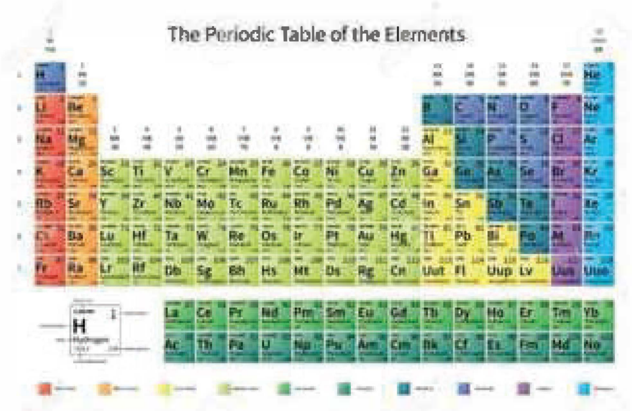
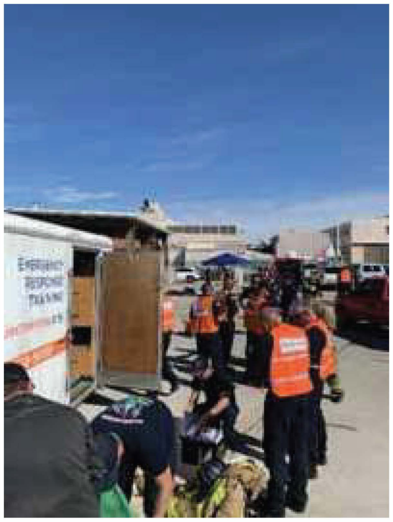
INDUSTRIAL EMERGENCY COUNCIL
Emergency Response Training

Hazardous Materials Technician 1A

Basic Chemistry





1301 Shoreway Road Suite 375 Belmont, CA 94002 (650) 508-9008 www.iectraining.org


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Table of Contents

Chapter 1: Orientation and Administration

Course Overview

This course builds on the previous week (Basic Chemistry) and gives students the tools and basic skills needed to select and operate monitoring and detection equipment, perform field analysis of chemical samples, find pertinent information on hazardous substances and evaluate the hazards of those substances.

Administrative Announcements

Course length: 40 hours.

Course completion requirements: attend at least 80% of the course, demonstrate the ability to perform assigned tasks and pass a written examination with a score of 70% or better.

Course management: the majority of the time in this course is spent on hands-on activities. The course manager will divide the class into groups of appropriate sizes to accomplish the assigned tasks in the most efficient manner. This may require you to periodically move to different training venues.

Facility policies: the course manager will advise you of all pertinent facility policies.

Course Objectives

Know the classification, identification, and verification of known and unknown materials by using field survey instruments and equipment. (Title 8 CCR §5192)

Through detection and monitoring verify the presence of hazardous material(s); determine the concentration of hazardous material(s) in the atmosphere, interpret, record and communicate the results of detection and monitoring equipment. (NFPA 472 7.2.1.2)

Collect and interpret hazard and response information from technical resources, computer databases and monitoring equipment. (NFPA 472: 7.2.2)

Estimate the likely size of an endangered area using applicable resources and equipment. (NFPA 472: 7.2.5)

Identify and/or classify unknown material using a field analysis system. (FIRESCOPE ICS Team Typing standard.)

Chapter 2: Introduction to Atmospheric Monitoring

Introduction

It's essential for a Hazmat Technician to know how to operate direct reading air monitoring instruments. They play an important role in hazard assessment and risk analysis. In addition, there are legal requirements for air monitoring. Title 8 California Code of Regulations §5192(q) has the following requirements for air monitoring.

- The Incident Commander shall "identify, to the extent possible, all hazardous substances…" (q)(3)(B).
- A Hazmat Technician must "Know the classification, identification, and verification of known and unknown materials by using field survey instruments and equipment." (q)(6)(C)(2).

Direct reading air monitors are devices that expose (either passively or actively) a sample of the atmosphere to one or more sensors. These sensors test a specific characteristic, such as flammability, unique to a chemical or a chemical family and provide results at the time of the sampling. In hazmat response they are used to identify oxygen-deficient or oxygen-enriched atmospheres, immediately dangerous to life or health (IDLH) conditions, elevated levels of airborne contaminants, flammable atmospheres, and radioactive hazards.

When released, many substances give off vapors, fumes or gases which can, or do, become airborne. Some vapors will displace Oxygen and make breathing in the area impossible. Others can create an explosive atmosphere and/or a toxic environment which cannot be seen or smelled. There are a wide variety of atmospheric combinations that can occur due to a chemical release many of which are capable of causing harm.

Air monitors are used to determine what is present or not present in the atmosphere. Direct reading air monitors are designed to provide specific information (e.g. concentration of Oxygen). The information they provide depends on the number and types of sensors installed in the instrument.

Airborne contaminants can be gases, vapors, fumes, mists, aerosols, particulates and/or ionizing radiation. When monitoring for airborne contaminants it is important for a Hazmat Technician to understand the principles of operation of direct-reading instruments, their limitations, how to operate them and how to interpret the information they provide.

Direct reading air monitoring instruments are used for the following purposes.

- Determining if an area is safe to enter or re-enter.
- Determining the level of a contaminant in the air.
- Selecting personal protective equipment.
- Delineating areas where protection is needed.
- Assessing the potential health effects of exposure.
- Identifying specific hazards (e.g. oxygen deficiency).
- Identifying specific contaminants (e.g. carbon monoxide).

Normal Atmospheres

Before the discussion of what can be detected in the atmosphere, it is important to understand the makeup of a normal atmosphere. There are a number of gases in a typical atmosphere. Most components are nontoxic (e.g., nitrogen, oxygen, argon, and carbon dioxide), however, some are quite toxic (e.g., nitrogen dioxide in higher concentrations). Any deviation from these concentrations can be hazardous.

Table 2.1: Composition of a Normal Atmosphere

Major Gases	Molecular Weight	Percent
Nitrogen	28.2	78.08
Oxygen	32.0	20.94
Argon	39.9	0.93
Minor Gases	Molecular Weight	PPM
Carbon dioxide	44.0	330
Neon	20.2	18
Helium	4.0	5
Methane	16.0	2
Krypton	83.7	1
Hydrogen	1.0	0.5
Nitrogen Dioxide	46.0	0.5
Xenon	131.3	0.08

For simplicity, throughout this text and during class we round off the figures as follows to represent a “normal” atmosphere: Oxygen=20.9%, Nitrogen=78% and Argon/Other Mixed or Minor Gases=1%.

Types of Direct Reading Air Monitors

There are several types of air monitoring instruments. Many air monitors used for emergency response to hazardous materials incidents do not identify the chemical; they only indicate the presence of a hazard. Responders will have to use other tools such as chemical-specific sensors, colorimetric tubes, pH paper, nitrate test strips and laboratory sample analysis to identify the product.

Atmospheric monitoring and detection devices can be divided into two general categories: air monitors and detectors.

Air monitors continuously measure the atmosphere for contaminants. They are used to detect the presence of a chemical characteristic which indicates the presence of that product and it's quantity in air, at the moment. Examples of these devices include flame ionization detectors, combustible gas indicators, photoionization detectors, infrared photo spectrometers, ion mobility, and electrolyte monitors.

Detectors are one-time measuring devices. Some, such as colorimetric tubes, test papers and strips, provide a positive or negative response. They may also provide quantification based on a fixed scale. Others, such as mass spectrometers and gas chromatographs, analyze a sample of the material. The key difference is that detectors analyze (or react to) one sample and need to be reset or replaced before another sample can be tested.

Monitoring and detection devices can be further classified by the method in which they define the presence of a substance.

The first are those that ionize materials as they enter a detection chamber. Ionization is the process of breaking compounds down into their anion and cation elements. This is accomplished by subjecting the material to sufficient energy to cause the ionization. These energy sources may be heat (flame ionization detector or combustible gas indicator), light (photoionization detector, infrared photo spectrometer or mass spectrometer), chemical (electrolyte), or a combination (gas chromatography and ion mobility).

The second method uses a chemical reaction to detect the presence of a substance. Examples include electrolytes, colorimetric tubes, test papers, and test strips.

Table 2.2: Various Atmospheric Monitoring Methods, Devices, and Capabilities

Method/Instrument	Capability	Limitations
Combustible Gas Indicator (CGI)	Measure combustible gases or vapors in air.	Not accurate in oxygen deficient atmospheres. Multiple sensitivities. Needs conversion factors.
Freon detection gun	Can qualitatively detect halogenated compounds in the air.	Neutralizing and masking gases.
Electrochemical	Detects specific compounds or groups of compounds using a reagent in a semi-permeable chemical cell.	Cell or electrolyte poisoning and possible oversaturation.
Oxygen Sensors	Measure oxygen levels in the air.	Affected by neutralizing and masking gases. Elevation will affect accuracy. CO_2 can poison the sensor.
Carbon Monoxide Detector	Detects the presence of carbon monoxide.	Neutralizing and masking gases.
Chemical specific cells	Reagents or substrates are placed into cells that react to gases passed over or through them.	May be prone to false positives.

Method/Instrument	Capability	Limitations
Flame Ionization Detector (FID)	Low detection levels for many compounds. Self-adjusting span for known compounds. Ionizes compounds by burning them in a hydrogen flame.	Can flame out at 10,000 ppm. Multiple sensitivities. Product must be ionizable.
Photoionization Detector (PID)	Measures volatile organic compounds and other gases.	Multiple sensitivities. Product must be ionizable. Can be adversely affected by humidity.
Infrared Detector (IR)	Detects atmospheric contaminants by passing various wavelengths of infrared light through them and seeing which wavelengths are absorbed.	Expensive. Humidity can affect readings.
Fourier Transform Infrared Spectroscopy (FTIR)	Analyze organic materials of particle size down to 10 micrometers. Library of several hundred thousand chemicals available. Programmable and light weight.	Complex, expensive, has difficulty with aqueous solutions, gives a percent certainty
Raman	Similar to FTIR, and it is not affected by aqueous solutions. Has the ability to penetrate most glass and plastic containers. Extensive library. Portable	Laser will ignite some substances. Expensive.
Gas chromatographs and gas chromatograph-mass spectrometers.	An FID or PID or electron capture sensor located at the end of a column packed to selectively separate gases and vapors.	Expensive. Requires professional maintenance.
Radiological Meters	Can detect ionizing radiation.	Each instrument may be configured differently. Not all will detect every type of ionizing radiation.
Mercury monitor	Can detect mercury vapor at very low levels by its reaction on gold films in a Wheatstone Bridge Circuit.	Very limited need for emergency responders. Interferences: Cl, H2S, most mercaptains.
Colorimetric Tubes	Can identify and measure the concentrations of specific compounds.	Cross-sensitivities. Interpreting results can be subjective. Many tubes can be inherently inaccurate.
pH Paper	Detects corrosive liquids or gases.	
Potassium Iodide (KI) Paper	Detects oxidizers in ionic compounds.	

