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**December 2015 / January 2016 Teacher's Guide for**

***Safety Data Sheets: Information That Could Save Your Life***

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# About the Guide

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Articles from past issues of *ChemMatters* can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013.

The *ChemMatters* DVD also includes Article, Title and Keyword Indexes that covers all issues from February 1983 to April 2013.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558.

Purchase information can be found online at [www.acs.org/chemmatters](http://chemistry.org/chemmatters/cd3.html).

# Student Questions

* 1. What was the high school teacher intending to demonstrate with the colored flames that produced the rainbow effect?
  2. A safer method for conducting flame tests that does not use methanol is suggested in the article. Describe the method that is suggested.
  3. What happened when the teacher added more methanol to the Petri dish? Be specific.
  4. What is the purpose of the Occupational Safety and Health Administration?
  5. What warning does this symbol represent?



* 1. Who is responsible for writing the Safety Data Sheets?
  2. What is **NOT** addressed in an SDS?
  3. List two factors from the Section #2 Hazard Identification that could have helped to prevent the methanol accident.
  4. State the difference between the flash point and the fire point.
  5. Which is NOT present in the SDS, the flash point or the fire point?
  6. When does spontaneous combustion occur?
  7. A methanol fire is an example of a class B fire. What is a class B fire?

# Answers to Student Questions

* + 1. **What was the high school teacher intending to demonstrate with the colored flames that produced the rainbow effect?**

*The teacher intended to demonstrate the characteristic emission spectra of metal ions.*

* + 1. **A safer method for conducting flame tests that does not use methanol is suggested in the article. Describe the method that is suggested**.

*The article suggests soaking wooden splints in salt solutions and then burning them in a Bunsen burner as a safer flame test method.*

* + 1. **What happened when the teacher added more methanol to the Petri dish? Be specific.**

*When more methanol was added to the Petri dish the flame traveled back up into the bottle and ignited the rest of the methanol. Pressure built up within the bottle and spewed a fiery stream of burning methanol 12 feet, hitting a student in the chest.*

* + 1. **What is the purpose of the Occupational Safety and Health Administration?**

*OSHA is a “… federal agency created to ensure a safe work environment for all employees.”*

* + 1. **What warning does this symbol represent?**



*This symbol represents a corrosive material.*

* + 1. **Who is responsible for writing the Safety Data Sheets?**

*The supplier or manufacture of the chemical is responsible for writing the SDS.*

* + 1. **What is NOT addressed in an SDS?**

*An SDS “… does not address the possible hazards that could occur as a chemical reaction moves forward and the constituents and concentration of the chemicals involved change.”*

* + 1. **List two factors from the Section #2 Hazard Identification that could have helped to prevent the methanol accident.**

*Factors that could prevent the methanol accident are:*

*a. “Highly flammable liquid and vapor”*

*b. “Keep away from heat, sparks, open flames, hot surfaces—No smoking”*

* + 1. **State the difference between the flash point and the fire point.**

*The flash point is the temperature at which the vapors above a liquid ignite if an outside ignition source (spark or flame) comes near. The fire point is the point at which a flammable liquid will not only catch on fire if lit but will also keep burning for five seconds.*

* + 1. **Which is NOT present in the SDS, the flash point or the fire point?**

*The fire point is not present in the SDS.*

* + 1. **When does spontaneous combustion occur?**

*Spontaneous combustion occurs when a substance reaches its autoignition temperature.*

* + 1. **A methanol fire is an example of a class B fire. What is a class B fire?**

*Class B fires involve the combustion of gasoline, oil, paint, and other flammable liquids.*

# Anticipation Guide

Anticipation guides help engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

**Directions:**  *Before reading*, in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. In just two months in 2014, more than 20 students were injured in the United States by a teacher demonstration involving methanol. |
|  |  | 1. Safety Data Sheets include safety precautions as well as potential health hazards. |
|  |  | 1. The United Nations developed safety pictograms which are used on products worldwide. |
|  |  | 1. Safety Data Sheets include information about hazards as chemical reactions occur and the concentration of chemicals change. |
|  |  | 1. Liquid methanol burns. |
|  |  | 1. You can easily see a methanol flame in good light. |
|  |  | 1. The flash point and the fire point are the same temperature for most flammable liquids. |
|  |  | 1. All fire extinguishers can be used on any type of fire. |
|  |  | 1. Substances require a flame to ignite. |
|  |  | 1. More students are injured in sports than in science labs. |

# Reading Strategies

These graphic organizers are provided to help students locate and analyze information from the articles. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the articles. The use of bullets helps them do this. If you use these reading and writing strategies to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

***Teaching Strategies:***

1. Links to **Common Core Standards for Reading**:

* ELA-Literacy.RST.9-10.1:Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
* ELA-Literacy.RST.9-10.5: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
* ELA-Literacy.RST.11-12.1:Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
* ELA-Literacy.RST.11-12.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.

1. Links to **Common Core Standards for Writing**:

* ELA-Literacy.WHST.9-10.2F: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
* ELA-Literacy.WHST.11-12.1E: Provide a concluding statement or section that follows from or supports the argument presented.

1. **Vocabulary** and **concepts** that are reinforced in this issue:

* Chemical safety
* Molecular structures
* Energy conservation
* Lipids
* Hydrophobic and hydrophilic structures
* Enzymes
* Evaluating scientific claims

1. Some of the articles in this issue provide opportunities, references, and suggestions for students to do further research on their own about topics that interest them.
2. To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles. The Background Information in the *ChemMatters* Teachers Guide has suggestions for further research and activities.

**Directions**: As you read, complete the graphic organizer below to describe what you learned about chemical safety and safety data sheets.

|  |  |  |
| --- | --- | --- |
| 3 | **New things you learned about chemical safety** |  |
| 2 | **Things to remember about the flash point and/or the fire point** |  |
| 1 | **Question you have about Safety Data Sheets** |  |
| ***Contact!*** | **What would you like to tell others about the dangers of methanol?** |  |

**Summary:** Write a tweet (140 characters or less) to warn others about the dangers of methanol.

# Background Information

**(teacher information)**

**More on** **the history of the Occupational Safety and Health Administration and Safety Data Sheets**

**Occupational Safety and Health Administration (OSHA)**

The establishment of the Occupational Safety and Health Administration (OSHA) was the result of a long evolution. In the 19th century U.S. economy, health and safety was not a priority. In 1877 the nation’s first health and safety legislation passed in Massachusetts. It required the guarding of belts, shafts and gears, protection of elevators, and adequate fire exits in factories. As a result, many other states began factory inspections and instituted safety measures. From that time until OSHA was established the government tried various legislative actions to establish a health and safety organization. It was a contentious battle between labor, business and the government that took decades for its enactment.

