# Improving Chemical Safety in Schools

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AMERICAN CHEMICAL SOCIETY

Appalachian STATE UNIVERSITY

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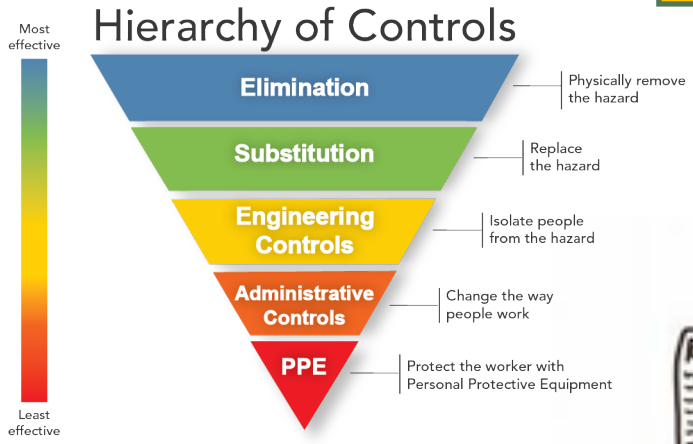
# Moving Academic Laboratory Safety into the 21st Century

## 20th Century: Selecting controls based on rules, guided by chemical Intuition & compliance

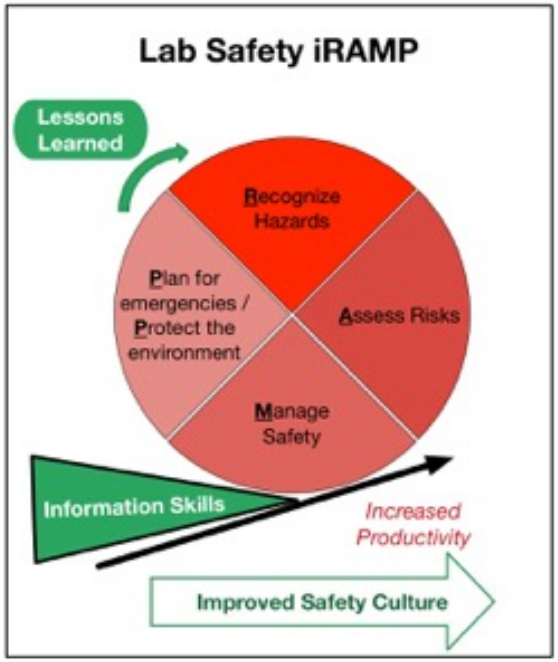
Identify Hazards from previous events





Culture Change through Safety Education

## 21st Century: A safety system built on education, positive culture, and documented risk assessment



# Chemical Safety Education

## 20th Century

- ***Technical aspects*** of safety are transferred as procedural skills learned during laboratory work
- ***The culture of safety*** is based on enforcement & compliance
- ***Information transfer*** is based primarily on training compartmentalized topics built on compliance with regulations
- ***Safety management*** **is** based on training and rules

## 21st Century

- ***Technical aspects*** of safety are transferred by teaching students to control risk through ***hazard identification and risk assessment which is applied to laboratory work***
- ***The culture of safety*** *is* ***based on leadership and empowerment***
- ***Information transfer*** involves development of chemical safety competencies (knowledge, skill, and attitude) learned as an ***educational subject integrated into the curriculum***
- ***Safety management*** **is** based on the development of a ***resilient, transferrable, and sustainable safety system***

# Building a Safety System

- Understand Scope
- Risk Assessment
- Reliable Information
- Chemical Management
- Hazardous Waste Management