Electrochemical Sensors

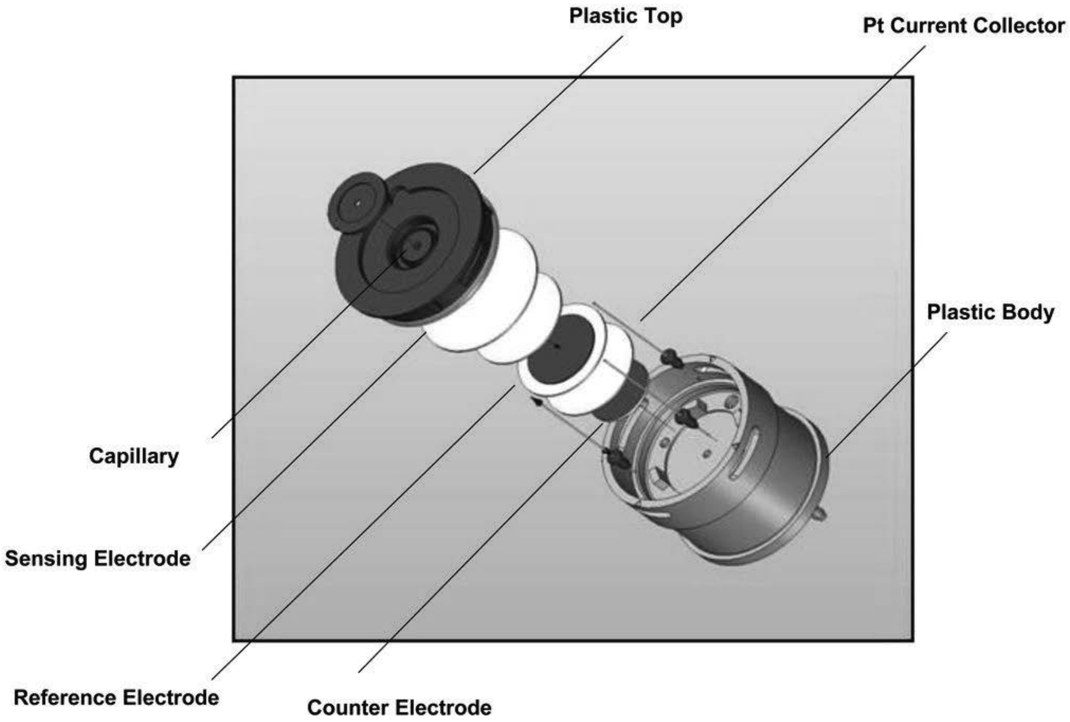
Sensors in monitoring instruments are designed to react to specific chemicals, family of chemicals or a specific atmospheric condition (e.g. flammable vapors). The following chapters will discuss in detail combustible gas indicators, photoionization detectors, ionizing radiation detection equipment and colorimetric tubes. In this chapter we'll focus on electrochemical sensors.

Electrochemical gas sensors measure the concentration of a gas by oxidizing or reducing the target gas at an electrode. The reaction generates an electrical current proportional to the concentration of the sample gas. The instrument will measure the resulting current and display the result in either parts per million or percent concentration.

The sensors contain electrodes, in contact with an electrolyte (a solution or gel that can conduct electricity). The electrolyte solution conducts electricity supplied from a battery. Atmospheric pressure forces the gas to diffuse into the sensor through a porous membrane to the electrode where it is oxidized or reduced. The chemical reaction produces an electric current that is directly proportional to the concentration of the gas. The change in current is amplified and displayed as a meter reading.

Figure 2.1: Electrochemical Sensors

Figure 2.2: Electrochemical Sensor Components



Electrochemical sensors, like other electrical detection devices, can be affected by interfering gases. A gas/vapor that is chemically similar to the gas you are monitoring for may give a positive result when it passes through an electrochemical sensor. For example, a sensor that reacts to formaldehyde will also react to alcohols.

Since the porous membrane requires the air to pass through it, it can become clogged by dust and particulates. The sensor electrolyte can be neutralized by some gases/vapors. Also, the electrolyte will eventually dry out so all electrochemical sensors have a limited shelf life. Low humidity can exacerbate this. (The acceptable humidity range for most electrochemical sensors is 15%-90%.)

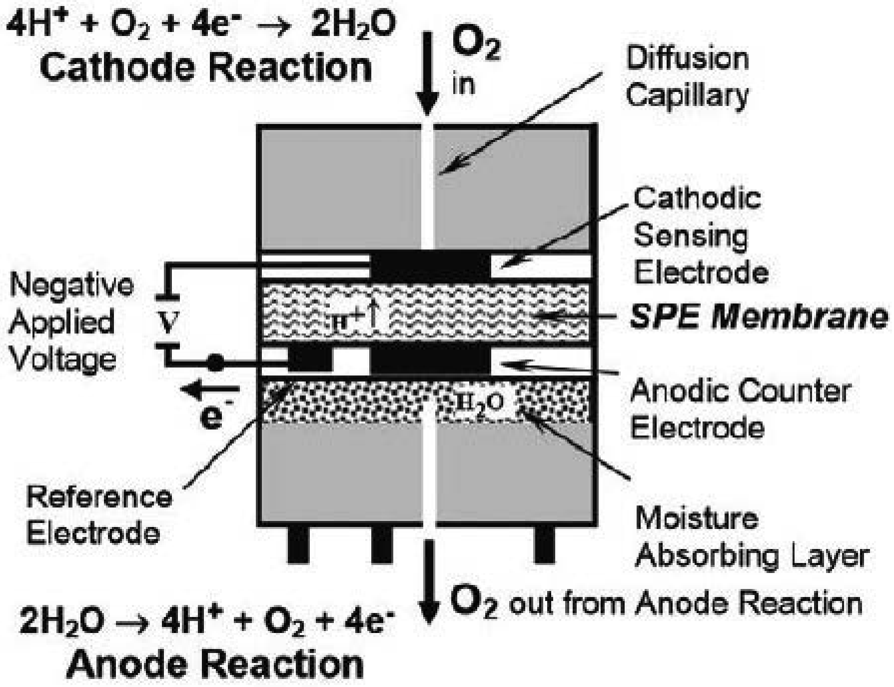
Since the electrolyte in the sensor is a gel. Low temperatures can reduce or even stop the current flow in the sensor. The sensors need an adequate oxygen level to function so their accuracy can be adversely affected by oxygen deficiency.

Electrochemical sensors can be “poisoned” by various common chemicals. Prolonged exposure to a poison may permanently destroy the sensor. Substances that can poison a sensor: Alcohols, Ketones, Phenols, Pyridine, Amines, or Chlorinated solvents.

Oxygen Sensors

Oxygen sensors are a type of electrochemical sensor. Like other such sensors, the gas will diffuse into the sensor and react with electrodes in an electrolyte. This electrochemical activity will cause the amount of electrical current generated to vary according to the concentration of oxygen in the gas sampled. The instrument will display this in terms of percent of oxygen present in the atmosphere. (Note: most CGIs have an oxygen sensor.)

Figure 2.3: Diagram of Oxygen Sensor



Limitations of Oxygen Sensors

Environmental Conditions

The effects of normal variations in humidity are insignificant. If the humidity is extremely low (less than 5%) then the electrolyte may dry out and give erroneous results. Sudden changes in humidity caused by such things as entering an air conditioned building from an area of high humidity may cause a transient response from the sensor. Most sensors will adjust to this change in humidity before the user even notices any change.

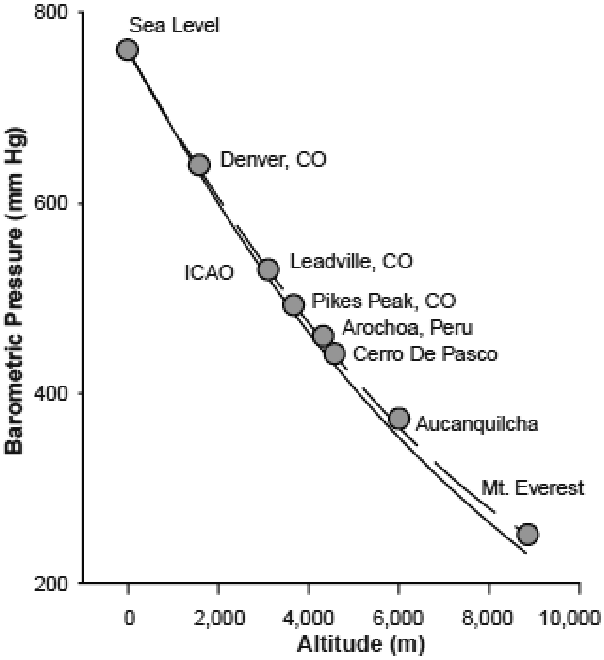
Changes in ambient temperature can cause differences in sensor response. Most instruments have firmware than compensates and adjusts for this. If the instrument used doesn't have this capability then the user may have to recalibrate the instrument if the ambient temperature changes significantly. Consult the manual for your instrument to see if the sensor has temperature compensation.

The instrument should be calibrated to the temperature at which it is used. The normal operating range for most oxygen sensors is between 32°F and 120°F (see manufactures recommendations for specific numbers). Between 0°F and 32°F, units will respond slower. Below 0°F, the sensors may be damaged.

Altitude

As altitude increases the atmospheric pressure will decrease. Most oxygen sensors will quickly adjust to moderate changes in atmospheric pressure so the effect of this is insignificant at altitudes below 7,000 feet.