The Occupational Safety and Health Administration (OSHA), as an agency in the Department of Labor, was finally established by Congress under the Occupational Safety and Health Act in December of 1970. Its mission as described by OSHA is to *“…* assure the safety and health ofAmerica's workers by setting and enforcing standards; providing training, outreach, and education; establishing partnerships; and encouraging continual improvement in workplace safety and health.” (<http://www.law.du.edu/thomson/AdminWiki/Labor_OSHA/EC77011AD85ABB5F713115C2C60D9CE9.html>)

The first five industries targeted by OSHA for safety hazards were marine cargo handling, roofing and sheet metal work, meat and meat products, miscellaneous transportation equipment (primarily mobile homes), and lumber and wood products. Five health hazards were also targeted: asbestos, lead, silica, carbon monoxide and cotton dust.

(<https://www.osha.gov/history/OSHA_HISTORY_3360s.pdf>)

OSHA covers most private sector employers and their workers. State and local government workers are excluded from federal coverage. The OSHA act encourages states to develop and operate their own programs. States operating their own state workplace safety and health program under plans approved by the US Department of Labor cover most private workers and are also required to cover the state and local government workers as well. The National Institute for Occupational Safety and Health (NIOSH) was created by OSHA as a research agency to determine major types of hazard in the workplace and methods of controlling them.

In the 45 years of OSHA existence great improvements in the workplace have resulted.

* Since **the agency was established in 1971, workplace fatalities have been cut by 62 percent and occupational injury and illness rates have declined 40 percent.**
* **At the same time, U.S. employment has nearly doubled from 56 million workers at 3.5 million worksites to 115 million workers at nearly 7 million sites.**

**(**<http://www.law.du.edu/thomson/AdminWiki/Labor_OSHA/EC77011AD85ABB5F713115C2C60D9CE9.html>**)**

**Safety Data Sheet (SDS)**

The Safety Data Sheet (SDS) replaced the Material Safety Data Sheet (MSDS) in 2012. The Material Safety Data Sheet was legislated by the Occupational Safety and Health Administration (OSHA) in 1983. MSDSs have been the foundation of OSHA’s Hazard Communication Standard. According to OSHA:

Hazard Communication Standard (HCS) is designed to ensure that information about these hazards and associated protective measures is disseminated. This is accomplished by requiring chemical manufacturers and importers to evaluate the hazards of the chemicals they produce or import, and to provide information about them through labels on shipped containers and more detailed information sheets called material safety data sheets (MSDSs). All employers with hazardous chemicals in their workplaces must prepare and implement a written hazard communication program, and must ensure that all containers are labeled, employees are provided access to MSDSs, and an effective training program is conducted for all potentially exposed employees.

The HCS provides people the right-to-know the hazards and identities of the chemicals they are exposed to in the workplace. When employees have this information, they may effectively participate in their employers' protective programs and take steps to protect themselves. In addition, the standard gives employers the information they need to design and implement an effective protective program for employees potentially exposed to hazardous chemicals. Together these actions will result in a reduction of chemical source illnesses and injuries in American workplaces.

(<https://www.osha.gov/dsg/hazcom/whatishazcom.html>)

The Hazard Communication Standard was revised in 2012 to align with the Global Harmonized System of Classification and Labeling of Chemicals (GHS). The GHS was developed by the United Nations in 2003 as a set of guidelines to ensure the safe production, transportation, handling, use and disposal of hazardous materials. The guidelines attempt to bring agreement to chemical regulations and standards of different countries. Their goal is to make the international sale and transportation of chemicals easier and the workplace conditions safer.

The adoption of the GHS resulted in significant changes to the MSDS, which is now labeled simply as the Safety Data Sheet. The purpose of the MSDS was to provide documents that were to travel with or ahead of the chemical shipment, to inform users and transporters about specific hazards that chemical could present. The MSDS had a number of different styles and formats used in the United States. As long as the MSDS contained the required information the format was not specified, so companies had varied MSDSs with varied formats and vital information in various locations. This resulted in making the reading of MSDSs a challenge. OHSA’s adoption of the GHS mandates the use of a single GHS format for the Safety Data Sheet. Using the SDS, with its standard format, creates a simpler and more effective way to communicate the hazards of chemicals.

The Safety Data Sheet’s current format has 16 sections which are listed below:

**Section 1, Identification** includes product identifier; manufacturer or distributor name, address, phone number; emergency phone number; recommended use; restrictions on use.

**Section 2, Hazard(s) identification** includes all hazards regarding the chemical; required label elements.

**Section 3, Composition/information on ingredients** includes information on chemical ingredients; trade secret claims.

**Section 4, First-aid measures** includes important symptoms/ effects, acute, delayed; required treatment.

**Section 5, Fire-fighting measures** lists suitable extinguishing techniques, equipment; chemical hazards from fire.

**Section 6, Accidental release measures** lists emergency procedures; protective equipment; proper methods of containment and cleanup.

**Section 7, Handling and storage** lists precautions for safe handling and storage, including incompatibilities.

**Section 8, Exposure controls/personal protection** lists OSHA's Permissible Exposure Limits (PELs); Threshold Limit Values (TLVs); appropriate engineering controls; personal protective equipment (PPE).

**Section 9, Physical and chemical properties** lists the chemical's characteristics.

**Section 10, Stability and reactivity** lists chemical stability and possibility of hazardous reactions.

**Section 11, Toxicological information** includes routes of exposure; related symptoms, acute and chronic effects; numerical measures of toxicity.

Section 12, Ecological information\*

Section 13, Disposal considerations\*

Section 14, Transport information\*

Section 15, Regulatory information\*

**Section 16, Other information,** includes the date of preparation or last revision.

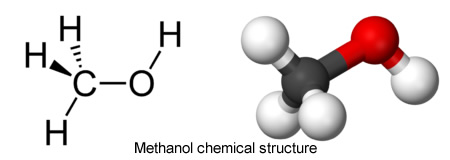
\*Note: Since other Agencies regulate this information, OSHA will not be enforcing Sections 12 through 15(29 CFR 1910.1200(g)(2)).

