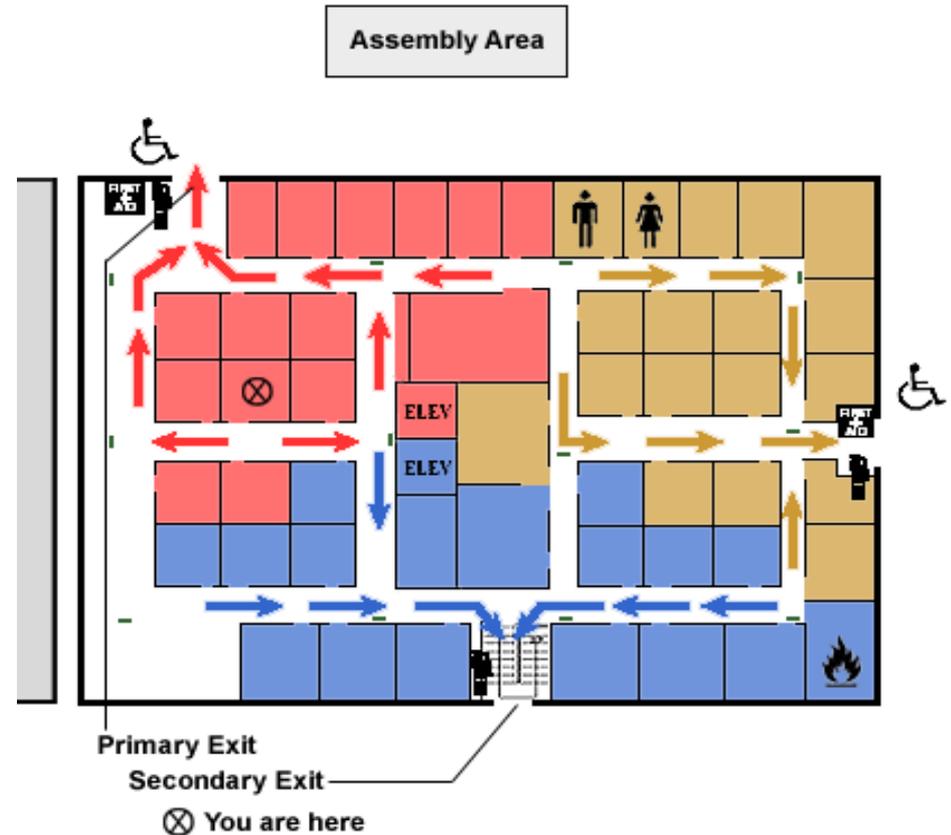
- The extinguisher runs out of agent
- Your path of escape is threatened
- The extinguisher proves to be ineffective
- You are no longer be able to safely fight the fire

...LEAVE THE AREA IMMEDIATELY!



Egress – Exit Route

- Continuous and unobstructed path from any point within a workplace
- Consists of three parts:
 - Exit access
 - Exit
 - Exit discharge

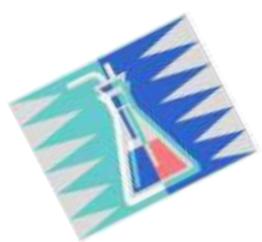




Egress – Exit Route

- Exit routes must be permanent
 - Exits must be separated by fire-resistant materials
 - Openings into an exit must be protected by an approved self-closing fire door that **remains closed or automatically closes in an emergency**
 - Unobstructed
- Well marked





Storage Containers

- **Containers should be tightly sealed when not in use.**
- **Approved safety cans are recommended for smaller quantities.**
 - The spring-loaded safety cap prevents spillage.
 - Prevents vapors from escaping
 - Acts as a pressure vent if engulfed in fire
 - Prevents explosions and rocketing of the can





Flame Arrester Screen

- Prevents fire flashback into can contents.
- Double wire - mesh construction
- Large surface area provides rapid dissipation of heat from fire so that vapor temperature inside can remains below ignition point.