Figure 2.4: Relationship of Barometric Pressure to Altitude



Source: *Medical Aspects of Harsh Environments Volume 2*, U. S. Army

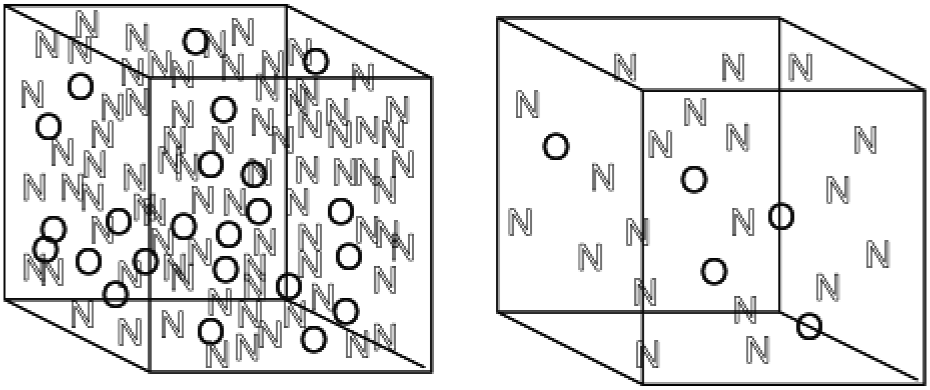
Changes in altitude will cause changes in the partial pressure of gases (including oxygen) in the atmosphere. Although the percentage of oxygen in air is constant at different altitudes, the fall in atmospheric pressure at higher altitude decreases the partial pressure of oxygen. Atmospheric pressure and inspired oxygen pressure fall roughly linearly with altitude to be 50% of the sea level value at 18,000 feet and only 30% of the sea level value at 29,000 feet (the height of the summit of Everest). A fall in inspired oxygen pressure reduces the driving pressure for gas exchange. This will reduce the apparent response of an oxygen sensor and cause the instrument to display inaccurate readings.

The table below shows the apparent oxygen readings at various altitudes

Elevation	Oxygen Reading
Sea level	20.9
500 feet	20.4
1,000 feet	20.1
2,000 feet	19.3
4,000 feet	18.0
6,000 feet	17.3
8,000 feet	15.4
10,000 feet	14.3

Changes in altitude will require the user to adjust the readings. The sensor must be fresh air zeroed or calibrated at the altitude of use for it to give accurate readings.

Figure 2.5: Partial Pressure of Oxygen at Various Altitudes



If the oxygen meter were adjusted to 21%, the percentage oxygen would in fact be correct. The boxes above represent one lung full of air. Both contain 21% oxygen. The amount of a gas per volume is called partial pressure. As you can see, the lung on the right has only one third the amount of oxygen that the lung at sea level on the left has. Although the percentage of oxygen hasn't changed, the amount of oxygen available to the body is far less. If the meter were correctly reading 19.5%, there would be far less again.

Interfering Gas

Interfering gases often produce false positive responses in electrochemical sensors. Acetylene, propane, and methyl alcohol are examples of commonly encountered gases or vapors that interfere with meter readings. In addition, strong oxidizing agents, like ozone or chlorine, can cause oxygen indicators to read high or normal when, in fact, the actual concentration may be normal or low. High concentrations of carbon dioxide can also shorten sensor life since it is an acid gas. The documentation for the instrument will list the gases that can interfere with the sensor(s) in the instrument.

Interpretation of Results

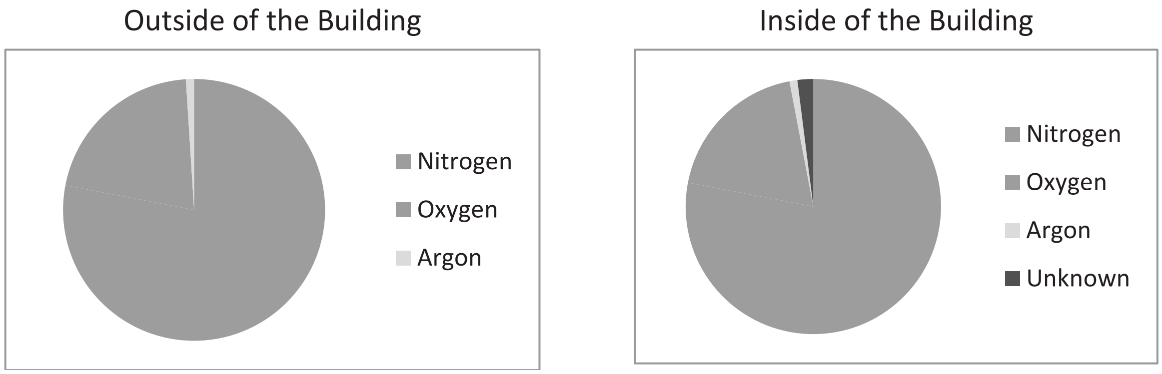
Oxygen meters provide a reading in terms of percent oxygen in air. The normal concentration of oxygen in air is 20.9%. The remaining 79% is comprised mostly of nitrogen.

When a decrease in oxygen occurs, it may be due to an oxidizing chemical reaction, which consumes the oxygen, or due to oxygen displacement from gases that are pushing the oxygen from the area. Examples of oxidizing chemical reactions include: rusting, decomposition of organic matter, breathing and even welding or drying paint. Conversely, any readings above 23.5% would be considered oxygen-enriched.

Oxygen meters monitor only oxygen, which is 1/5th of the atmosphere. Therefore 4/5th is "invisible" to the meter. For example, a decrease in oxygen of 1% (for example, from 20.9% to 19.9%) indicates that 5% of the atmosphere has been displaced.

An example: the Oxygen concentration outside a building is 20% and 19% inside the building. The concentration of oxygen in the building has dropped by 10,000 parts per million (1%). Since oxygen makes up 1/5 of the atmosphere, a 10,000 ppm drop in oxygen means the oxygen was displaced by 50,000 ppm of another gas.

Figure 2.6: Oxygen Displacement and Unknown Contaminants



Readings showing oxygen deficiency mean two things for the person not wearing an SCBA: an immediate hazard because of decreased oxygen concentrations and potential health hazards from the displacing gas.

Toxicology and Air Monitoring

Toxicology is the study of the adverse systemic effects of chemicals. *It is not just the study of poisons.* Many substances can be toxic without being classified as poisons (e.g. lead). "Poisons" are chemicals that produce illness or death in very small quantities. There are very specific definitions of this term. Responders should keep in mind that they need to assess the toxic properties of *all* substances involved in a response and not just those classified as poisons.

Assessments of the toxic properties of substances will affect decisions such as: what kind of chemical protective ensemble to wear, what kind of air monitor to use, whether to evacuate a population or shelter them in place. This section of the chapter will provide an overview of toxicological tools and terminology applicable to emergency response so you can better complete a hazard and risk assessment in an incident.

There are two key factors to consider when assessing the risk of toxicity: the dose received and the toxicity of the material involved. Virtually all of the substances a hazmat technician will encounter have been tested and evaluated for toxicity. There are several standard measures of toxicity. Most are recommendations by government agencies or industry groups. One measure of toxicity, Permissible Exposure Limit (PEL), is an OSHA regulation. These exposure limits are tools for determining relative toxicity and for evaluating the potential effects of exposure. *Many measure occupational (chronic) exposures and may not apply to emergency (acute) response exposures*. Also, most exposure limits are intended for use in the workplace. As such, they measure the toxic effects of a substance on healthy adults not on the general population.

Exposure Limits for Chronic Exposures

- **TLV**: Threshold Limit Value. A level at which exposure at or below the level of the does not create an unreasonable risk of disease or injury. *American Conference of Governmental Industrial Hygienists*
- **PEL**: Permissible Exposure Limit. OSHA's mandatory limits for air contaminants above which workers must not be exposed. PELs generally refer to how long a worker can be exposed to a hazardous substance. They are expressed three ways: Time weighted averages (PEL-TWA), Short-term limits (PEL-STEL) or Ceiling limits (PEL-C).

Exposure Limits for Acute Exposures

- **STEL**: Short Term Exposure Limit. The concentration to which workers can be exposed continuously for a short period of time without suffering from irritation, chronic or irreversible tissue damage. . *American Conference of Governmental Industrial Hygienists*
- **IDLH (NIOSH)**: Immediately Dangerous to Life and Health. Conditions that pose an immediate threat to life or health, or conditions that pose an immediate threat of severe exposure to contaminants, such as radioactive materials, which are likely to have adverse cumulative or delayed effects on health. *National Institute for Occupational Safety and Health (NIOSH)*

- **IDLH (OSHA)**: Immediately Dangerous to Life and Health. An atmospheric concentration of any toxic, corrosive or asphyxiant substance that poses an immediate threat to life or would cause irreversible or delayed adverse health effects or would interfere with an individual's ability to escape from a dangerous atmosphere. *Occupational Safety and Health Administration (OSHA)*
- **REL**: Recommended Exposure Limit. Occupational exposure limits recommended to protect workers from hazardous substances and conditions in the workplace. Most RELs are expressed as time-weighted average (TWA) exposures, for up to 10 h day -1 during a 40 h workweek. *National Institute for Occupational Safety and Health (NIOSH)*
- **LC_{50}**: Lethal Concentration 50%. Standard measure of the toxicity of the surrounding medium that will kill half of the sample population of a specific test-animal in a specified period through exposure via inhalation (respiration). LC_{50} is measured in micrograms (or milligrams) of the material per liter, or parts per million (ppm), of air or water; lower the amount, more toxic the material. LC_{50} values *cannot* be directly extrapolated from one species to the other or to humans.
- **LD_{50}**: Lethal Dose, 50%. The amount of a toxic agent (such as a poison, virus, or radiation) that is sufficient to kill 50 percent of a population of animals usually within a certain time. LD_{50} values *cannot* be directly extrapolated from one species to the other or to humans.

Note: most of these levels apply to healthy, adult, male workers. They may not apply to children or people with health problems.

Exposure Limits Applicable to the General Population

- **AEGL**: Acute Exposure Guideline Level. Describes the human health effects from once-in-a-lifetime, or rare, exposure to airborne chemicals. Used by emergency responders when dealing with chemical spills or other catastrophic exposures, AEGLs are set through a collaborative effort of the public and private sectors worldwide.
- AEGLs are calculated for five relatively short exposure periods – 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours – as differentiated from air standards based on longer or repeated exposures. AEGL “levels” are dictated by the severity of the toxic effects caused by the exposure, with Level 1 being the least and Level 3 being the most severe.
- All levels are expressed as parts per million or milligrams per cubic meter (ppm or mg/m3) of a substance above which it is predicted that the general population could experience, including susceptible individuals. The levels are:

Level 1	Notable discomfort, irritation, or asymptomatic non-sensory effects. Effects are not disabling, are transient and reversible upon cessation of exposure.
Level 2	Irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.
Level 3	Life-threatening health effects or death.

AEGL values represent threshold levels for the general public. That includes susceptible subpopulations, such as infants, children, the elderly, persons with asthma, and those with other illnesses. However, individuals, subject to unique or idiosyncratic responses, could experience the adverse effects at concentrations below the corresponding AEGL.

Exposure Limits and Air Monitoring

In general, the values described above are used to establish a level of risk to a population within a geographical area, in the event of a chemical release. The level is commonly called the Level of Concern (LOC). The LOC is a tool that can be used to make decisions about setting control zones, selecting PPE and selecting protective actions.

Most monitoring instruments are set to alarm when a specific concentration of a chemical reaches a predetermined point. These predetermined points are usually one of the levels defined above.