(<https://www.osha.gov/Publications/HazComm_QuickCard_SafetyData.html>)

**More on** **Methanol**

**Chemistry**

Methanol or methyl alcohol is the simplest of the alcohols, having only one carbon atom. It is a clear, colorless liquid also known as wood alcohol with the chemical formula CH3OH. It is called wood alcohol because it was originally produced by the destructive distillation of wood. Destructive distillation is a chemical process in which an organic material is heated to high temperatures in the absence of air.



*(*[*http://www.biologycorner.com/worksheets/articles/wood\_alcohol.html*](http://www.biologycorner.com/worksheets/articles/wood_alcohol.html)*)*

Today methanol is produced from a wide variety of materials, as long as the material will produce carbon monoxide and hydrogen. The most common starting material is natural gas. The production of methanol occurs in two steps. The first step converts methane, CH4, from the natural gas into carbon monoxide, carbon dioxide and hydrogen. The second step uses a catalyst to convert these gases into methanol.

2 CH4 + 3 H2O 🡪 CO + CO2 + 7 H2

CO + CO2 + 7 H2 🡪 2 CH3OH + 2 H2 + H2O

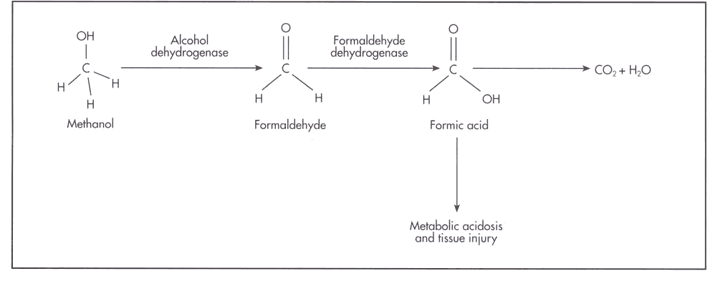
**Uses**

Ancient Egypt used methanol as an embalming fluid. Most of the methanol today is used as a starting material in the production of other substances, such as formaldehyde, dimethyl ether, methyl tertiary butyl ether, and acetic acid. In the lab, methanol is a common solvent. Methanol is also used as a fuel. It burns to produce carbon dioxide and water. It can be used as an additive to gasoline to improve combustion, or it can be used in its pure form.

3CH3OH + 3O2 🡪 2CO2  + 4H2O

**Toxicology**

Methanol is highly toxic, either by ingestion, inhalation or absorption through the skin. In the body, alcohol dehydrogenase converts the methanol to formaldehyde. This is a slow process which explains why methanol poisoning can take hours or days to manifest itself. Once the formaldehyde is produced it is quickly converted to formic acid. Formic acid is metabolized slowly in the body so when it builds up it can damage the ocular nerve resulting in permanent blindness and can lead to death. Blindness can occur with as little as 10 mL of methanol. The National Institute of Health states that ingestion of 60–213 mL can be fatal.



*Metabolic Pathway of Methanol Toxicity*

*(*[*http://web.archive.org/web/20111005043548/http://www.antizol.com/mpoisono.htm*](http://web.archive.org/web/20111005043548/http://www.antizol.com/mpoisono.htm)*)*

Poisoning from methanol does not only happen in the lab. People, either by accident or on purpose, have actually imbibed methanol. It is a common contaminant in moonshine. Alcoholics, desperate for alcohol, have been known to drink methanol. Ethanol, CH3CH2OH—the alcohol that IS drinkable—is also commonly used in chemistry and biology labs, as a fuel or solvent in the lab. To prevent lab staff from buying ethanol from science supply houses without paying tax on it (from the federal government), and to prevent them from drinking it, lab ethanol is commonly denatured using 5% methanol. This renders the ethanol unfit for human consumption. Alcohol tax is not assessed on denatured ethanol, since it’s not drinkable, which makes it cheaper and safer to use in the lab.

**Accidents involving demonstrations using methanol**

For years teachers and demonstrators have used methanol in demonstrations involving fire. One of the most common demonstrations in known as the “Rainbow”, the demonstration discussed in the Rohrig article. It is used to show the emission spectra of metal ions. The following table gives a few examples of the accidents that have occurred involving a sudden flash-fire of methanol during a demonstration. All of these involve children.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Date** | **Location** | **City, State** | **Demonstration** | **Number Injured** |
| 1/23/2006 | Western Reserve Academy | Hudson, OH | Rainbow | 1 |
| 12/1/2011 | Maple Grove Jr High | Maple Grove, MN | Demo with Methanol | 4 |
| 1/2/2014 | Beacon High School | Manhattan, NY | Rainbow | 2 |
| 9/3/2014 | Terry Lee Wells Nevada Discovery Museum | Reno, NV | Fire Tornado | 13 |
| 9/15/2014 | Smart Academy | Denver, CO | Rainbow | 4 |
| 10/20/2014 | Cub Scouts event | Raymond, Il | Rainbow | 4 |

All of these accidents were preventable and the result of insufficient knowledge about the behavior of methanol. As a result, the American Chemical Society published this advisory:

The American Chemical Society Committee on Chemical Safety recommends that the “Rainbow” demonstration on open benches involving the use of flammable solvents such as methanol be discontinued immediately. When carried out on open benches (outside of a chemical hood) these demonstrations present an unacceptable risk of flash fires and deflagrations that can cause serious injuries to students and teachers. On an open bench, invisible flammable vapors can flow across and off of the bench to the floor where they can be ignited by a flame, a spark (even static electricity), or even a hot surface. Even carrying out this demonstration in a hood poses risks if solvents are not adequately controlled. If you are considering this “Rainbow” demonstration or have used it in the past, we urge you to stop using this demonstration. There are alternatives available that demonstrate the same rainbow colors but don’t use flammable solvents on an open bench. These alternate demonstrations involve soaking wooden splints in salt solutions and then placing the splints in a Bunsen burner to observe the salt’s characteristic color.

(<http://www.acs.org/content/acs/en/about/governance/committees/chemicalsafety/safety-alert-rainbow-demonstration.html>)

Likewise the chairman of the Chemical Safety Board, an independent federal agency, also recommended against the use of methanol in demonstrations.