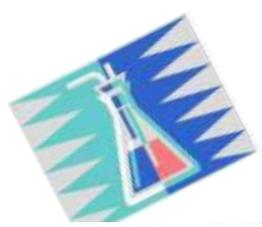
OSHA Office of Training and Education



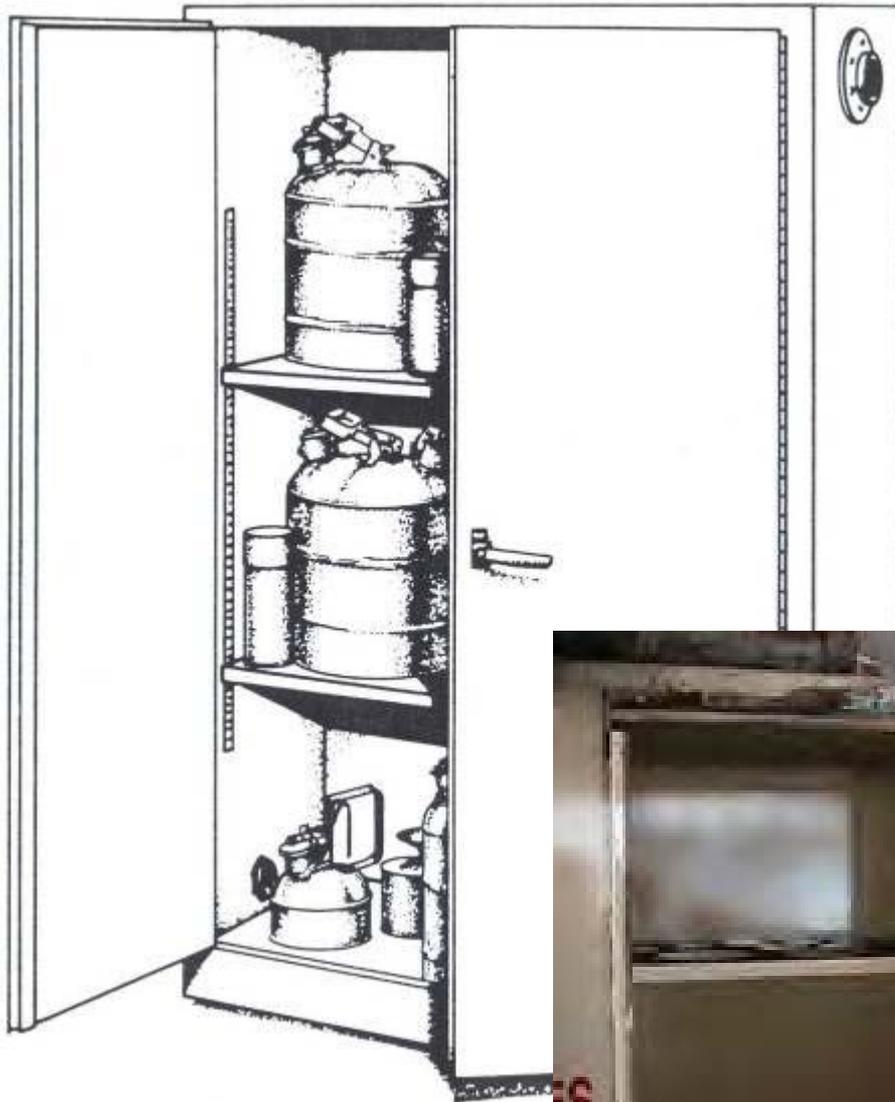
Storage Cabinets

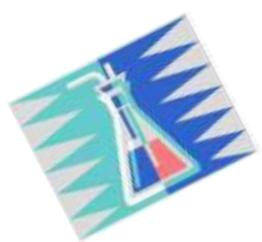
- Not more than 225 L of Class I and/or Class II liquids, or not more than 450 L of Class III liquids permitted in a cabinet.
- Must be conspicuously labeled, **“Flammable - Keep Fire Away”**
- Doors on metal cabinets must have a three-point lock (top, side, and bottom), and the door sill must be raised at least 5 cm above the bottom of the cabinet.





Flammable Storage Cabinets

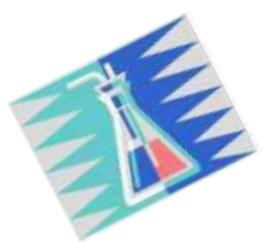




Fire Prevention Inspections

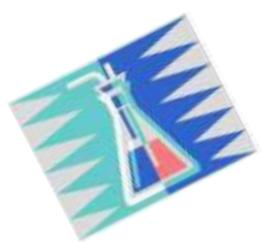
- **Minimize size of fires**
 - Control storage of combustible and flammable materials
- **Reduce possibility of a fire**
 - Control ignition sources
- **Ensure fire protection equipment is operational**
 - Fire extinguishers not blocked
- **Ensure exits are maintained**
 - Don't block egress pathways
 - Don't prop open fire doors