The general rules of thumb for the various LOCs are:

- TLV – If the concentration of a hazardous gas or vapor is above the TLV then responders should consider this to be a red flag. The concentration closer to the source is likely to be higher.
- STEL – If the concentration is above the STEL responders should consider designating that area the Exclusion Zone.
- IDLH – If the concentration is above the IDLH then responders shouldn’t enter that area without wearing an SCBA.
- AEGL – If the concentration is above the AEGL then responders should consider implementing protective actions for the affected population.

Exposure Limits, Air Monitoring and Risk Management

A hazmat technician has to systematically evaluate possible courses of action, identify risks and benefits, and determine the best course of action for any given situation. This process includes detecting hazards, assessing risks, and implementing and monitoring risk controls to support effective, risk-based decision-making. The following are definitions of the basic concepts in risk management.

- **Hazard**: Any real or potential condition that can endanger a mission; cause personal injury, illness, or death; or damage equipment or property.
- **Exposure**: The amount of time, number of cycles, number of people involved, and/or amount of equipment involved in a given event, expressed in time, proximity, volume, or repetition.
- **Severity**: An event’s potential consequences in terms of degree of damage, injury, or impact on a mission or task.
- **Risk**: The loss or adverse impact from exposure to various hazards; the chance of injury or property damage. Risk is a function of severity and probability.

Hazards

Air monitoring will help you detect and possibly identify airborne hazards. How precisely you can identify the hazard depends upon the instrument used.

Severity

Many instruments can detect a specific substance *and* ascertain the concentration. This information can help you evaluate the possible consequences of exposure. Using the information the instrument gives you with the information on toxicity provided by the exposure limits described above can help you evaluate the risk of exposure.

Risk and Toxicity

There are three general types of risks. The exposure levels described above can help you evaluate the types of risks present in an incident.

- **Acceptable risk:** The part of identified risk that is allowed to persist after controls are applied. Risk can be determined acceptable when further efforts to reduce it would cause degradation of the probability of success of the operation. *Rule of thumb:* if the levels of airborne contaminants are below the TLV then this would be an acceptable risk since basic PPE used in hazmat response will be adequate to protect responders.
- **Unacceptable risk:** That portion of identified risk that cannot be tolerated, but must be either avoided, eliminated or controlled. *Rule of thumb:* if the levels of airborne contaminants are above the IDLH then this would be an unacceptable risk without PPE that includes an SCBA.
- **Residual risk:** The portion of total risk that remains after management efforts have been employed. Residual risk comprises acceptable risk and unidentified risk. If atmospheric monitoring detects airborne contaminants then there is a residual risk present. Your ability to evaluate the level of residual risk would depend on the capabilities of the monitoring instruments used. *Rule of thumb:* if the levels of airborne contaminants are at or above the TLV then responders would have to consider continuing mitigation efforts. If the levels are below the TLV or are undetectable then responders can consider terminating the response.

Summary

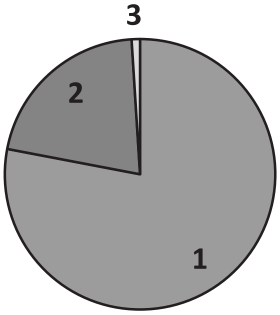
Air monitoring can help to determine whether release has actually occurred and, if so, identify the substance(s) and measure exposure levels.

Air monitors are used to determine what is present or not present in the atmosphere, within the limits of the instrumentation. Depending on the number and types of sensors installed in the instrument (called the *sensor configuration*) air monitors are designed to provide specific information. As an example, one type of air monitor, called a combustible gas indicator or CGI can either be a stand-alone combustibility meter or a combination meter. The combination meter will normally include a combustion sensor, Oxygen sensor and at least two specific toxic gas sensors (commonly carbon monoxide and hydrogen sulfide). (In the industry, this is known as a confined space configuration.) Up to 6 sensors may be combined into one “box” or “case” and sold as a multi gas meter.

Air monitoring is one of the most critical skills a responder must learn in order to determine what contaminates are or are not in the atmosphere. Understanding how sensors operate is the key to recognizing their capabilities and limitations.

Chapter Review

The pie chart below shows the main elements that make up a normal atmosphere. Identify the element that corresponds to each slice number.



1 ______________________________

2 ______________________________

3 ______________________________

Which of the following is an example of a direct reading air monitoring tool that is capable of *identifying* a substance?

1. Combustible gas indicator (CGI).
2. Flame ionization detector (FID).
3. Colorimetric tubes.
4. pH paper.

Which of the following is an example of a limitation of electro-chemical sensors?

1. Shelf life is sensitive to barometric pressure.
2. Can become clogged by dust and particulates.
3. Sensors are small in size.
4. Electrolyte can become dislodged if the instrument is dropped.

A gas that can produce false positive responses in electrochemical sensors is called a/an:

1. Irritant gas.
2. Masking vapor.
3. Interfering gas.
4. Pi bond generator.

A numerical value that can be used to quantify a level of risk to a population within a geographical area is commonly called the ________________________.

1. Area of impact factor.
2. Level of effect.
3. Coefficient of toxicity.
4. Level of Concern

The portion of total risk that remains after mitigation efforts have been employed is called:

1. Proportional risk.
2. Residual risk.
3. Acceptable risk.
4. Summary risk.

Chapter 3: Combustible Gas Indicators

Introduction and History

Combustible Gas Indicators, also known as CGIs are used to determine the concentration of flammable vapor or gas in an atmosphere. They are used during entry into hazardous materials incidents and for locating leaks from containers. This chapter discusses how a CGI operates and the critical importance of understanding how they function.

Combustible gas indicators (CGIs) are one of the most frequently used and important air monitoring instruments used at a hazardous materials incident. According to the U. S. Department of Transportation 50% of transportation-related hazmat incidents involve substances in Hazard Class 3 (Flammable/Combustible Liquids). From 2010 to 2014 there were 53 fatalities from transportation-related hazmat incidents. 49 of these were from incidents involving flammable liquids or gases. ATSDR statistics show that 34% of incidents at fixed facilities involve flammable gases. Hazmat Technicians are likely to use these instruments more than any other.

Coal mines were an important part of the economy in the United Kingdom in the 19th Century. These mines often had flammable gases (mostly methane) embedded in the rock. As miners excavated coal they would encounter pockets of flammable gases (called "fire damps"). If the gases were ignited the resulting fire could be catastrophic. In one such incident in England in 1835 102 miners were killed. Before the development of electric lighting coal mines used candles for illumination. Miners would use candles to find pockets of flammable gases. They would hold the candle in one hand and crawl over the floor to check on an area suspected to have gas present. The candle flame would change size and color if flammable gases were present. The inherent flaws in this process are rather obvious. Over the years various devices were developed to replace candles for illumination. Miners often used them as quasi-CGIs by observing changes in the flame. They were crude devices and weren't designed to detect flammable gases. They were often unreliable, inaccurate and easily damaged.

John Haldane, a prominent British physiologist, studied the effects of various gases found in coal mines. Haldane was known for self-experimentation. He exposed himself to high concentrations of carbon monoxide and found the symptoms he suffered were nearly identical to the symptoms exhibited by coal miners who were asphyxiated in mine accidents. He concluded carbon monoxide as the cause of deaths in the mines. He suggested that miners carry small animals like mice or canaries to detect dangerous levels of the gas in their working environment. Canaries had a high basal metabolic rate, making them exhibit symptoms of poisoning before gas levels became harmful to humans. He also found that a flame safety lamp could be used to detect methane since the height of the flame increased in the presence of methane. Conversely, it could be used to detect oxygen-displacement by the decrease in the flame. Until electronic detection devices were developed these techniques were the standard methods in mines for detecting carbon monoxide and methane.

Lower Explosive Level (LEL) Review

During A-Week you learned the concept of the Flammable Range of a vapor or gas. This is broken into two principal parts, the Lower Flammable Limit (Lower Explosive Limit) and the Upper Flammable Limit (Upper Explosive Limit) abbreviated LEL/LFL and UEL/UFL respectively. The LEL is defined as the leanest vapor/gas to air concentration that will ignite and burn when an adequate heat source is applied – spark, static, open flame and etc. (For simplicity, we will refer to all flammable airborne vapors, mists and gases as "vapor" in this chapter.)

Table 3.1: Basics of Flammable Range

As discussed in the previous section, most hazmat emergency responses will involve products that are flammable or combustible. Determining how close the vapor and air mixture is to the LEL is a critical, and common, safety issue.

Figure 3.2: Flammable Range of Formic Acid

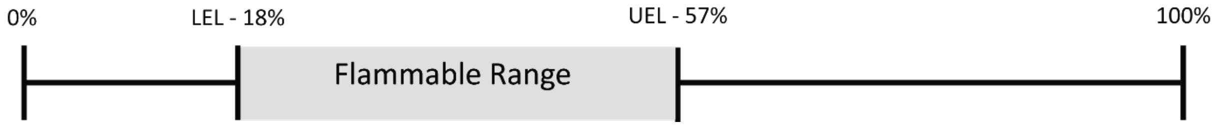
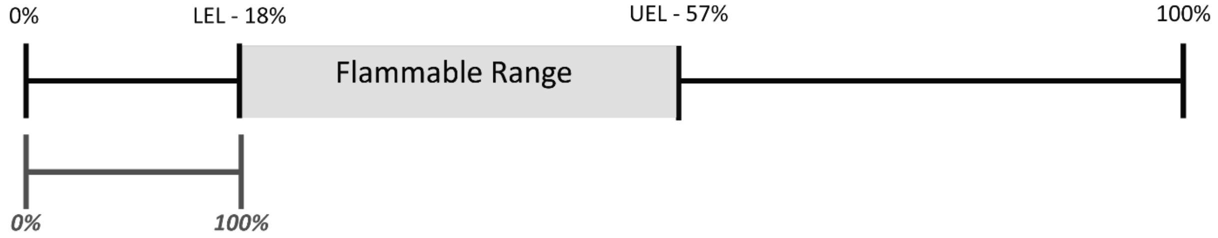


Figure 3.3: Formic Acid – What the CGI Measures (Percent of LEL)



The CGI measures the concentration of flammable vapors in the air. It displays the results on a scale of zero to one hundred percent *of the vapor's LEL*. (Note: the actual concentration may be above the LEL but the CGI won't tell you how far above the LEL you are.) The readings on a CGI are a percent of a percent.