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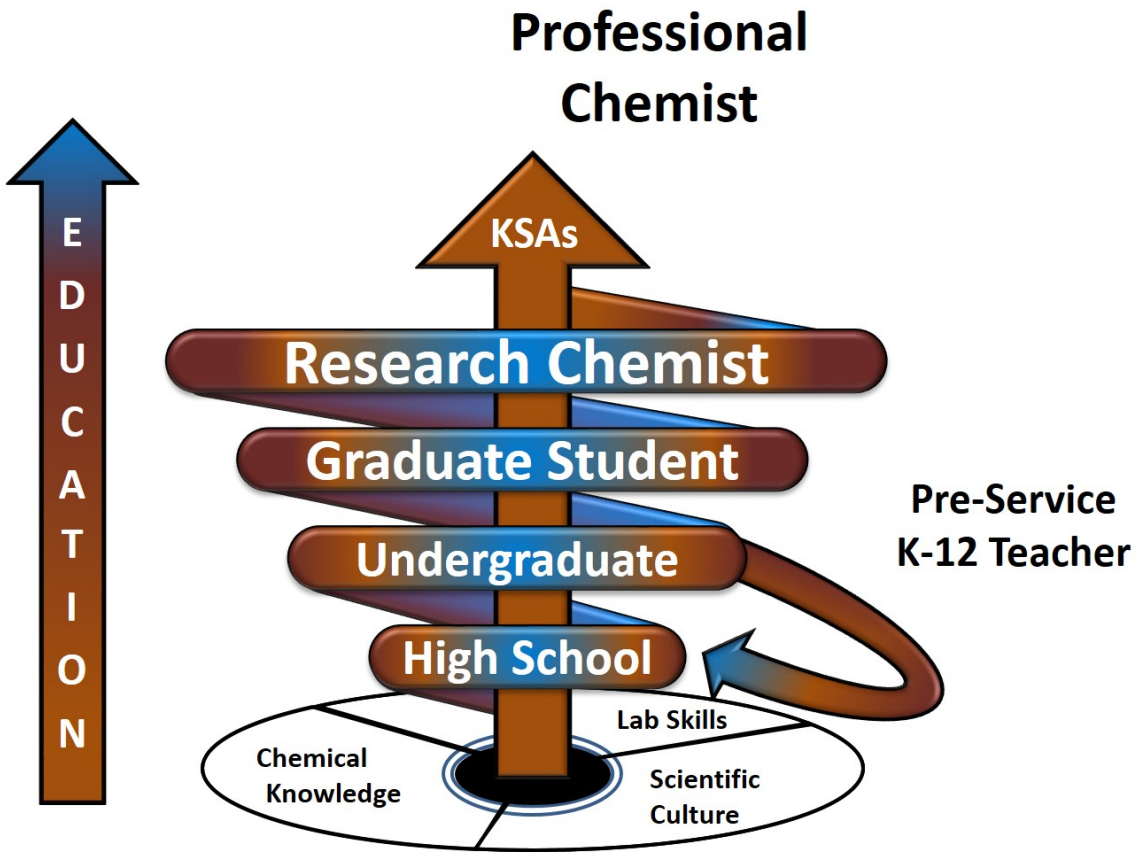
# Understand Scope

- Your chemical safety responsibilities as an educator (leadership and accountability)
- Best Practices
- Utilizing ACS and other information resources
- Due Diligence