Violations





Violations

6-Way Multi-plug



Multi-plug





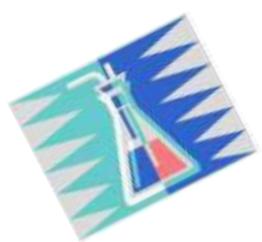
Tea Break



Chemical Management



Best Practices



Cradle - to - grave care of chemicals



Receipt



Storage

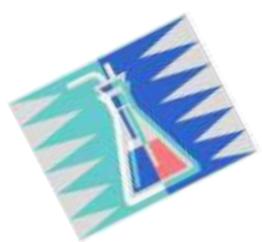


Use



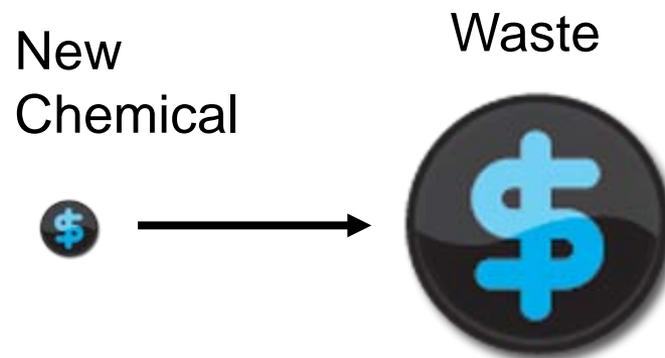
Disposal

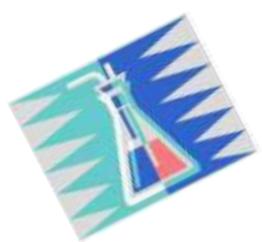




Chemical Management is a Best Practice for Safety *and* Security

- Reduces hazardous waste
- Reduces cost
 - New purchases
 - Waste disposal
 - More efficient
- Improves security
 - Insider threat
 - Outsider threat
- Facilitates environmental compliance
- Improves quality of research
- Improves quality of lab instruction

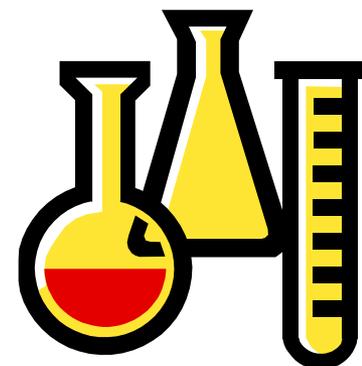


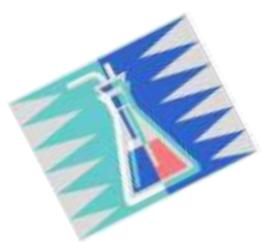


Proper chemical management program has several essential elements

Chemical Management Elements

- **Source reduction**
- **Procedure for chemical ordering and disposal**
- **Inventory and tracking**
- **Storage in stockrooms**
- **Access control**
- **Recycling of chemicals, containers and packages**

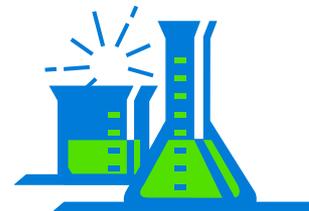




Plan experiments in advance!

What chemicals are needed?

How much is needed?



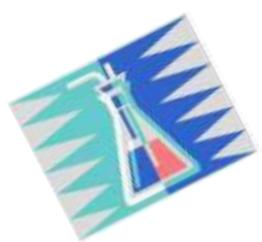
How will the chemicals be handled?

What are the reaction products?

How will the chemical be stored?

How will disposal take place?





Inventory management

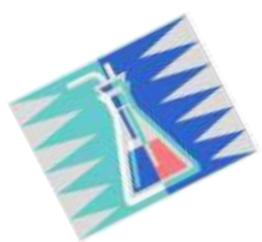
Less is Better !

- Order only what you need
- Reduce size of experiment
 - It costs less to store
 - It costs less to dispose



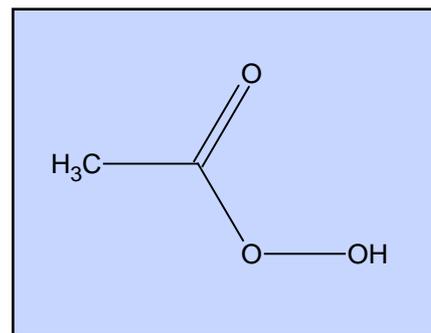
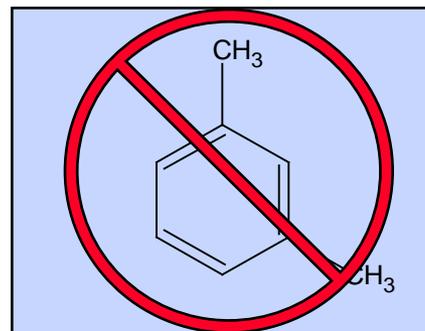
Less is Better: Guide to minimizing waste in laboratories”, Task Force on Laboratory Environment, Health and Safety, American Chemical Society, 2002.