Chairperson Rafael Moure-Erason said, “These key lessons, if followed, will prevent future injuries. Educators should substitute or minimize the use of flammable chemicals and perform an effective hazard review prior to conducting an educational demonstration. Safety must be the absolute priority and educators should demonstrate chemical safety concepts as well as the science topic.”

(<http://www.csb.gov/csb-releases-key-lessons-for-preventing-incidents-from-flammable-chemicals-in-educational-demonstrations-in-wake-of-several-serious-methanol-accidents-that-injured-children-and-adults/>)

[Editors’ Note:] Just as this Teacher’s Guide was going to press, national news reports came in (10/30/2015) of another fire in a high school chemistry classroom in Woodson High School, Fairfax, Virginia. It appears to be the result of a teacher doing “a demonstration of fire in the different colors”, according to the news report. While the actual fuel was yet to be determined, it sounds very much like the other “accidents” listed above, using methanol. One student from the class who was interviewed said, "She [the teacher] was demonstrating the experiment ... with the different elements causing the fire to change color, and as the fire was dying down she added more alcohol." ([https://twitter.com/mattacklandfox5/status/660149372412366848](https://urldefense.proofpoint.com/v2/url?u=https-3A__twitter.com_mattacklandfox5_status_660149372412366848&d=BQMFaQ&c=lb62iw4YL4RFalcE2hQUQealT9-RXrryqt9KZX2qu2s&r=meWM1Buqv4IQ27AlK1OJRjcQl09S1Zta6YXKalY_Io0&m=CbehrvD8q5vQGKSKjcxqRKpWvKxObvDqG9NNMQoyzXU&s=5Wjk0akwrg-vDROBwkZpv5oV6uQ_Jenr1a0YUpJXjlU&e=))

Although the specific alcohol had not yet been determined, methanol is the likely culprit.

With this latest news story, if you feel the need to show the demonstration to your students, the Teacher's Guide editors ENCOURAGE you to use one of the video clips listed in the “More sites on the rainbow demonstration and flame tests” near the end of this article’s Teacher’s Guide, and we want to DISCOURAGE you from actually doing the demonstration in your own classroom. We remind you of the quote above from the American Chemical Society Committee on Chemical Safety: “… we urge you to stop using this demonstration.”

**No demonstration—no matter how exciting—is worth the risk of harm to students.**

**More on safety in the chemistry classroom**

It is imperative to create a culture of safety in the science classroom from day one. One way to do this is to consider the four principles of safety as described by Robert H. Hill, Jr. and David C. Finster in their book *Laboratory Safety for Chemistry Students*.

The first principle, to **recognize** the hazards of chemicals, equipment and procedures**,** requires that you know and recognize the hazard of the chemicals that you are using. The second principle, **assess** risks of hazards associated with exposures and procedures, is perhaps the most important of all the principles. The third principle, **minimize** risks, requires careful attention to both the design and execution of an experiment. Finally, despite efforts to prevent incidents (accidents) and exposure in the laboratory, it is prudent to prepare for them. Thus, we present the fourth principle: **prepare** for emergencies.” Hill, R and Finster, D. *Laboratory Safety for Chemistry Students*, John Wiley & Sons, Inc.: Hoboken, New Jersey, 2010, pp 1–7.

Hill and Finster describe their four principles as RAMP—Recognize, Assess, Minimize, and Prepare—and the use of these principles is expected to lead to an accident-free classroom.

Generating general safety understandings for the laboratory setting is the responsibility of the teacher. The following are some of the essential requirements to ensure a safe chemistry classroom:

**General safety rules**

There are many resources to guide the classroom teacher in adopting an appropriate set of safety rules for a given laboratory setting. The list of rules can be extensive. It is recommended that the list for the students be manageable and specific for a particular setting and course. Not only should a set of guidelines be given and explained to students, but it is important to provide a safety contract for the students and parents to sign. This provides the evidence that you, the teacher, take safety seriously and you have a plan for operating a safe laboratory setting. In an effort to ensure that the students not only have *read* the safety guidelines but also *understand* them, it is recommended that each student demonstrate their knowledge on an assessment such as a quiz. This further emphasizes the fact that the students are familiar with the safety expectations in the lab and that the teacher emphasizes a culture of safety.

**Globally Harmonized System (GHS) symbols**

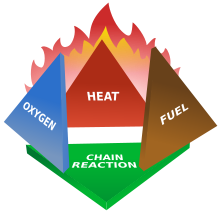
Teachers and students should be familiar with these symbols and their meanings.

|  |  |  |  |
| --- | --- | --- | --- |
| Symbol | | Usage | |
| GHS-pictogram-explos.svg | | Explosive   * Explosives * Self-Reactives * Organic Peroxides | |
| GHS-pictogram-flamme.svg | | Flammable   * Flammables * Pyrophorics * Self-Heating * Emits Flammable Gas * Self-Reactives * Organic Peroxide | |
| GHS-pictogram-acid.svg | | Corrosive   * Skin Corrosion/Burns * Eye Damage * Corrosive to Metals | |
| GHS-pictogram-rondflam.svg | | Oxidizer   * Oxidizers | |
| GHS-pictogram-bottle.svg | | Compressed gas   * Gases Under Pressure | |
|  | |  | |
| Symbol | | Usage | |
| GHS-pictogram-skull.svg | | Toxic   * Acute Toxicity (fatal or toxic) | |
| GHS-pictogram-exclam.svg | | Irritant   * Irritant (skin and eye) * Skin Sensitizer * Acute Toxicity * Narcotic Effects * Respiratory Tract Irritant * Hazardous to Ozone Layer (Non-Mandatory) | |
| GHS-pictogram-silhouete.svg | | Health Hazard   * Carcinogen * Mutagenicity * Reproductive Toxicity * Respiratory Sensitizer * Target Organ Toxicity * Aspiration Toxicity | |
| Environment | | Environmental (Non-mandatory)   * Aquatic toxicity | |

*(*[*https://www.osha.gov/Publications/HazComm\_QuickCard\_Pictogram.html*](https://www.osha.gov/Publications/HazComm_QuickCard_Pictogram.html)*)*

**Laboratory-specific signage**

Instructors and students should have knowledge and use of laboratory specific signage such as the ones given below.