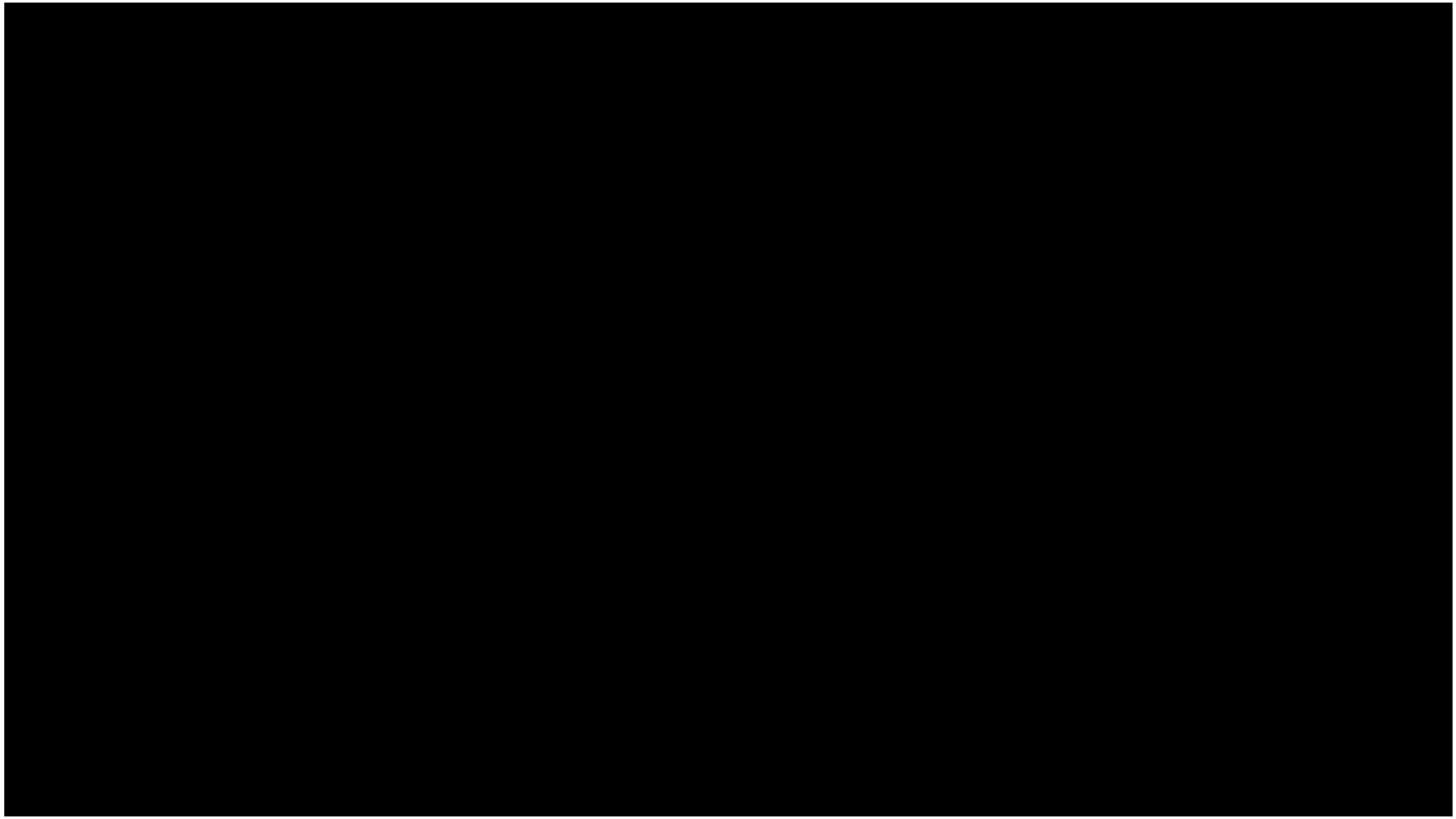
# A Spiral Learning Approach to Safety Education

The spiral curriculum supports habits of:

- continuous risk assessment
- documented management choices and
- sharing of Lessons Learned



# Safety in the Chemistry Classroom



"After the Rainbow", 11th Grade, Hudson, Ohio, January, 2006

# …but that was an isolated event, right?

## Recent demonstration methanol fires:

1. Oklahoma City, OK – November 2011
2. Maple Grove, MN – December 2011
3. Frisco, TX – September 2013
4. Avondale, AZ - November , 2013
5. New York, NY – January 2014
6. Reno, NV – September 2014
7. Denver, CO – September 2014
8. Raymond, IL – October, 2014
9. Chicago, IL – November, 2014
10. Tallahassee, FL – May 2015
11. Washington, DC – October 30, 2015
12. Perth Amboy, NJ – May 24, 2017


Figure 3. Methanol igniting on the day of the incident[8]

And over a decade ago, the Associated Press reported that at least 150 students had been seriously injured in school laboratory accidents between 1998 and 2002. http://www.nydailynews.com/new-york/beacon-teacher-faulted-experiment-leaves-students-badly-burned-article-1.1565533

# NFPA 45 – 2015 Edition

Fire Protection for Laboratories Using Chemicals

## 12.2 Instructor Responsibilities

Where instructors are performing demonstrations or students are conducting experiments using hazardous materials, the instructor shall be required to perform a documented hazard risk assessment, provide a safety briefing to students, provide adequate personal protective equipment (PPE), and place a safety barrier (as required) between students and the demonstration or experiment to prevent personal injury.