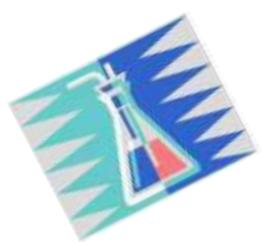
http://membership.acs.org/C/CCS/pub_9.htm



Substitute reagents to reduce waste

- Citrus based solvents for xylene in histology lab
- Peracetic acid for formaldehyde for cleaning kidney dialysis machines
- Non mercury thermometers
- Enzyme and peroxide based cleaners for chromerge (NoChromix)
- When purchasing automated equipment think of chemical waste



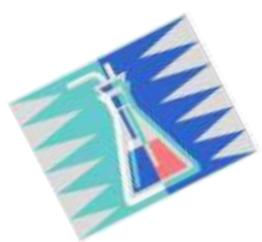


Practical examples of recycling

- Hexane contaminated with small amount of inert solvent used in prep lab
- Chemistry students given a finite quantity of solvent, then had to recycle for subsequent experiments
- Acetone 50% in water for washing. Azeotrope is 88.5% which is then diluted back with water for reuse
- Use rotovap recovery rather than evaporation. Student will redistill; 60% recovery.
- Third wash was captured and used as first wash on next experiment



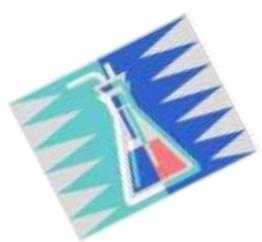
Source : Handbook of Laboratory Waste Disposal, 1986.
Marion Pitt and Eva Pitt, John Wiley and Sons, ISBN 85312-634-8



Best practice - ordering and stocking chemicals

- See if your institution already has it (surplus)
- Order minimum needed (large quantities are not a bargain)
- Check on special storage (refrigeration, dry box...)
- Mark the receipt /open date (unstable chemical)
- Can it eventually be disposed of (rad waste, mixed waste)

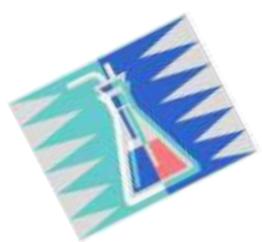




Ordering chemicals- chemical inventory

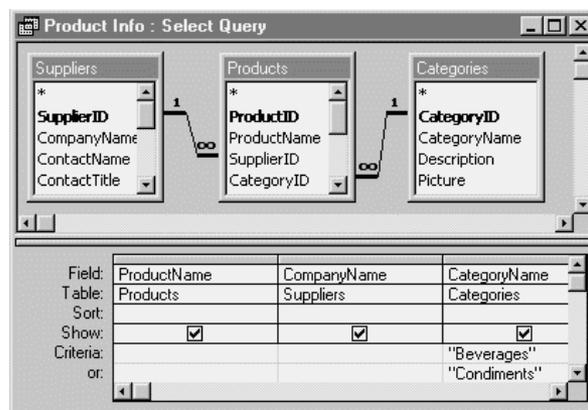
- **Database or Spreadsheets are tools to track the chemical inventory**
 - **Barcoding can be used**
 - **Chemicals can be found easily**
 - **Chemical ages can be tracked**
 - **Chemical standards maintain traceability**
 - **Disposal can be documented**
- **Physical reconciliation**
 - **Assures accuracy of database**
 - **Provides visual inspection of chemical condition**





Inventory and tracking

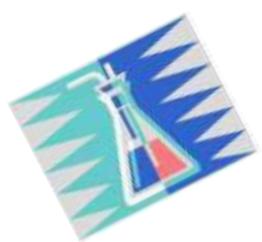
Database or spreadsheet designs



Home made – Access or Excel programs

Freeware – Based on Access or Excel

Commercial – Chemicals and MSDS included



Database helps safely track and report chemical storage and use

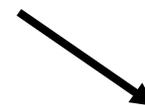
Searches and Reports:

Find an (M)SDS

Chemical Inventory Search Menu

Chemical Regulatory Reports Search Menu

Find Chemical Storage Locations



Transfers, Removal, Verification and Inventory Entry:

Transfer or Remove a Bar-coded Chemical from the Inventory

Verify Chemical Inventory Menu

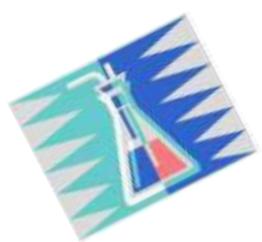
Add Chemical Inventory

Chemical Exchange Menu

Procedures, Forms and Links:

See Inventory procedures, forms and other documents

See Other Chemical Related Links



Inventory queries

Chemical or tradename search

CAS number search

Ingredient search

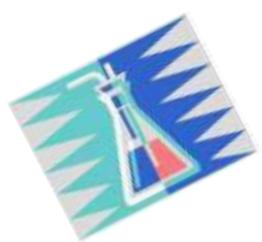
Location/organization search

Location owner search

Requester search

Barcode search

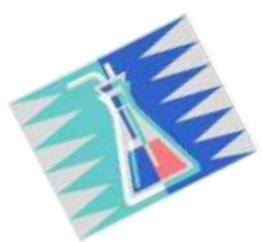




Query result for toluene – barcode, location, department, quantity and order date

BARCODE	LOCATION	DEPT	QUANTITY	UNIT	Purchase Date
AQ00600682	NM/518/1111	1725	1	L	10/24/2006
AQ00602185	NM/518/1123	1111	100	mL	11/20/2006
AQ00582298	NM/518/1302	1131	1	L	8/8/2006
AQ00602186	NM/518/1302	1131	100	mL	11/20/2006
AQ00602187	NM/518/1302	1131	100	mL	11/20/2006
AQ00582307	NM/518/1302	1131	4	L	8/8/2006

(M)SDS and Certificates of Analysis may also be included



Chemicals likely to be useful in other labs

ACIDS

Acetic acid (glacial)
Hydrochloric acid
Sulfuric acid

SOLVENTS

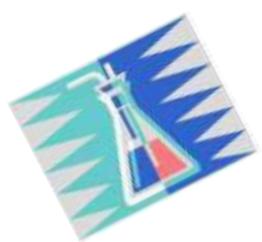
Dichloromethane (methylene chloride),
Acetone Chloroform, Ethyl acetate, Glycerol,
Hexanes Isopropyl alcohol, Methanol,
Petroleum ether Toluene, Xylenes

OXIDIZERS

Bromine, Potassium chlorate, Potassium
dichromate, Silver nitrate

POISONS

Indicators, Iodine (solid or solution) Metals
(powders, dust, shot)
Sodium, calcium, silver, and potassium salts



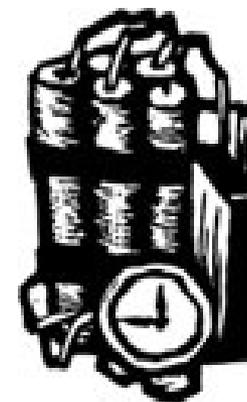
Inventory management

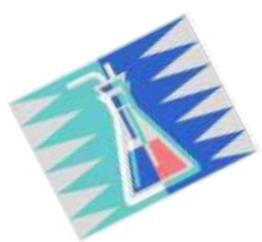


Less is Better !
It's Safer!

It may be cheaper to order **diethyl ether** in large containers

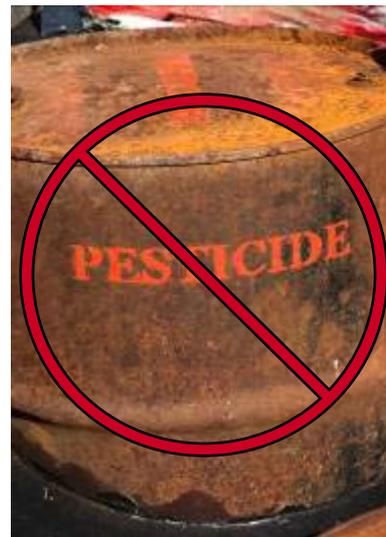
But, if it's opened for a long time—peroxides can form!

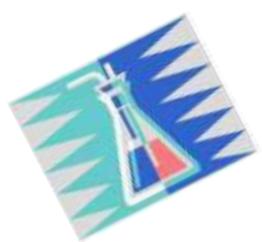




Inventory management – chemical aging

- How old are your chemicals?
- Some chemicals degrade over time
 - rotate stock
 - label & date
- Chemical assays have expiration dates