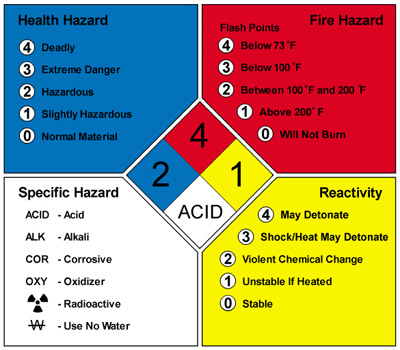
The **Fire Tetrahedron** is a simple way of understanding the factors of fire. The four essential ingredients needed to have a fire are represented in the tetrahedron. The four ingredients are:

* + - Enough oxygen to sustain combustion
    - Enough heat to raise the material to its ignition temperature
    - Some sort of fuel or combustible material
    - A sustained rate of rapid oxidation that produces a chain reaction

*(*[*https://en.wikipedia.org/wiki/Fire\_triangle*](https://en.wikipedia.org/wiki/Fire_triangle)*)*

**The National Fire Protection Association (NFPA) hazard identification system,**

The NFPA system, called the “Standard System for the Identification of the Hazards of Materials for Emergency Response” (NFPA 704), employs a diamond symbol to show the user the hazards associated with a specific chemical.



*(*[*http://www.mica.edu/Images/EHS/nfpaexample.jpg*](http://www.mica.edu/Images/EHS/nfpaexample.jpg)*)*

The diamond is a quick visual representation of the **health hazard**, **flammability**, **reactivity** and **special hazards** that a chemical presents. The diamond is broken into four colored fields; blue, red, yellow and white. The blue, red and yellow fields which represent health, flammability, and reactivity respectively use a numbering scale ranging from 0–4. A value of zero means that the material poses essentially no hazard while a rating of four indicates extreme danger. The white field is used to convey special hazards.

The NFPA hazard sign for methanol might look like this:

(<http://www.safetysign.com/images/catlog/product/large/M3347.png>)

**Assessing Each Experiment**

It is essential for teachers to spend time planning and preparing for each experiment and each demonstration. They should assess each experiment carefully before, during and after its execution. Below are some guidelines for assessing a given experiment.

Before the experiment:

1. Know what you are working with. You should always identify the substances you are working with.
2. Find and evaluate hazard information using the information found in the Safety Data Sheets.
3. Ensure the proper concentrations were prepared.
4. Ensure the bottles were properly labeled.

During the experiment:

Students should be closely and carefully supervised in the laboratory at all times.

1. During the pre-laboratory lecture, discuss potential hazards of the chemicals, safety considerations of the lab, proper use of personal protective equipment (chemical splash goggles and aprons or lab coats), methods of disposal of waste, and emergency procedures specific to the experiment.
2. Students and instructors must wear goggles, aprons and closed toed shoes. Long hair and dangling clothing must be pulled back.
3. Be aware of students’ handling of chemicals, use of equipment and good housekeeping procedures.

After the experiment:

1. Students should return any chemicals to the appropriate location or dispose of them according to the instructions. They should clean any used glassware and wipe down the lab table.
2. The Instructor should return glassware and equipment. Ensure that: all reagent containers are clean, closed and stored properly; disposal of chemicals is correctly handled; and the laboratory is left clean and dry.

**Chemical Hygiene Plan**

Every school should have a Chemical Hygiene Plan, a CHP. This is the plan to help protect people working in a laboratory setting. You should be familiar with your school’s CHP. It should be readily available to all. The components of a CHP are listed below:

* Standard operating procedures involving use of hazardous chemicals
* Criteria to determine and implement control measure to reduce employee exposure to hazardous chemicals
* Requirements to ensure control measures perform properly
* Employee information and training
* Operation requiring prior employer approval
* Medical consultation and examinations
* Designation of chemical hygiene officers
* Requirements for handling particularly hazardous chemicals
* Designated areas
* Containment equipment
* Procedures for safe removal of contaminate waste
* Decontamination procedures

The information listed above was taken from Hill, Robert H and Finster, David C. *Laboratory Safety for Chemistry Students*, Wiley, Hoboken, N.J., 2010, pp 3–48.

Note: Much of the information in this section is modified from a draft of the Safety Guidelines for Secondary School Science Education produced by the American Chemical Society Safety Task Force.

**More on hazards vs risk**

The terms hazard and risk are frequently used interchangeably but there is a distinct difference.

**Hazard** is any source of potential damage, harm or adverse health effects on someone under certain conditions at work.

**Examples of Hazards and Their Effects**

|  |  |  |
| --- | --- | --- |
| **Type of Hazard** | **Example of Hazard** | **Example of Harm Caused** |
| Thing | Broken glass | Cut |
| Substance | Potassium hydroxide | Blistering of skin |
| Source of energy | Bunsen burner | Burn |
| Condition | Wet floor | Slip or fall |

**Risk** is the chance or probability that a person will be harmed or experience an adverse health effect if exposed to a hazard.

A simple example is a wet floor is a hazard but the risk of falling would be reduced by placing signs warning of the wet floor.

Whenever preparing for a laboratory activity or demonstration one should always preform a risk assessment. According to OSHA:

Risk assessment is the process of:

* Identifying hazards.
* Analyzing or evaluating the risk associated with that hazard.
* Determining appropriate ways to eliminate or control the hazard.

(<http://www.ccohs.ca/oshanswers/hsprograms/hazard_risk.html>)

# Connections to Chemistry Concepts

**(for correlation to course curriculum)**

1. **Chemical Safety**—Throughout this article the importance of safety in the chemistry classroom is stressed. It emphasizes the importance of knowing the hazards of the material being used and assessing the risks they pose. The article cites how to learn about the hazards of a substance by using its Safety Data Sheet.
2. **Chemical reactions**—The combustion of methanol is the focus of this article, but any combustion reaction done in the classroom/lab has its own hazards**.**
3. **Combustion**—The requirements for combustion are explained, including the fact that the vapor, not the liquid, is what burns. Explanation of a flash point, fire point and autoignition are included in the article as well.
4. **Chemical and physical properties**—The chemical and physical properties of methanol (and any other substance) is described in its Safety Data Sheet.
5. **Kinetic energy and evaporation**—The article describes that as the temperature increases the average kinetic energy increases. When the molecules have enough kinetic energy to escape the attractive forces between molecules in the liquid phase, the molecules are able to evaporate and enter the vapor phase.