NFPA 45 Free Access

# American Chemical Society Takes Action

- The ACS has over 150,000 members from academia, industry and government
- Numerous ***advocacy*** and ***leadership*** roles in the chemical enterprise
- All levels of chemical education are served – In 2014 American Association of Chemistry Teachers was launched – https://teachchemistry.org

"The association is dedicated to improving chemistry education and providing specialized resources to more than 1 million K–12 chemistry and physical science teachers nationwide.

ACS Chemistry for Life®

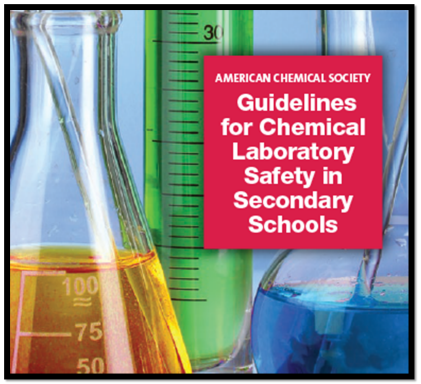
# Safety in ACS Policy

*Goal 3 …Through educational resources, instruction, and mentorship, ACS and its members will promote principles of safety and ethics throughout pre-college, undergraduate, graduate, and post-graduate education…*

- In 2017 -
  - "Safety" was added to the **ACS Strategic Plan Core Values**
  - The ACS added a policy statement "**Safety in the Chemistry Enterprise**"
  - **All ACS publications** were required to have experimental details address and emphasize unexpected, new, and/or significant hazards or risks

# Selected ACS Safety Resources

1. *Identifying and Evaluating Hazards in Research Laboratories* 2013 (Web Site version, 2017)
2. *Guidelines for Chemical Laboratory Safety in Secondary Schools*, 2016
3. *Guidelines for Chemical Laboratory Safety in Academic Institutions*, 2016
4. CHED Safety Committee Demonstration Guidelines, 2016
5. *Five Key Questions for Safe Research and Demos* inChemistry, 2016
6. *Safety in Academic Chemistry Labs*, 8th Edition, 2017
7. Video evaluation rubric, in process





Links available from
http://www.acs.org/safety

# On Due Diligence…

The point is that being able to demonstrate 'due diligence' is not about *having* a thing (a policy or a system or a heap of procedures and checklists) it is about *doing* a thing.

Demonstrating due diligence is about *being* diligent. And diligent is defined as "*showing persistent and hard-working effort in doing something*". So, demonstrating due diligence is focused on *doing*; it is an *activity thing*.

Due Diligence is about Effort, Not just Ticking Boxes

# Building a Safety System

- Understand Scope
- Risk Assessment
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# What is a "Risk Assessment"?

- Risk assessment is a systematic approach one uses to evaluate an experiment or demonstration in order to both document obvious hazards and uncover latent ones. The tool then communicates the barriers or controls needed to all stakeholders – the goal being to prevent harm or damage (students, faculty, student teachers, audiences, etc.)
- It should be designed at a level that meets the needs of the users
- **It is a strong educational and communication tool**

# Risk Assessment, cont.

- The purpose of the "risk assessment" is not to simply restate how to prepare and perform the experiment or demonstration
- Pedagogical information can be included to gage whether the educational value justifies the risk
- Ask "What can go wrong?" and "How can my controls prevent it?" Redundancy adds protection for higher risk
- There are many forms the documentation can take and a good tool will Recognize, Assess, Manage, and Prepare the user for safe operations.[1]
- Is an iterative process – not one and done!

[1] Hill, R.H.; Finster, D.C. *Laboratory Safety for Chemistry Students,* 2nd Ed; Wiley: Hoboken, NJ, 2016.

# How Might a Risk Assessment Have Changed the Outcomes in Methanol Fire Incidents

1. Replacing the Hazard
2. Engineering Controls: Fume Hood?
3. Education, Training & Oversight
4. Personal Protective Equipment
5. Emergency Planning and Response


https://youtu.be/kkBFG1mTSBk

# Five Question Assessment

1. What are the most important chemical (GHS) and process (physical) **hazards** associated with this work?
2. What **ventilation** is required for this work and why?
3. What **Personal Protective Equipment** is required for this work and why?
4. What **emergencies** should we be ready for?
5. What **wastes** will be generated and where will they go?