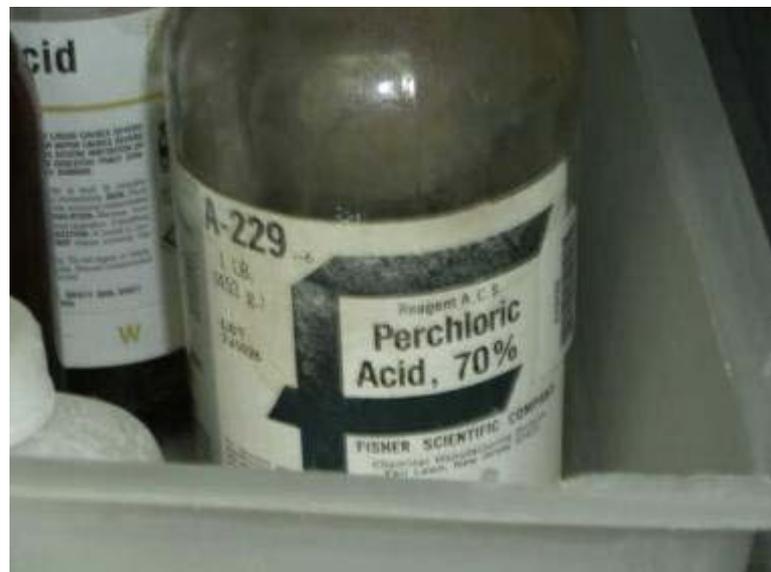
Explosives and Reactives

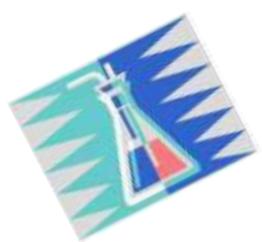
Examples:

- Peroxide-forming - ethers
- Perchlorate-forming – perchloric acid
- Water/moisture sensitive – Na, K, Li, LAIH, flammable metals

Control measures:

- Inventory control
- SOPs, inspections





Inventory management

-R-O-O-R-

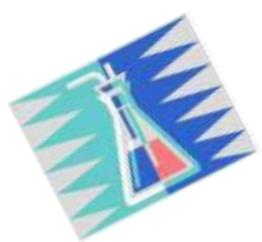
Peroxide Forming Chemicals

Even with inhibitors they can become dangerous over time

- discard or test if unsure
 - label & date when received, when opened, and provide expiration date

Peroxide test kits and strips should be available

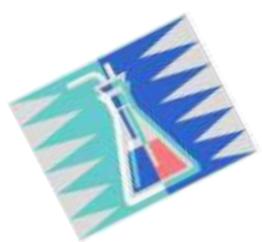




Peroxide forming chemicals

- Peroxide formation is caused by an autoxidation reaction.
- The reaction is initiated by light, heat, introduction of a contaminant or the loss of an inhibitor (BHT).
- Inhibitors slow, but do not stop peroxide formation.
- Most organic peroxide crystals are sensitive to heat, shock, or friction.
- It is important not to let peroxide forming chemicals evaporate to dryness or accumulate under screw caps.

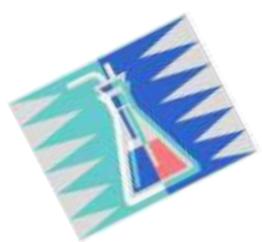




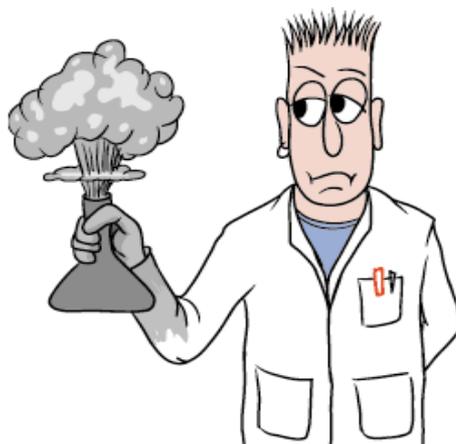
Chemical storage: Basic concepts

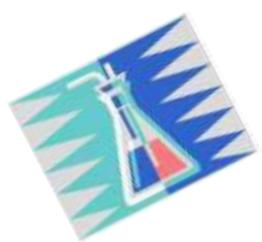
- **Separate incompatible chemicals**
- **Separate flammables/explosives from ignition sources**
- **Use flammable storage cabinets for large quantities of flammable solvents**
- **Separate alkali metals from water**
- **Separate acids and bases**





Use flammables storage cabinets

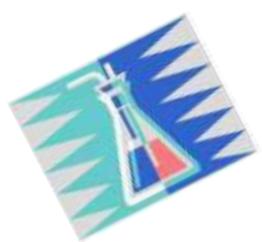




Chemical storage: Basic concepts

- Store nitric acid separately
- Store large containers on bottom shelves
- Lock up drugs, chemical surety agents, highly toxic chemicals
- Do not store food in refrigerators with chemicals

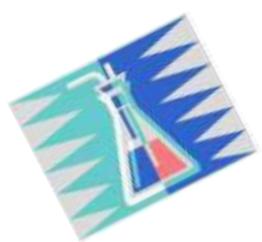




Compressed Gas Cylinders

- **Uses**
- **Types**
- **Hazards**
- **Control Measures**
 - Inventory control
 - Procurement authorization
 - Training
 - Inspection