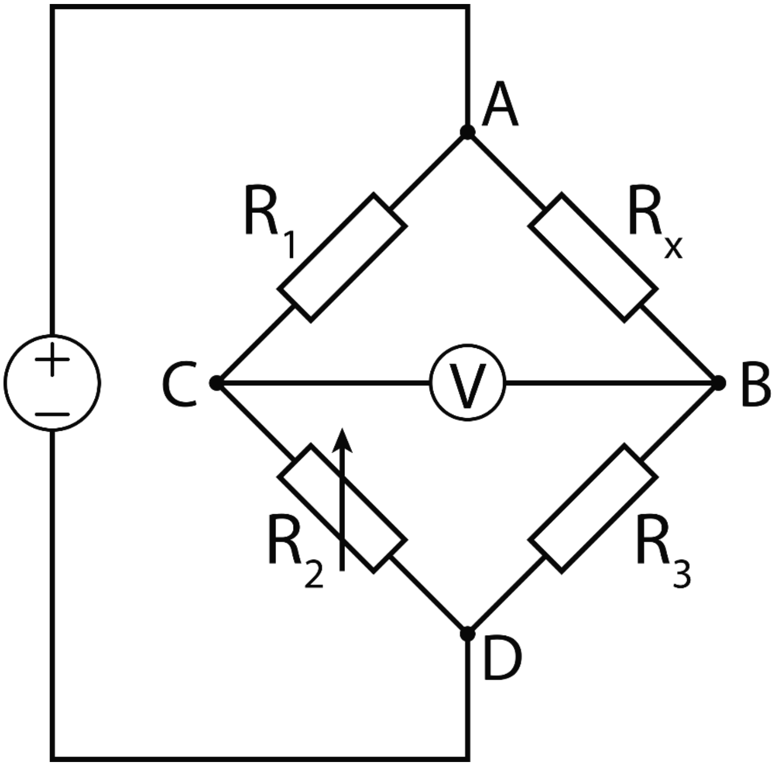
Operating Principles

There are three major types of CGI sensors: catalytic bead, non-dispersive infrared and semiconductor.

Catalytic bead CGIs

The first CGIs available were of the catalytic bead (hot wire sensor) type. Catalytic bead CGIs utilize two heated catalytic platinum wires connected to a Wheatstone bridge circuit.

Figure 3.4: Wheatstone Bridge Circuit



This type of CGI has a filament (R_x) that is coated with a catalyst. The catalyst forms a "bead" on the surface of the filament (usually a fine coil of platinum wire). The catalyst allows flammable gases to exothermically oxidize (i.e. burn) on that filament. The other filament (R_3) is called a compensating filament and is protected from exposure to the atmosphere. Each active bead is paired with a passive bead that contains no catalyst and is treated to ensure no flammable gas will oxidize on its surface. This "compensator" element is used as a reference resistance to which the sensor's signal is compared, to remove the effects of environmental factors (other than the presence of a flammable gas).

The instrument draws air across the two filaments and heats them with an electric current. As flammable gases/vapors oxidize on the catalyst the temperature on that filament will increase in direct proportion to the concentration of flammable vapor/gas present. This increases the electrical resistance which decreases the current flow across that circuit. The instrument will measure the difference in electrical properties of the two sides of the circuit. The differences are correlated to a known concentration of a calibrant gas. The instrument will then calculate the concentration of the sampled gas/vapor based on the changes in the electrical properties of the circuit.

It’s important to remember that a catalytic bead CGI doesn’t directly measure the concentration of the gas/vapor. It measures changes in the electrical properties of the Wheatstone Bridge circuit. The percent of LEL readings it displays are based on the gas it’s calibrated to. Other gases have different properties and will cause the sensor to behave differently when they oxidize on the catalytic bead. If you are monitoring a different gas you will have to use a correction factor for that gas to compensate for this. (Many instruments will automatically apply the appropriate correction factor to get an accurate measurement of the concentration.)

Some manufacturers of catalytic bead instruments also offer a separate infrared sensor to detect flammable/combustible vapors. These sensors use infrared light to detect and measure the quantity of vapors in the air. This type of sensor doesn’t “burn” the gases so it doesn’t require oxygen to operate. Unlike the catalytic bead sensor this sensor will read concentrations above the LEL. They are also not affected by contaminants that would “poison” a catalytic bead sensor.

Figure 3.5: LEL Sensors

Note: The catalytic reaction on a Wheatstone Bridge is *not* designed to detect combustible fumes, dusts, fibers, aerosols, or mists.

Solid State CGIs

In a solid state CGI the sensor is a semiconductor chip. The sensor is coated with a porous metal oxide, such as zinc oxide or aluminum oxide, and a heating element is embedded in the chip. The heating element regulates the sensor temperature. The sensors exhibit different gas response characteristics at different temperature ranges. This heating element can be a platinum or platinum alloy wire, a resistive metal oxide, or a thin layer of deposited platinum. Oxygen atoms capture electrons on the semiconductor surface thereby increasing its resistance. When voltage is applied to the circuit specific gases displace the adsorbed oxygen causing a reduction of resistance across the circuit. Electrodes imbedded in the metal oxide measure its conductivity change. The changes in the conductivity of the sensor resulting from the interaction with the gas molecules is measured and displayed as the concentration of the gas being measure.

Figure 3.6: Solid State Gas Sensor

Infrared (IR) Sensors

Some CGIs may have infrared sensors to detect and measure combustible gases/vapors. These are often used in fixed installations but they are also available for use in handheld instruments. These sensors use an infrared light source to measure the concentration of combustible gases/vapors.

These sensors consist of a single IR source, a beam splitter, and two detectors. One detector is the active detector and the other is a reference detector. As hydrocarbon molecules flow past the IR source they will absorb some of the infrared energy. The active detector will measure the amount of light absorbed by the hydrocarbon molecules flowing through the sensor. The reference detector isn't exposed to the gas being monitored. The receiver detects any difference in the energy received by the two detectors. If no hydrocarbons are present within the gas sampled, then energy reaching the detectors is the same. Any difference between the two detectors indicates the amount of hydrocarbon gas present.

Limitations of CGIs

CGI s must be “intrinsically safe” which means the instrument must be constructed to prevent the ignition of combustible atmospheres. The National Fire Protection Association (NFPA) has identified types of hazardous atmospheres in its National Electrical Code (NEC). The NEC, which is published every three years, categorizes hazardous atmospheres according to class, division, and group. Response personnel must use only CGIs that are UL listed or FM approved as intrinsically safe for use in Class I/Division 1 atmospheres.

CGIs, like all monitoring instruments, are susceptible to damage from corrosive atmospheres. A catalytic bead CGI can be damaged or inhibited by exposure to hydrogen sulfide, organic heavy metals, compounds containing sulfur or phosphorus, silicones, silicates or halogenated hydrocarbons. Those substances can coat or damage the catalytic bead and render inaccurate or unusable. Catalytic beads can be “poisoned” when the bead absorbs a contaminant or it can be rendered unusable by contaminants coating the catalyst. (Infrared sensors aren’t damaged by exposure to silicones.)

A catalytic bead CGI “burns” a sample of the air to detect flammable vapors. If the atmosphere doesn’t have a normal level of oxygen then the meter readings may be inaccurate. If the oxygen level is below 10% the sensor will likely not function at all. Levels of 10-15% can cause decreased meter response. Oxygen levels above 21% can cause exaggerated readings. (Infrared sensors don’t require oxygen to operate.)

CGIs may be susceptible to electro-magnetic (EM) interference. When electrical interference is present (e.g., from magnetic fields, high voltage wires, static electricity, radios, and cellular telephones), the meter readout can respond erratically, sometimes indicating a positive reading and sometimes indicating a negative reading. Electromagnetic fields may be encountered near high tension power lines, in utility vaults, buildings, and sewers.

No CGI, regardless of the sensor used, will detect all types of combustible gases/vapors. It’s important to check the documentation for your instruments to determine their limitations.

Preparing the CGI for Use

The following are general instructions applicable to most CGIs. However, response personnel should always check the manufacturer’s documentation for operating instructions specific to the instrument(s) they use.

Turn on the meter

Turn the meter on in a clean atmosphere away from operating vehicles and portable engines exhaust. Allow the meter to warm up as per the manufacturer’s operating instructions.

Calibrate the instrument

Calibration ensures the accuracy of a CGI. It is not necessary to calibrate the instrument before each use (unless the manufacturer recommends it). Most manufacturers recommend that a calibration check be performed monthly or quarterly.

Instrument Calibration is accomplished by passing a known concentration of a combustible gas (for an LEL sensor) through the instrument. The response is then compared with performance data supplied by the manufacturer and adjustments are made in accordance with that manufacturer's instructions. Most CGIs are delivered with the appropriate calibrant gas-air mixtures, typically known as "5-nines gas" (99.999%), and flow-regulating equipment that regulates the pressure of the gas delivered to the instrument. Calibration involves adjusting the readings on the instrument to match the calibration gas. If the instrument cannot be sufficiently adjusted then it must be returned to the manufacturer as per their instructions.

Calibration checks should be performed on a regular basis and the results recorded. This recording is called a calibration log. You should check the calibration log prior to an incident to ensure the instrument has been calibrated as per the manufacturer's specification. (Several manufacturers now have docking/charging stations that automatically calibrate at predetermined intervals while in storage.)

"Zero" the meter

To Zero a meter is to set the meter to read Zero. Zeroing is part of the start-up procedure and must be performed in clean air. The process is often called a "Fresh Air Zero." In situations where the instrument is no longer being exposed to a chemical, but will not reset to zero, a demand zero may be indicated. There are several ways to Zero a meter. One is to pre-program the meter to automatically Zero after you turn it on, another is to manually initiate a Zero by pressing the designated button or sequence of buttons.

Field-check (Bump Test) the instrument

A "Bump" test is a process of briefly exposing the instrument sensors to a known concentration of gas (also referred to as a "functional test"). A bump test checks for sensor and alarm functionality but does *not* measure sensor accuracy. No adjustments are made to the instrument during a bump test (i.e. calibration).

Bump tests are commonly done prior to using the instrument but manufacturer recommendations on Bump test intervals vary. Check the manual for you instrument to determine how often to perform this test. Some manufacturers provide a docking station for the instrument that automatically performs Bump tests.

This is a quick way to confirm that the sensor is detecting the target gas and is providing data to the readout. It is *not* used to confirm calibration, but is used to confirm that the instrument functions. When using a flammable source, be extra cautious *not* to over saturate the sensor. The best source is calibration gas as it will activate all of the sensors. Check with your manufacturer for the different types of Bump Tests and how best to validate them.

The only way to verify proper sensor and alarm operation is to perform a bump test.

The bump should accomplish the following:

1. Activate the sensor and get readings.
2. Use enough gas to activate the alarms for the different sensors.
3. Ensure that the readings return to Zero in a reasonable time.

Using calibration gas will accomplish all of the above desired results.