# Assessing Risk for Undergraduate Research and Demonstrations

Samuella B. Sigmann, Appalachian State University, Boone, NC
Ralph Stuart, Chemical Hygiene Officer, Keene State College, Keene, NH

## 1 What are the Chemical (health, physical, & environmental) and Physical Hazards?

(temperature, pressure, etc.)?

The GHS labelling elements (Hazard Statements, Precautionary Statements, Pictograms, & Signal Words) are the key to identifying chemical hazards.

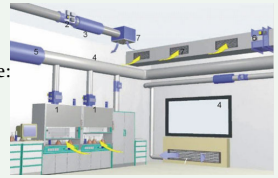
Look especially for the "DANGER" signal word to identify high hazard chemicals – **these are chemicals that require special planning.**

| Physical Hazards | | |
|---|---|---|
| Icon | GHS class | Signal Words |
| | Explosive | Danger or Warning |
| | Oxidizer | Danger or Warning |
| | Flammable | Danger or Warning |
| | Corrosive | Warning only (physical) |
| | Compressed Gas | Warning only |

| Health Hazards | | |
|---|---|---|
| Icon | GHS class | Signal Words |
| | Corrosive | Danger only (health) |
| | Toxic | Danger only |
| | Health Hazard | Danger or Warning |
| | Irritant | Warning only |
| | Environmental | Warning only |

## 2 What Ventilation Do I Need?

How much ventilation you need will depends on the **fire and toxicity** hazards are associated with the demonstration or experiment.



The room ventilation choices are:

1. No Ventilation Required
   (0 air changes/hour)
2. General Lab Ventilation
   (6 or more air changes/hour)
3. Fume Hoods
   (>40 ACH for gently released gasses)
4. Outdoor Settings
   (variable air changes, dependent on wind speed and direction)

## Abstract

Effective chemical safety education for undergraduates requires teaching risk assessment without going into excessive details about potential risks. This poster will outline 5 key questions that undergraduates should understand how to apply to their teaching, research and chemistry lab experiences.

## 5 Key Questions To Ask and *Answer*

In 2016, the ACS Division of Chemical Education (CHED) updated their "Safety Guidelines for Chemical Demonstrations". The Guidelines are available at the CHED web site. Look at DCHAS web site to see how these guidelines align with the "5 Key Questions".

This poster provides a quick overview of the five key safety questions that anyone planning chemical demonstrations or experiments should ask and answer prior to work. It is also important to be aware that local jurisdictions may require more extensive planning for some demonstrations and so for everyone's safety – check with the local Fire Department for help with planning your demonstration.

### The Five Key Questions are:

1. **What specific chemical or physical reactivity hazards are associated with the way I'm using these chemicals?**
2. **What type of ventilation do I need?**
3. **What personal protective equipment do I need?**
4. **What emergency response protocols will be needed if something goes wrong?**
5. **What will I do with the waste?**

Sigmann, S.; Stuart, R. Assessing Risk: Five Key Questions for Safe Research and Demos. inChemistry Magazine, 2016, September/October, 6-9.

Following these steps is an application of a **RAMP** analysis and will demonstrate that you are well prepared. **Document your safety planning to fulfill the NFPA 45 requirements**

- Recognize the **Hazards**
- Assess the **Risks**
- **Manage** Safety as You Work
- **Prepare** for Emergencies & **Protect** the Environment


## 3 What PPE Do I Need?

**Selecting Personal Protective Equipment (PPE) requires balancing three factors:**

1. The hazards of the chemicals being controlled
2. The scenario of concern (environment)
3. The fit of the PPE on the person using it

According to the NFPA, PPE is not only for the presenter, but for any audience members who may be within 10 feet of the demonstration.


## 4 What Emergencies Should I Plan For?

The key emergencies that need to be considered when planning a chemical demonstration or experiment are:

- **Fires**
- **Medical Emergencies**
- **Hazmat Spills**
- **Unexpected Crowd Actions**


### Key Tips

- ✓If anyone is endangered, call 911 for assistance
- ✓Be sure that the leader of the demonstration points a "safety officer" to take control should an unplanned incident occur
- ✓If you plan on using a fire extinguisher, be sure to have hands on training before the event
- ✓Ensure the spill kit is stocked with materials appropriate for the chemicals being used
- ✓Make sure Exits are accessible