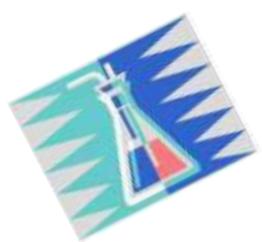




Chemical storage: Gas cylinders

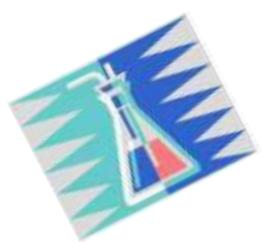
- **Secure (chain/clamp) and separate gas cylinders**
- **Screw down cylinder caps**
- **Store in well-ventilated area**
- **Separate & label empty cylinders**
- **Store empty cylinders separately**
- **Separate flammable from reactive/oxidizing gases**



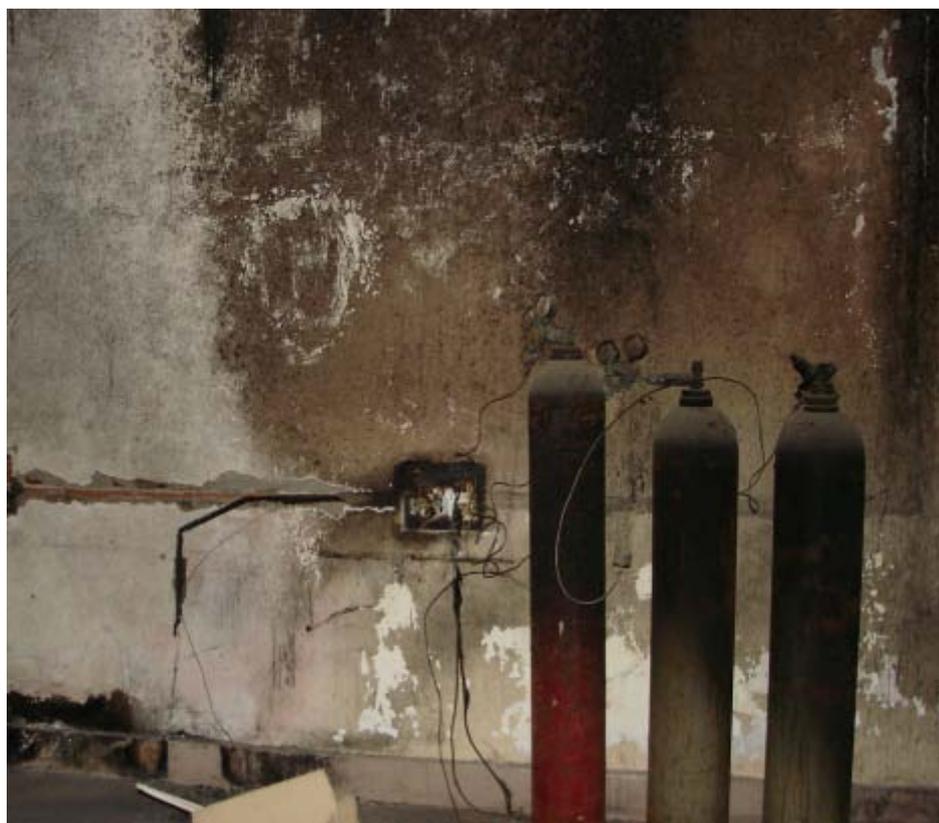


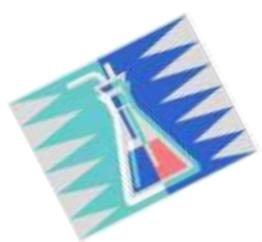
Improper gas cylinder storage





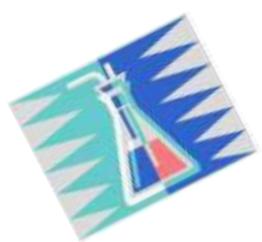
Damage from Gas-cylinder fire





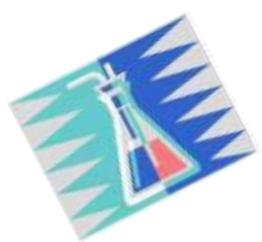
An Accident Waiting to Happen





CSB video: Compressed gas fire

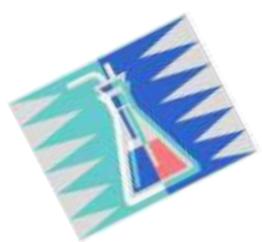




Chemical storage: Good practices

- **Limit access**
 - Label “Authorized Personnel Only”
 - Lock area/room/cabinets when not in use
- **Be sure area is cool and well ventilated**
- **Secure storage shelves to wall or floor**
- **Shelves should have a $\frac{3}{4}$ ” front lip**
 - In earthquake territory, have a rod several inches above shelf