Attachments and Appliances

Many CGIs come with probe filters. The four most common types are water traps, dust filters, inhibitors, and activated charcoal. Water traps prevent liquids from entering the sampling chamber. Dust filters provide the same protection from solid particulates. Activated charcoal filters are designed to absorb complex hydrocarbons, like aromatics. This can help in the identification process through elimination. Inhibitors prevent certain reactions from taking place within the sampling chamber. Other appliances include tube extenders.

Some manufacturers provide methane elimination switches that are designed to prevent methane from masking other gases or to be read by the device. These must be activated by opening up the instruments. They can help in the identification process by eliminating methane as a masking agent.

Monitoring Considerations

As the entry team approaches an incident or confined space atmosphere, it's important to verify that the oxygen levels are close to normal and that flammable conditions do not exist. If the oxygen levels are too low, the CGI won't function properly. (Most CGIs require a minimum of 10% oxygen to operate properly. An oxygen-enriched atmosphere (>23.5%) is an OSHA turn-back point in confined space entry and a potentially flammable atmosphere due to the increased oxygen. Both oxygen levels and flammable conditions will normally be checked simultaneously. It also must be pointed out that a reading of "0" on the % LEL sensor indicates a concentration less than 1% LEL, up to 499 ppm if the LEL sensor is calibrated to methane. (LEL of methane is 5% in air, 50,000 ppm X 1% = 500 ppm.)

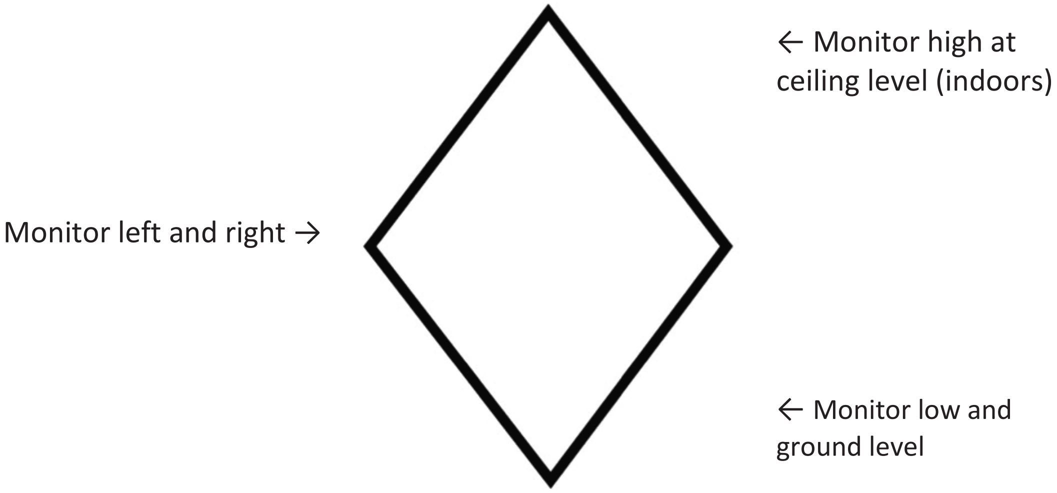
Catalytic bead sensors read from 0-100% of the LEL. An atmosphere that is above 100% of the LEL will over-saturate the sensor. Most instruments will display an overrange alarm and the catalytic bead sensor will shut down to avoid damage to the catalyst. Oversaturation can also displace oxygen causing the sensor output to decrease. This can cause the instrument to indicate that gas levels are decreasing when, in fact, they aren't.

If the gas is being drawn into the CGI by a probe or tube, there will be a delay period between the point of time when the sample enters the probe or tube tip and when the contaminant reaches the sensor. This is known as the "lag time" of the instrument. This delay period increases when an extension hose is added to the sampling probe. There will be a second delay period, known as the "response time." This period is the amount of delay between when the meter first recognizes the presence of a contaminant and when the meter reading measures with 90% accuracy. Approximate delay times can be determined during the field-testing process. Note how long it takes the meter to respond after introducing the bump test or calibration gas into the sample port.

Your actions throughout the event should be based on your observations of the lag and response time for the meter. Some meters require a minimum of 30 seconds to reach 90% accuracy. For this reason, responders should approach an area slowly and deliberately, giving the CGI time to react to any contaminants present. If the survey is done too quickly, the responder may miss a pocket of gas or unwittingly enter a hazardous area before the meter provides a warning.

Which locations to sample is an important factor. Heavier-than-air gases may settle in low areas and lighter-than-air gases may pocket near ceilings. The responder should attempt to sample as much space as possible with the instrument and sampling wand.

Figure 3.7: Diamond sampling pattern



Interpreting the Results – Calibration

CGIs are calibrated to a specific gas. A CGI won’t give accurate readings for other gases and vapors.

There are two primary reasons for this.

Molecule Size

A catalytic bead sensor can only detect gases that are able to come into contact with the bead. Catalytic bead sensors have a flame arrestor and diffusion barrier. Gases such as hydrogen are small molecules and easily move through the diffusion barrier on the sensor. Vapors such as diesel fuel are made up of much larger molecules and are slower to cross the diffusion barrier. The result is, a CGI sensor is more sensitive to lighter gases such as hydrogen and methane than it is for heavier vapors such as jet fuel. The smaller molecules reach the sensor faster and are detected quickly. Larger molecules such as hexane take longer to reach the catalytic bead. The sensor responds more slowly to such substances. This effect is especially pronounced with substances such as diesel fuel and kerosene.

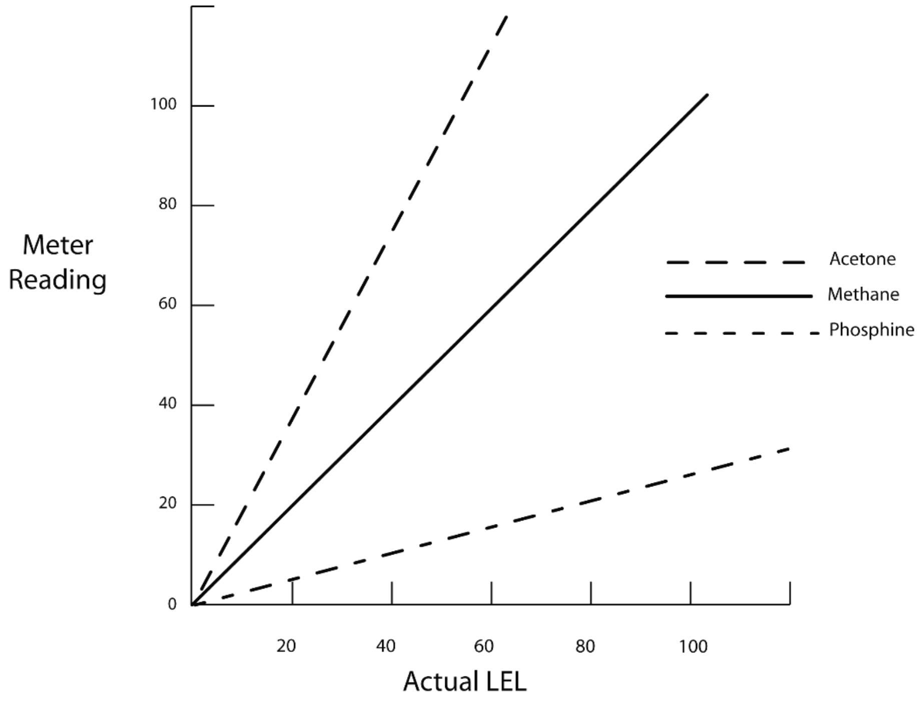
Wheatstone Bridge Calibration

As discussed earlier, the Wheatstone Bridge circuit in a CGI measures changes in the electrical properties of the circuit that result from exposure to flammable gases/vapors. To convert that reading to a useful measure (such as percent of LEL) the readings have to be correlated to a specific calibration gas. Other gases and/or vapors will affect the sensor differently than the calibrant gas will.

Response Curves

The figure below shows how different substances produce different LEL readings than the readings for the calibrant gas, in this case methane. The readings for other substances can differ significantly from the actual level of flammable gas present.

Figure 3.8: Simplified Response Curves



Conversion Factors (Also called "Correction Factor" or "Correlation Factor.")

A CGI is calibrated with a specific gas. The instrument will display LEL values that assume that all of the gases you're monitoring are that one specific gas. If a sensor calibrated to methane detects ethane, the instrument will display LEL values assuming the gas it's monitoring for is methane.

When monitoring for a gas that the instrument isn't calibrated for the user will have to apply correction factors to obtain an accurate reading. In general, correction factors increase as the size of the molecule increases. (Note: Correction Factors for catalytic bead sensors will differ from those used for infrared sensors.)

Formula	Name	CF
CH_4	Methane	1.0
C_2H_6	Ethane	1.4
C_3H_8	Propane	1.6
C_4H_{10}	Butane	2.0
C_5H_{12}	Pentane	2.2
C_6H_{14}	Hexane	2.3
C_7H_{16}	Heptane	2.4
C_8H_{18}	Octane	2.9
C_9H_{20}	Nonane	3.2
$C_{10}H_{22}$	Decane	3.4

Manufacturers will calculate conversion factors for various gases and vapors. They are used to describe an estimated response curve. Response curves for most gases and/or vapors are often non-linear at the extreme ends. To simplify the calculations correction factors assume that the response curve of a given gas is linear. This may create a deviation of up to 20% of the actual concentration and a ±5% deviation in the LEL reading. Correction factors are specific to each CGI model and manufacturer and should not be interchanged.

CGIs are often programmed with a library of conversion factors. The CGI will calculate the adjusted reading for the gas sampled. If the instrument doesn't have a built-in library of conversion factors or if the gas you are sampling isn't in the instrument's library then you will have to manually calculate the actual LEL reading. To do this you multiply the reading displayed on the instrument by the correction factor. For example, you have a CGI calibrated to methane. You are monitoring a propane leak. The meter display says the concentration of propane is 5% of the LEL. The correction factor for propane is 1.6. The actual concentration is 5 X 1.6, 8% of the LEL.

Interpreting Results – High Concentrations

High concentrations of a vapor or gas can give erroneous readings. Occasionally in atmospheres containing a high concentration of gas, the meter will go to 100% LEL and then immediately drop back to 0% LEL. This indicates an extremely dangerous condition: the lower explosive limit (LEL) has been exceeded. Instruments may read "Over" , "Out of Range" "OR+" or another manufacture specific message to indicate that the concentration met or exceeded the LEL and/or the UEL. (Many manufacturers have circuitry that shuts down the heat source to the catalytic bead to prevent damage to the instrument.)