## 5 What Will I Do With Wastes?

It is important to check with the host of the demonstration before the event to know what waste streams they are prepared to accept

### Consider These Wastes:

- Chemicals
- Biological materials
- Contaminated lab materials
- Broken glassware
- General trash & recycling

# Building a Safety System

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# The Globally Harmonized System

- This is the best way to understand the hazards presented by chemicals
- This enables the user to Recognize & Assess
- It is important that you understand the basics of this system

# Reliable Online Information

- NIH
  - ChemidPlus Advanced – 400,000 chemical records
  - NIH Fact Sheet – Links to the NIH sites
  - Pubchem Laboratory Chemical Safety Summary – 103,000 chemical records based on GHS
- NOAA
  - CAMEO Chemicals – Mix chemical in silico

# Critical Reading of SDS's

Comparing two SDS's for Nitric Acid

## Safety Information

| | |
|---|---|
| Symbol |  GHS03, GHS05 |
| Signal word | Danger |
| Hazard statements | H272-H290-H314 |
| Precautionary statements | P210-P220-P260-P280-P305 + P351 + P338-P370 + P378 |
| Supplemental Hazard Statements | Corrosive to the respiratory tract. |
| RIDADR | UN2031 - class 8 (5.1) - PG 2 - IATA PAX forbidden - Nitric acid >=65% - <= 70% |
| WGK Germany | 2 |

# Evaluating the Chemical Education Literature using a 21st Century Approach

Which of these aspects does the article demonstrate?

1. Risk assessment
2. Safety system
3. Leadership and empowerment
4. Educational topic

JOURNAL OF CHEMICAL EDUCATION — Communication — pubs.acs.org/jchemeduc

**Using Elephant's Toothpaste as an Engaging and Flexible Curriculum Alignment Project**

Daniel S. Eldridge*

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Supporting Information

ABSTRACT: There is an increasing focus across all educational sectors to ensure that learning objectives are aligned with learning activities and assessments. An attractive approach previously published is that of curriculum alignment projects. This paper discusses the use of the fun and famous "Elephant's Toothpaste" experiment as a customizable curriculum alignment project that can be tailored to address a large number of learning activities and learning outcomes in chemistry suitable for students ranging from late high school through to first year university.

KEYWORDS: *High School/Introductory Chemistry, First-Year Undergraduate/General, Demonstrations, Inquiry-Based/Discovery Learning, Applications of Chemistry, Catalysis, Thermodynamics, Gases, Kinetics, Stoichiometry*

# Evaluating Videos using a 21st Century Approach

JOURNAL OF CHEMICAL EDUCATION

Communication

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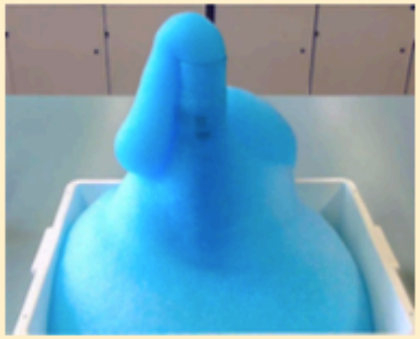

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# Elephant's Toothpaste

# Elephant's Toothpaste

# Building a Safety System

- Understand Scope
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# Steps to Organization

- Assess the situation – Do you need help?
  - Do you have unknowns? Secondary containers?
  - Do you have leaking or suspicious bottles?
- Create an Inventory and obtain SDSs for chemicals you keep
  - Wear gloves (what kind?)

| Name | CAS # | Amount | Conc. | Age | GHS Label | Storage | Notes | Keep? | SDS? |
|---|---|---|---|---|---|---|---|---|---|
| Nitric acid | 7697-37-2 | 2.5 L | 16 M | > 5 years | no | Acid, oxidizer | Store separate from all chemicals | yes | yes |
| Acetic acid | 64-19-7 | 1 L | 17 M | < 5 years | yes | Acid, organic | Combustible | yes | yes |

# Steps to Organization

- **Create an Inventory**
- Check the label first to see what GHS is telling you. If it is an older bottle, find a GHS SDS and check the H codes.
- Note any special storage conditions based on incompatibilities given in Section 10
- If more information is needed on compatibility, check NOAA's site – CAMEO Chemicals [Complete instructions on Computer Aided Management of Emergency Operations can be found here]
- Yet more information can be found at ChemIDPlus Advanced