# Possible Student Misconceptions

**(to aid teacher in addressing misconceptions)**

1. **“All Safety Data Sheets for a given substance are the same.”** *Since each manufacturer or supplier is responsible for writing the SDS for a substance, they do vary. The format is now standard but the information does vary to some degree. Compare the following SDS for methanol:*

[*http://www.flinnsci.com/Documents/SDS/M/MethylAlcohol.pdf*](http://www.flinnsci.com/Documents/SDS/M/MethylAlcohol.pdf)*, from Flinn Scientific,*

[*http://www.labchem.com/tools/msds/msds/VT430.pdf*](http://www.labchem.com/tools/msds/msds/VT430.pdf)*, from Val Tech Diagnostics, Inc. and*

[*http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=US&language=en&productNumber=322415&brand=SIAL&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fproduct%2Fsial%2F322415%3Flang%3Den*](http://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=US&language=en&productNumber=322415&brand=SIAL&PageToGoToURL=http%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fproduct%2Fsial%2F322415%3Flang%3Den)*, from Sigma-Aldrich.*

*Note that the variations in content may very well depend on the audience for which they are intended. Flinn Scientific’s SDSs are written for teachers; Val Tech Diagnostics, Inc. writes their SDSs mainly for suppliers and manufacturers; and Sigma-Aldrich SDSs are geared toward chemists.*

1. **“Since ethanol is consumed when adults drink wine it must be safer than methanol.”** *Ethanol is less toxic than methanol, but still toxic. Methanol has an LD50 rat (oral) of 6,200mg/kg while ethanol has an LD50 rat (oral) of 10,470 mg/kg. (This simply means that it requires less methanol to kill a rat than ethanol.) Pure ethanol is just as flammable (flash point = 9 oC, versus 11 oC for methanol) and should be handled with the same kind of caution. Note that wine is not 100% ethanol (pure). It is only about 12% on the average. At this concentration the wine at room temperature will not ignite with a spark. Only if the wine is heated will the alcohol evaporate enough to be ignited with a spark.*
2. **“So, methanol’s spontaneous combustion is just like Human Spontaneous Combustion!”** *Methanol’s spontaneous combustion is due to its temperature reaching the liquid’s autoignition temperature, 464 oC. That’s the temperature at which it will spontaneously ignite, with no other source of heat, like a match or spark. I’ve read that human flesh will begin to burn at 1400 oF (that’s 760 oC), and that crematoriums run at   
   1800 oF (982 oC). But those temperatures reflect how hot it has to be for it to burn at all, not the temperature at which it will spontaneously ignite, or autoignite.*

*For a human body to burn spontaneously it would need two things: intense high heat and a flammable substance. Under normal conditions, neither exist. There is no scientific evidence that Spontaneous Human Combustion (SHC) occurs. The majority of SHC cases involve people that have little mobility, either from poor health, old age or obesity, and have died in their sleep. The cases usually involve either candles, cigarettes or alcohol. It is believed that once they catch fire they are unable to move. As* Benjamin Radford, M. Ed. writes:

*Only about a dozen claimed real-life cases of SHC have been investigated in any detail. Researcher Joe Nickell examined many "unexplainable" cases in his book "Real-Life X-Files" and found that all of them were far less mysterious than often suggested. Most of the victims were elderly, alone and near flames (often cigarettes, candles, and open fires) when they died. Several were last seen drinking alcohol and smoking.*

*If the person is asleep, intoxicated, unconscious, infirm or otherwise unable to move or put the flames out, the victim's clothes can act as a wick (most people spend most of their time wrapped in flammable clothing made up of cottons and polyester blends). The flames draw on the body's fat (a flammable oil very near the skin's surface which combines with the burning clothing) to fuel the fire.*

*If SHC is a real phenomenon, why doesn't it happen more often? There are 7 billion people in the world, and yet we don't see reports of people bursting into flame while walking down the street. No one has ever been seen, filmed or videotaped (for example, on a surveillance camera) suddenly bursting into flames. It always happens to a single person left alone near a source of ignition.*

*(*[*http://www.livescience.com/42080-spontaneous-human-combustion.html*](http://www.livescience.com/42080-spontaneous-human-combustion.html)*)*

# Anticipating Student Questions

**(answers to questions students might ask in class)**

1. **“As a student, where can I find the Safety Data Sheet for a chemical we use in the lab?”** *Your teacher should have access to the SDS for each substance that she uses in lab or in demonstrations. Your teacher should teach you how to read SDSs and make them available. It is always easy to locate them in an online search as well.*
2. **“In Section 5 of the SDS for methanol, it states that water will cause a methanol fire to spread. Why does this happen?”** *Water may not cool the fire to a temperature below methanol’s flash point. Since water is denser than methanol it will sink below the burning methanol, leaving the methanol exposed to oxygen in the air to continue burning. The temperature of the burning methanol will cause the water to turn to steam and in that process carry the burning methanol into the air.*
3. **“How do we know the information in the SDS is accurate, since it is written by the manufacturer?”** *The manufacturer wants to produce SDSs that are thorough and accurate. Providing inaccurate or false information could lead to serious harm and/or a lawsuit.*

## In-Class Activities

**(lesson ideas, including labs & demonstrations)**

1. Flame tests are always fun and exciting for students. It is a wonderful way to teach about the atomic emission spectra of elements. But it must be done in a safe manner. One safe method for flame tests is done using wooden splints soaked in concentrated metal salt solutions. A procedure for this method can be found at <http://www.nsta.org/publications/news/story.aspx?id=50902>. The American Chemical Society recommends a similar procedure at <http://www.acs.org/content/dam/acsorg/about/governance/committees/chemicalsafety/safetypractices/flame-tests-demonstration.pdf>.

Another safe method is to use a platinum or nichrome wire dipped into metal salt solutions and then into the flame of a lab burner. A procedure for this can be found at <http://imagine.gsfc.nasa.gov/educators/lessons/xray_spectra/activity-flame.html>.