Interpreting Results – Zero ≠ Nothing There

It’s important to remember when monitoring hazardous atmospheres is that *any* reaction of the CGI, whether expected or not, indicates a potentially hazardous condition. A mere 1% LEL reading on a CGI meter can indicate the presence of several thousand ppm of a contaminant. Many gases are considered highly toxic at far lower concentrations than that. Furthermore, field CGIs are somewhat insensitive; a “0” reading on the CGI meter would not rule out the possible presence of 600 to 1000 ppm of a contaminant. If the instrument reading is “0” that means your meter didn’t detect anything. It doesn’t mean there’s nothing there.

Chapter Review

Why is it important to monitor for oxygen levels when using a CGI to measure flammable gases/vapors?

What is a “bump test” and how do you perform one?

What is meant by response time on a CGI? How does it impact the way in which monitoring is done?

What conclusions can you draw if you get a “0” reading on a CGI?

What are some of the limitations associated with a CGI?

You've respond to a hexane spill. You get a meter reading of 20% LEL on your CGI. The manufacturer's instructions state that the conversion factor for hexane of 1.3. The LEL of hexane is 1.1%. What is the actual concentration of hexane in percentage LEL and ppm?

LEL:

PPM:

What environmental conditions would cause you to consider using a probe filter?

You are monitoring an atmosphere that you suspect contains flammable vapors. Your meter gives you a reading of "Out of Range" on the meter display. What does this mean? Does it indicate a dangerous condition?

Chapter 4: Photoionization Detectors (PID)

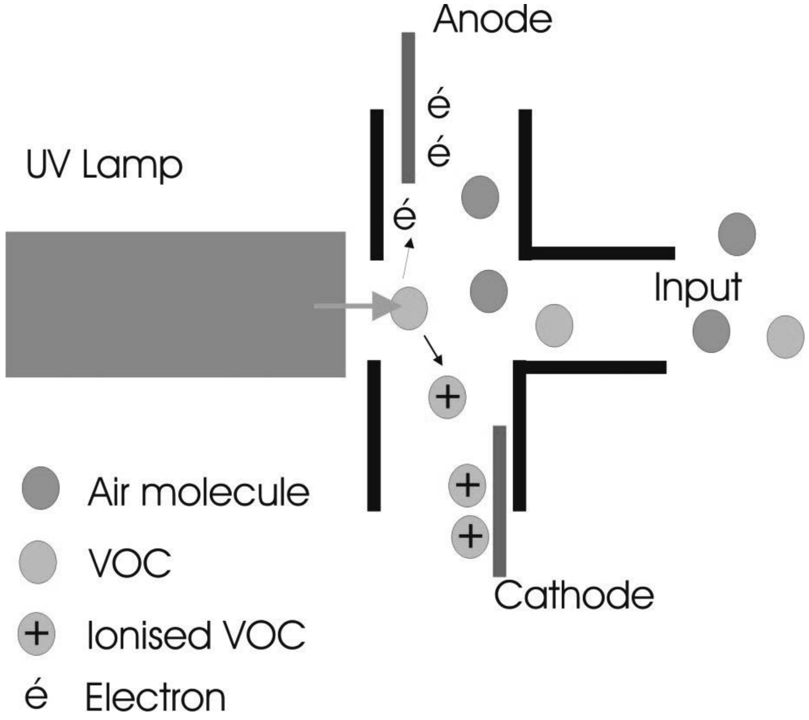
Introduction

PIDs are instruments that detect and measure low concentrations of volatile organic compounds (VOC). They can detect concentrations in the range of 0.1 to 10,000 ppm, but sometimes as low as the parts-per-billion range. (Note: a PID can detect some inorganic gases such as ammonia and hydrogen sulfide.)

They use ultraviolet (UV) light to ionize molecules of a gas or vapor to produce electrically charged particles (ions). These charged particles are attracted to a charged electrode and generate measurable electrical current at that sensor. This change in the current is proportional to the amount of VOCs present. The instrument measures this current and displays as a digital reading indicating the level of organic vapors present. PIDs are non-specific. They will measure the level of contaminants present but they won't identify the contaminant(s).

A Photoionization detector consists of a probe, a detection chamber containing an energy source, a power supply, an amplifier, and a meter.

Figure 4.1: Diagram of Photoionization Detector Basic Operation



Photoionization Detector Operation

Photoionization detectors (PIDs) use high-energy ultraviolet (UV) light to ionize molecules from contaminants in the air in a process known as photoionization. As compounds enter the detector they are bombarded by high-energy UV photons and are ionized when they absorb the UV light, resulting in ejection of electrons and the formation of positively charged ions. The ions produce an electric current, which is the signal output of the detector. The magnitude of the current is proportional to the concentration of the gas/vapor being sampled. The greater the concentration of the gas/vapor, the more ions are produced, and the greater the current.

The energy required to ionize a compound is referred to as its ionization energy. (Note: this property was formerly known as “ionization potential” but this is an obsolete term that isn’t scientifically correct. This document will use the current correct term.)

Ionization energy is measured in electron volts (eV). The ionization energies of common gases and vapors can be found in reference sources such as the *NIOSH Pocket Guide to Chemical Hazards* and in PID manufacturers’ documentation. (Many reference sources haven’t been updated in several years and still use the obsolete term “ionization potential” instead of ionization energy.)

Figure 4.1 illustrates the PID detection process. Sample gases enter the instrument and pass by an ultraviolet lamp. The UV light breaks down the gas into positive and negative ions causing the gas to become electrically charged. The charged ions flow to charged electrodes and generate an electric current. The instrument measures this current and displays it as the concentration of the organic vapors in the atmosphere.

Photoionization detectors cannot ionize the major components of air: oxygen, nitrogen, carbon dioxide (IE 15+), water vapor, carbon monoxide (IE 12.0 – 15.6), or methane (IE 12.98). If it could, the detector would be worthless for routine use and constantly in alarm mode.

Photoionization Detector Lamps

A key component of a PID is the UV lamp. The UV light energy emitted by the lamp is measured in electron volts (eV). The UV energy given off by the lamp will determine what substances it can ionize (and therefore detect). A given lamp can only ionize gases that have an ionization energy less than the eV energy of that lamp. For example, a 9.8 eV lamp will detect gases with an ionization energy of 9.8 eV or less. If a gas has an ionization energy greater than the eV energy of the lamp then that instrument won’t detect that gas. For example, carbon monoxide has an ionization energy of 14.01. No PID currently in existence can detect CO.

The eV rating of the lamp will determine whether or not you can use a PID. It will also determine what gases/vapors the instrument will detect.

There are a variety of UV lamps available with different eV capacities. The most commonly used PID lamp is the 10.6 eV. Other standard lamps have ionization energy capacities of 9.8, 10.2 or 11.7 eV. Since the eV rating of the lamp will determine which substances it can detect it would seem reasonable to select the lamp with the highest eV rating. In practice, though, this isn’t always a good tactic. The 11.7 eV lamp is much less specific than a lamp with a lower eV rating. An 11.7 eV lamp will detect *everything* with an ionization energy of 11.7 eV or less. That means the instrument will detect so many gases that you won't be able to tell if the gas you're looking for is present or if the instrument is detecting one or more gases that are of no concern. A PID is sensitive but not selective. Increasing the eV rating of the lamp makes it more sensitive to more substances but also makes it less selective.

There are other factors to consider when selecting a UV lamp for a PID. The lamps rated for higher eV usually have shorter service lives; often measured in months. The different lamps are constructed of different materials. The windows used in an 11.7 eV lamp are made from lithium fluoride. This material is degraded by UV light and easily absorbs water. This reduces the service life of the lamp. Although an 11.7 eV lamp can ionize more substances it generates a weaker ion current. The instrument has to amplify this current and that makes the 11.7 eV lamp have a lower resolution.

The 10.6 eV lamp offers the best balance of specificity detection capability and lamp life. For these reasons the 10.6 eV lamps are the most commonly used.

Ionization Energy of Common Materials

Substance	**Ionization Energy**
Carbon Monoxide	14.01
Methane	12.61
Ammonia	10.15
$CFCl_3$ (Freon)	11.77
Propane	11.1
Sarin	10.5/10.6
Vinyl Chloride	10.0
Acetone	9.69
MEK	9.53
Benzene	9.25
Toluene	8.82

The PID order of sensitivity (most sensitive to least sensitive)

- Aromatics, Iodine Compounds
- Olefins, Keytones, ethers, amines, sulfur compounds
- Esters, aldehydes, alcohols, Aliphatics
- Chlorinated aliphatics, ethane
- Methane (No Response)

Photoionization Detector Limitations

Unfortunately the lamps (or bulbs) are not always interchangeable. The amplifier in most PIDs is specific to a particular eV bulb rating. Do not mix bulbs, probes, and amplifiers unless the manufacturer specifically provides for this capability.

PID lamps are sensitive and must be treated carefully. The lamp face is treated and can be affected by fingerprints (body oils) and other residue. Dirt, dust and other particulates can affect the meter readings by obscuring the UV light. This is exacerbated by the nature of the lamp itself. The lamp is designed to separate and collect charged ions. Electrically charged dust and particulates can collect on the lamp and degrade the amount of UV light the lamp gives off.

All of the lamps have a limited service life (usually 24-36 months). As a lamp ages the meter readings can drift and increase meter sensitivity to temperature extremes.

PIDs are sensitive to moisture. Water vapor can’t be ionized but it can deflect, scatter and absorb the UV light. This would lower meter readings and degrade the effectiveness of the instrument.

As with all monitoring instruments, exposing an instrument to corrosive atmospheres won’t turn out well. Corrosive gases/vapors can permanently etch or fog the lamp window.

What a PID *won’t* detect.

- Radiation
- Common toxics (CO, HCN & SO_2)
- Natural gas
- Acid gases (HCl, HF, HNO_3)
- Freons, ozones, hydrogen peroxide & PCBs

Calibration

Like CGIs, a PID’s responses are relative to its calibration gases. PIDs are typically calibrated with Isobutylene, a stable gas with a slightly pungent odor. It’s used to calibrate PIDs because its responsiveness is about at the midpoint in the range of sensitivity of PIDs. It is relatively easy to obtain, easily stored and is non-toxic and non-flammable at the low concentrations used for calibration (usually 100 ppm). PIDs used to be calibrated with benzene, but because of its carcinogenic properties benzene calibrations have been phased out. While PIDs are typically calibrated with isobutylene, they can be calibrated with any ionizable gas. Consult the operating manual for your instrument to determine which calibration gas to use.