# Segregate Based on Hazard Classes *

- Flammables (red)
- Oxidizers (yellow)
- Corrosives (blue)
  - Acids
  - bases
- Highly Reactive (yellow, white)
- Extreme Toxics/Regulated Materials (blue, green)
- Low Hazard (black)

*Be careful with color schemes – they can vary from company to company or lab to lab

# Household Chemicals

- Remember – they are still chemicals
- Label food items as, “NOT FOR HUMAN CONSUMPTION” once they are brought into the lab (have the kids do this!)
- Know what the active ingredient hazards are – the Household Product Database can help with this
- Remember that what you might put down the drain at home, may not be suitable for drain disposal at work!

# In General…

- Store chemicals in containers made from compatible materials
- Store chemicals in cool rooms – locked!
- Store chemicals with secondary containment when possible
- Label secondary containers well***
- Do not store chemicals in direct sunlight
- Check containers on a regular basis
- Maintain an up-to-date inventory and SDSs
- Do not store flammables in domestic refrigerators
- Do not store chemicals above eye level
- Do not buy more than you can use in a reasonable timeframe
- **Do not accept chemical "donations" from the public**

# Need Help?

- National Institute for Occupational Health & Safety (NIOSH) – School Chemistry Laboratory Safety Guide
- National Research Council – Prudent Practices in the Laboratory
- Flinn – Safety Reference Articles
- American Chemical Society – Guide for Chemical Spill Response Planning in Laboratories
- American Chemical Society – Division of Chemical Health & Safety (DCHAS)

## General Storage

aluminum chloride

calcium chloride

copper(II) chloride

copper(II) sulfate

ammonium chloride

magnesium

magnesium sulfate

zinc

## Corrosives

### Bases

potassium hydroxide

sodium hydroxide

### Acids

sulfuric acid

Inorganic Acids

hydrochloric acid

nitric acid*

acetic acid

Organic Acids

## Flammables

ethanol

methanol

## High Toxicity

barium chloride

lead(II) nitrate

## Oxidizers

~~Wood~~

silver nitrate

lead(II) nitrate

calcium nitrate

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# Subject to Resource Conservation and Recovery Act (RCRA)?

- RCRA contains the famous, “Cradle to Grave” phrase
- Does the solution have one of the following “characteristics”?
  - Toxicity
  - Ignitability
  - Reactivity
  - Corrosivity
- Does the solution contain an EPA “listed” substance?
- EPA Site on Hazardous Waste

# A Few Basics

- Various types of unwanted solutions and substances are generated in the laboratory on a regular basis, but not all waste is “hazardous”.
- In chemistry laboratories, the term “waste” should only be used for **Hazardous Waste**

# A Few Basics

- Any materials that will be disposed of in house should not have the word “waste”.
- Labels such as “Excess acid to be neutralized” or “Used salts” would be appropriate
- Some chemicals can safely go in the trash can or can be disposed of down the sink, but this must be verified by contacting the local water treatment/sewage authorities or your regional CHO, as local regulations may vary

# Heavy Metals (Toxicity)

- The "RCRA 8"
  - Arsenic, Barium, Cadmium, Chromium, Lead, Mercury, Selenium, Silver
- There are lists of common aqueous ions that are *usually* considered "drain disposable", but you really need to talk to the personnel at the local water treatment plant – they have the final say

# Corrosivity

- In most cases, solutions that contain no other characteristic besides corrosivity can be neutralized and disposed of down the drain with water
- pH should be adjusted to between 5 and 9 – but again this can vary by district

# Big NO NOs!

- Open containers of hazardous waste: purchase Eco Funnel Systems
- No labels – Label must have name of chemical spelled out and most waste companies want percentages
- Waste treatment other than consolidation

# Always…

- Make sure that the label contains the words, “Hazardous Waste”
- Use secondary containment
- Have a stocked spill kit present
- Store securely

# Accumulation

- This is a tricky one for the high school setting
  - Likely you are listed as a “very small generator” (formally conditionally exempt)
  - There regulations are more lenient, but changing
  - When a container is full, date the container
  - Identify your storage area