1. Showing a video of the flame test is an alternative to performing the actual flame test. This flame test video (8:28) also teaches how to light a Bunsen burner. (<https://www.youtube.com/watch?v=o3nn4zqzf6M>) More videos of the rainbow demonstration can be found in the “More sites on the rainbow demonstration”, below.
2. Flame tests are also routinely use to identity metal ions and identify unknown substances. This Flinn video (13:26) is an excellent example of such an experiment. It provides a clear method for setting up such an experiment in your classroom. <https://www.youtube.com/watch?v=ZsvsptBQUVQ>
3. An introductory lesson on laboratory safety is essential for all science classes. One interactive safety lesson could involve activities in a series of stations. This has a good example of the safety activities that could be set up at eight stations. (<https://www.ocps.net/cs/services/cs/currareas/sci/IR/lessonplans/MID_LP/001Lab%20Safety%20Station%20Activity_0910.pdf>)
4. It is important for students to know and understand laboratory safety rules. One way to create a culture of safety with students is to have them create a safety spider activity. Before students are given any laboratory safety rules, the students are put into small groups. In their groups the students are to generate eight safety rules and write them on the arms of the spider (see below). They are instructed to be prepared to discuss each rule and to provide a justification for it. As a class, the students discuss the rules they generated and from that discussion a set of class safety rules is created. The teacher may add her own rules if there are any that are omitted.

**Laboratory Safety**

**Directions:** In your group, generate a list of 8 safety rules. Be prepared to discuss them as a class.

**Group Names:**

1.

2.

3.

4.

1

2

3

4

5

6

7

8

1. Safety demonstrations that emphasize the importance of wearing goggles are easy and effective. One such demonstration is to represent what would happen if acid got into your eye. Using a petri dish with an eye drawn on the bottom of it, an egg is cracked into it. It is then placed on the overhead projector stage and few drops of hydrochloric acid are added to the egg. Another demonstration is performed to show the effectiveness of goggles. A pie pan full of shaving cream is gently smashed into a volunteer’s face who is wearing goggles and an apron. Explicit directions for both these demonstrations can be found at <https://www.flinnsci.com/media/621876/91803.pdf>.
2. A valuable lesson would involve teaching students how to read a Safety Data Sheet. Flinn Scientific has a good handout that explains how to read the SDS at this site: <https://www.flinnsci.com/media/1041084/how_to_read_an_sds.pdf>. Another lesson involving the reading and understanding of Material Safety Data Sheets is given below. This activity could be easily modified to the new Safety Data Sheets. (<http://links-for-teachers.ashe.schoolfusion.us/modules/locker/files/get_group_file.phtml?gid=1583705&fid=7244573>)
3. To emphasize the importance of safety rules the teacher could perform the Flinn Safety Challenge. As described in their procedure: “A great way to show students that the safety rules make a lot of sense is to role-play what happens when the rules are deliberately ignored or violated. The purpose of the laboratory safety challenge is to have students witness lab procedures gone awry, and then use their observations to derive a common-sense set of safety rules.”

If the teacher prefers not to actually do the Safety Challenge, there is a video (12:55) that role-plays the poor use of safety rules. The complete instructions and video can be found at <http://www.flinnsci.com/teacher-resources/teacher-resource-videos/best-practices-for-teaching-chemistry/safety/laboratory-safety-challenge/>.

1. In teaching laboratory safety, it is important for students to be able to identify pieces of laboratory equipment and their uses. These two sites provide online quizzes for testing student’s knowledge of laboratory equipment: <http://www.sciencegeek.net/Chemistry/taters/labequipment.htm> and <http://chemistry.about.com/od/testsquizzes/l/blglasswarequiz.htm>.
2. A paper-and-pencil activity involving MSDSs, titled “Avoiding Chemical Warfare” can be found at <http://www.uwsp.edu/cols-ap/polyed/Documents/PDF/exercises/chem_warfare.pdf>. The activity has students describe and compare safety ratings for materials in household chemicals using SDSs (says “MSDS”, but can easily be modified to “SDS”) and RHFs (the NFPA diamond rating). This is similar to the Out-of-class Activity described below.
3. You could assign students to obtain their own set of SDSs (from the Web sources you provided from this TG) for a specific lab experiment (assigned by you during the year), and you could provide a list of specific items you want to see them summarize from those sheets. Items could include: physical properties of each, chemical properties, hazards they might face as they do the experiment, and potential hazards they might develop later (hopefully, none). This would certainly enhance their understanding of the need for safe behavior in the lab.

# Out-of-Class Activities and Projects

**(student research, class projects)**

1. A good activity that could be conducted at home is to have students inspect the cleaning materials used in their home. They could take one or two items and, using the internet, find the Safety Data Sheet for each of the main ingredients in the products. From the SDSs they would report out the physical and chemical properties of the substances and their hazards and decide if the warning on the label of the product is sufficient, based on the SDS.
2. The students could work in small groups to create a safety video. The safety videos could be submitted and shown in the class and then critiqued by the class (and, if the video is good, it can be used by you for future chemistry classes).
3. Along those same lines the students could create their own role play like the Safety Challenge mentioned above and videotape it. It could be shown and discussed in class. The Safety Challenge can be found at: <http://www.flinnsci.com/teacher-resources/teacher-resource-videos/best-practices-for-teaching-chemistry/safety/laboratory-safety-challenge/>.

# References

**(non-Web-based information sources)**



**30 Years of *ChemMatters***

Available Now!

**The references below can be found on the *ChemMatters* 30-year DVD (which includes all articles published during the years 1983 through April 2013 and all available Teacher’s Guides, beginning February 1990). The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [http://ww.acs.org/chemmatters](http://www.acs.org/chemmatters)**. Click on the “Archive” tab in the middle of the screen just under the *ChemMatters* logo. On this new page click on the “Get 30 Years of ChemMatters on DVD!” tab at the right for more information and to purchase the DVD.**

**Selected articles and the complete set of Teacher’s Guides for all issues from the past three years are available free online at the same Web site, above. Simply access the link and click on the aforementioned “Archive” tab.**

Tinnesand, M. Material Safety Data Sheets: Passports to Safety? *ChemMatters*, 2006, *23* (3), pp 18–19. This article describes the purpose and uses of the MSDS.

The October 2006 *ChemMatters* Teacher’s Guide for the above article provides additional information on Material Safety Data Sheets, fire extinguishers and goggles. It has some additional ideas for activities for in and out of the classroom.

# Web Sites for Additional Information

**(Web-based information sources)**

**More sites on** **Safety Data Sheets**

A brief history of recording the hazards of chemicals is traced back to ancient times at this site: <https://jrm.phys.ksu.edu/safety/kaplan.html>

At this Department of Labor site, OHSA explains each section of the SDS: <https://www.osha.gov/Publications/OSHA3514.html>.

A concise discussion of SDSs is given at <https://www.msdsonline.com/resources/ghs-answer-center/ghs-101-safety-data-sheets-sds>.