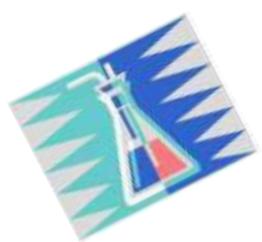




Chemical storage: Bad practices

- **Do Not Store Chemicals**
 - on top of cabinets
 - on floor
 - in hoods
 - with food or drinks
 - in refrigerators used for food
 - where there are wide variations in temperature, humidity or sunlight

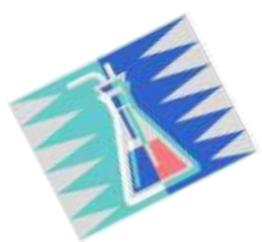




Chemical storage: Containers

- Don't use chemical containers for food
- Don't use food containers for chemicals
- Be sure all containers are properly closed
- Wipe-off outside of container before returning to storage area
- Transport/carry all containers safely
 - Preferably use outer protective container





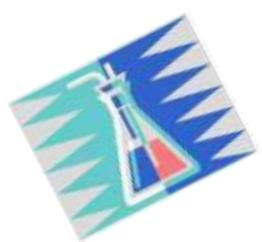
Improper chemical storage



**Never use hallways
for storage**

Safety Hazard!!

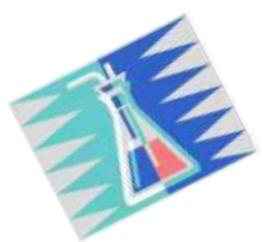
**Blocks exit path in
emergencies!!!**



Chemical storage: Good practices

- **Separate incompatible chemicals**
 - Organize chemicals by compatible groups
 - Alphabetize chemicals only within compatible groups

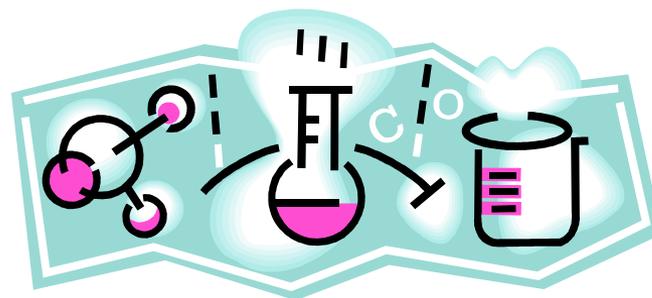


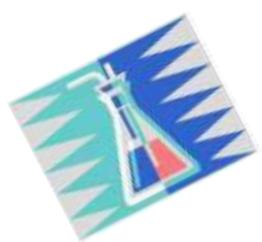


Suggested shelf storage groups: Organics

- Acids, anhydrides
- Alcohols, amides, amines
- Aldehydes, esters, hydrocarbons
- Ethers, ketones, halogenated hydrocarbons
- Epoxies, isocyanates
- Azides, peroxides
- Nitriles, sulfides, sulfoxides
- Cresols, phenols

From: "School Chemistry Laboratory Safety Guide," US NIOSH Publication 2007-107

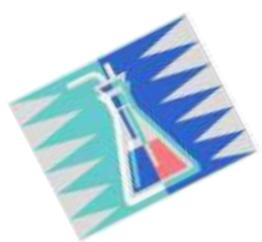




Suggested shelf storage groups: Inorganics

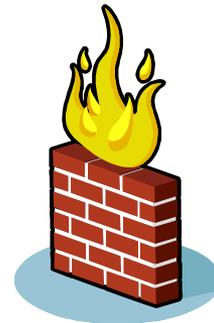
- **Metals, hydrides**
- **Halides, halogens, phosphates, sulfates, sulfides**
- **Amides, azides, nitrates, nitrites**
- **Carbonates, hydroxides, oxides, silicates**
- **Chlorates, chlorites, perchlorates, peroxides**
- **Arsenates, cyanides, cyanates**
- **Borates, chromates, manganates**
- **Acids**
- **Arsenics, phosphorus, sulfur**

From: "School Chemistry Laboratory Safety Guide," US NIOSH Publication 2007-107



Best practice: access control

- Proper training of chemical handling personnel
- Only trained and approved personnel
 - have access to stock room and keys
 - administrative privileges to inventory and database
- Locked doors and cabinets for controlled substances
 - Radioactive materials
 - Drugs and consumable alcohol
 - Explosives (special handling facility)
 - Dual use chemicals
 - Hazardous waste - high toxicity chemicals





Lunch