This site provides the “OSHA Quick Card” reference to the SDS:

<https://www.osha.gov/Publications/HazComm_QuickCard_SafetyData.html>.

These two sites provide a comparison of the Material Safety Data Sheet and the new Safety Data Sheet. Both also provide a little history and why the change was made.

(<https://www.msdsonline.com/blog/compliance-education/2012/08/20/from-msds-to-sds>) and (<http://www.dwt.com/OSHA-Takes-the-M-out-of-MSDS-and-Changes-Chemical-Labeling-Requirements-07-17-2013/>)

This site provides a variety of places to find SDSs: <http://www.ehs.pitt.edu/chemical/msds.html>.

This Flinn site provides SDSs that were written by science instructors and are easy to use: <http://www.flinnsci.com/msds-search.aspx>.

**More sites on** **the** **Occupational Safety and Health Administration**

The Department of Labor official site for OSHA can be found here: <https://www.osha.gov/>.

A short history of OSHA is provided at this site: <http://www.law.du.edu/thomson/AdminWiki/Labor_OSHA/EC77011AD85ABB5F713115C2C60D9CE9.html>.

A timeline of the accomplishments of OSHA can be found at <https://www.osha.gov/osha40/OSHATimeline.pdf>.

This Department of Labor site provide the history of establishing OSHA and the evolution of the process. (<http://www.dol.gov/dol/aboutdol/history/osha.htm>)

**More sites on** **methanol**

A description of methanol, its uses and applications, can be found at <http://knowledgeoman.com/en/community-speaks/methanol-uses-and-applications-2.html>.

A short history of the production of methanol is given at this site: <http://journeytoforever.org/biofuel_library/wood_alcohol.html>.

The chemistry of the production of methanol is explained at <http://www.methanol.org/methanol-basics/overview/how-is-methanol-made-.aspx>.

The toxicity of methanol in bootleg liquor is discussed at this site: <http://www.livescience.com/23305-bootleg-liquor-methanol.html>.

The complete safety alert on the use of methanol in the rainbow demonstration that was issued by the American Chemical Society is given at this site: <http://www.acs.org/content/acs/en/about/governance/committees/chemicalsafety/safety-alert-rainbow-demonstration.html>.

The Chemical Safety Board discussion of the hazards associated with the rainbow connection demonstration with methanol can be found at this site. It also gives a safer alternative for performing this activity. (<http://www.rsc.org/eic/2014/09/methanol-demonstration-combustion-safety>)

At this site, the series of accidents as a result of using methanol is described by the Chemical Safety Board. It also provides suggestions for preventing such accidents. (<http://www.csb.gov/csb-releases-key-lessons-for-preventing-incidents-from-flammable-chemicals-in-educational-demonstrations-in-wake-of-several-serious-methanol-accidents-that-injured-children-and-adults/>)

This video, “After the Rainbow” (4:54), tells the story of the accident that occurred in 2006 that severely injured a student. It is produced by the Chemical Safety Council as a safety message for the prevention of accidents in high school chemistry labs. (<https://www.youtube.com/watch?v=g6vR0BdRCNY>)

NSTA provides procedures for safely handling alcohol in the laboratory setting at this site: <http://www.nsta.org/safety/alcohol.aspx>.

**More sites on the rainbow demonstration and flame tests**

**CAUTION**: The two rainbow demonstration listed here are provided for use in the classroom. It is HIGHLY recommended by the American Chemical Society Committee on Chemical Safety AND the U.S. Chemical Safety Board (and the *ChemMatters* Teacher’s Guide editors) that this demonstration NOT be performed in the classroom. It is much safer to show the video.

This 3:29 video clip shows the rainbow demonstration without audio, so that you can add your own lesson as you use it in your classes: <https://www.youtube.com/watch?v=MDOOYZCDT3Y&feature=player_embedded>.

This video clip (2:26) has audio with it, explaining how the rainbow demonstration works. A teacher could use this information as they show the video above, with their own “voiceover”. (<http://wn.com/metal_flame_testing>)

This short video (4:48) is another traditionally-executed flame test. The images are clear and the clip provides excellent color example of the metal ions Li, Na, K, Ca, Sr, Ba and Cu.

(<https://www.youtube.com/watch?v=NEUbBAGw14k>)

**More sites on safety in the classroom**

At this site the American Chemical Society provides links to a wealth of safety information. It includes links to documents on safety for the elementary classroom, safety information for the chemistry teacher and their supervisors, and a safety code of conduct. It also includes safety documents for the college level. (<http://www.acs.org/content/acs/en/about/governance/committees/chemicalsafety/chemical-safety-in-the-classroom.html>)

The School Chemistry Laboratory Safety Guide produced by the U.S. Consumer Safety Product Commission (CSPC), Department of Health and Human Services (DHS), Centers for Disease Control and Prevention (CDC), and National Institute for Occupational Safety and Health (NIOSH) can be found here: <http://www.cdc.gov/niosh/docs/2007-107/pdfs/2007-107.pdf>.

This National Science Teachers Association site provide links to a variety of papers dealing with safety issues in the science classroom: <http://www.nsta.org/safety/>.

At this site is a series of ideas for lesson plans dealing with teaching safety in the science classroom: <http://mjksciteachingideas.com/safety.html>.

This Dartmouth University site provides information on safety, including safety rules, hazard and techniques. It also has a section on the proper use of chemical laboratory equipment. (<http://www.dartmouth.edu/~chemlab/info/logistics/info.html>)

This site contains a clear and simple list of chemical equipment and its purpose. The pictures could easily be used by teachers in their classroom documents. (<https://quizlet.com/74150354/lab-equipment-names-and-pictures-flash-cards/>)

OSHA provides a simple fact sheet that lists the requirements for a Chemical Hygiene Plan here: <https://www.osha.gov/Publications/laboratory/OSHAfactsheet-laboratory-safety-chemical-hygiene-plan.pdf>.

**More sites on hazards vs risks**

A comprehensive guide to evaluating hazards and assessing risks in the science laboratory can be found at this site: <http://www.ccohs.ca/oshanswers/hsprograms/hazard_risk.html>.

A clear discussion of hazard vs. risk can be found at this site: <http://www.hsa.ie/eng/Topics/Hazards/>.

This video (5:30) provides an excellent explanation and examples of hazards and risks. It also discusses evaluating the hazard and assessing risk. (<https://www.youtube.com/watch?v=PZmNZi8bon8>)