Zeroing the Meter

There are two methods of “Zeroing” a PID. The user can set the background atmosphere as “zero” on the meter. The other method is to use air from a supplier that is free of hydrocarbons. Ambient background air is not “clean” air. There are always atmospheric contaminants present. They would include naturally occurring gases and non-hazardous gases/vapors from sources unrelated to the release you are responding to. Naturally occurring sources of organic vapors include citrus fruit, trees (especially conifers), grasses and flowers. Non-hazardous sources of organic vapors would include things such as perfume, insecticides and vehicle exhaust. Consult the manufacturer’s documentation to determine the correct zeroing procedures for your instrument.

Meter Readings

Meter reading fluctuations can be caused by the following conditions:

- Bad bulbs (damaged or past the expiration date)
- Mixed gases (masking effect)
- Air flows and drafts
- Electromagnetic interference

The meters may not exactly match the levels of a calibrant gas at low and high concentrations. The response curve can be non-linear from 500 ppm to 1,000 ppm. The same is true for concentrations above 10,000 ppm. Most instruments have software to compensate for this.

Inaccurate low readings can also be caused by the presence of water vapor (especially hard or salt water vapor), high concentrations, or nonionizing gases that decrease the efficiency of the PID (sometimes called the “quenching” effect). The charged particles found in diesel exhaust, smoke, and soil may affect meter readings as well. The lamp and ionization chamber are also affected when high concentrations of gas condense inside the instrument.

PIDs measure a change in the ion current and display a reading accordingly. They respond accurately to the calibrant gas *only*. Unknown gases, unknown vapors, and mixed gases will not reflect the actual concentration of the gas present. The reading represents the total concentration of gases in air that the PID *can* ionize.

The reading reflects the instrument’s response relative to the calibrant gas. As discussed earlier, a PID is *sensitive* but not *selective*. Because of this, PID readings are often described as “PID Units” or “Meter Units” (raw meter readings)

Many compounds have ionization energies above the capabilities of the PID. Many classes of chemical compounds exhibit weak responses on the PID. Materials that are not ionized as well as the calibrant gas or aromatic hydrocarbons provide readings that are often low compared to the actual concentration of gas present. Because of this the user may have to apply correction factors to the meter reading. (In many cases they are applied automatically.) A correction factor is a measure of the PIDs sensitivity to a specific gas other than the calibrant gas. Correction factors are specific to their instrument and to the eV of the lamp. Users should consult the manufacturer’s documentation to obtain the corrections factors for their instrument.

Summary

PIDs can detect many materials at low concentrations. Contaminants may be present even when there is no response from a PID. A PID, more than any other detection device, should be used in conjunction with other instruments, especially in unknown atmospheres. No single instrument, including one as sophisticated and sensitive as a PID, should be trusted as your only source of information.

PIDs are particularly well suited for the detection of the aromatics like benzene, toluene, xylene, as well as vinyl chloride. As with any detection instrument, the PID has strengths and weaknesses. Responders must be familiar with the particular equipment available within their departments. They must not only know how to use the equipment, they must also understand the limitations of each device, and know how to interpret the results.

Review Questions

What types of substances are photoionization detectors (PIDs) designed to detect?

How does ionization energy affect your choice for a PID lamp? What common reference source will list ionization energies?

What are some of the conditions that can cause false readings from a PID?

Why won’t a PID detect carbon monoxide?

What is “masking effect” and how does it affect your interpretation of the meter’s readings?

Chapter 5: Radiation Detection Equipment

Introduction

Radiation detection instruments are some of the simplest monitoring equipment used by the Hazardous Materials Emergency Responder. The mechanics of using the instruments are very simple, but learning to understand the readings takes a little work. In this chapter, we will investigate the use of radiation detection equipment and discuss the elements you will need to know when developing an action plan based on the readings obtained.

The number of radiation incidents that Hazardous Materials Emergency Responders encounter is relatively low. According to U. S. Department of Transportation statistics, there is an average of 14.5 transportation-related incidents involving radioactive materials each year. Looking at these statistics, it’s easy to come to the conclusion that one might never encounter an accident involving radioactive materials over one’s career. Yet, it is very important to understand how to deal with these incidents when they do occur in order to prevent needless exposure to radiation.

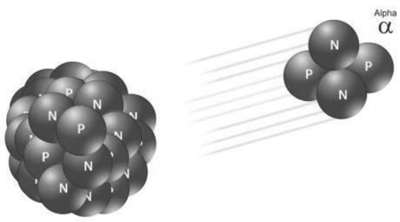
Types of Ionizing Radiation

This section will briefly review the types of radiation and the differences between an exposure and a contamination. The review is designed as an A-Week refresher and to provide a solid basis upon which to build a further understanding of the principals of radiological detection. Later in this chapter, we will discuss the different methods and sensors used in radiological detection and provide insight into detection and monitoring tactics.

There are four types of ionizing radiation: alpha, beta, gamma and neutron.

Alpha

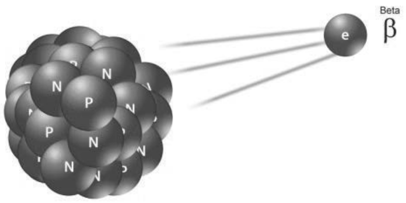
Alpha particles (α) are positively charged and made up of two protons and two neutrons from the atom’s nucleus. Alpha particles come from the decay of the heaviest radioactive elements, such as uranium, radium and polonium. Even though alpha particles are very energetic, they are so heavy that they use up their energy over short distances and are unable to travel very far from the atom.



The health effect from exposure to alpha particles depends greatly on how a person is exposed. Alpha particles lack the energy to penetrate even the outer layer of skin, so exposure to the outside of the body is not a major concern. Inside the body, however, they can be very harmful. If alpha-emitters are inhaled, swallowed, or get into the body through a cut, the alpha particles can damage sensitive living tissue.

Beta

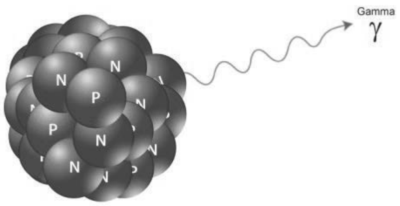
Beta particles (β) are small, fast-moving particles with a negative electrical charge that are emitted from an atom's nucleus during radioactive decay. These particles are emitted by certain unstable atoms such as hydrogen-3 (tritium), carbon-14 and strontium-90.



Beta particles are more penetrating than alpha particles, but are less damaging to living tissue and DNA because the ionizations they produce are more widely spaced. They travel farther in air than alpha particles, but can be stopped by a layer of clothing or by a thin layer of a substance such as aluminum. Some beta particles are capable of penetrating the skin and causing damage such as skin burns. However, as with alpha-emitters, beta-emitters are most hazardous when they are inhaled or swallowed.

Gamma

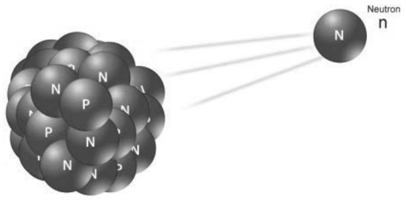
Gamma rays (γ) are weightless packets of energy called photons. Unlike alpha and beta particles, which have both energy and mass, gamma rays are pure energy. Gamma rays are similar to visible light, but have much higher energy. Gamma rays are often emitted along with alpha or beta particles during radioactive decay.



Gamma rays are a radiation hazard for the entire body. They can easily penetrate barriers that can stop alpha and beta particles, such as skin and clothing. Gamma rays have so much penetrating power that several inches of a dense material like lead, or even a few feet of concrete may be required to stop them. Gamma rays can pass completely through the human body; as they pass through, they can cause ionizations that damage tissue and DNA.

Neutron

Neutrons are high-speed nuclear particles that have an exceptional ability to penetrate other materials. Of the four types of ionizing radiation discussed here, neutrons are the only one that can make objects radioactive. This process, called neutron activation, produces many of the radioactive sources that are used in medical, academic, and industrial applications (including oil exploration).



In living tissue, neutrons have a relatively high relative biological effectiveness, and are roughly ten times more effective at causing biological damage compared to gamma or beta radiation of equivalent energy exposure. Neutrons are particularly damaging to soft tissues like the cornea of the eye.

Symbols: types of radiation and units of radioactive measurement

Symbol	Unit of Measure
α	Alpha radiation
B	Beta Radiation
γ	Gamma Radiation
CPM	Counts per minute
μ	1 microRem -- μrem (1/1,000,000th of a Rem)
milli	1 milliRem – 1/1,000 of a Rem – mr or mR
Rem/R/RAD	One full unit of measure
Kilo	One thousand Rems/RADs or Roentgens

Note: It is very common to find the symbols or units of measure presented as all lowercase or all uppercase or any combination of the above.

Radiation Contamination Vs Exposure

Contamination

Think of contamination as being dirty. Contamination is the presence of something on a person (or in a person). One victim, contaminated with a radioactive material is at risk of passing that contamination on to others, by touching them or just having the contaminate fall off their clothes. Once all of the contamination is removed, there is no longer a danger of that person contaminating others.

Exposure

The amount of radiation traveling through the air. Many radiation monitors measure exposure. The units for exposure are the roentgen (R) and coulomb/kilogram (C/kg). When radiation energy (particles or photons) emitted from a source do, or can, strike the body; the body is considered *Exposed.* Radiation striking the body is measured as a dose, just as we would measure a toxic chemical being absorbed through the skin. A person contaminated with a radioactive material is also receiving an exposure, however the exposure stops once the contamination is removed from the body and the person is removed from the contaminated area. An exposed person (exposed only to a radioactive material by proximity) may have received a dose of radiation and sustained cellular damage, however unless they are contaminated with a radioactive material, decontamination may not be needed and they pose no risk to others.

Acute Exposure

High doses of radiation in a short period of time (acute exposure) can cause radiation sickness. Symptoms of radiation sickness include nausea, vomiting and diarrhea. Mild to moderate radiation sickness can occur with exposures of 100-300 REM. Moderate to severe radiation sickness, infection, hair loss and temporary sterility can occur with exposures of 300-600 REM. The LD 50/30 for radiation is around 450 REM (without medical attention). These are general examples which have not taken into account the variables of exposure and the type of source.

Chronic Exposure

Chronic Exposure is defined as repeated low level doses (within legal limits) of exposure over a long period of time. No immediate, adverse effects have been linked to chronic radiation exposure. This does not mean there is no harm; it simply states no acute effects have been observed with chronic radiation exposures. Some possible long term effects may be an increased risk of cancers, various organ damage, cataracts, and a decreased life span. Other variables such as an individual’s health, diet, tobacco use and hereditary factors make it difficult to draw a direct connection between an illness and a chronic radiation exposure.

Measuring Radiation Dose

Radioactivity

The amount of ionizing radiation released by a material. Whether it emits alpha or beta particles, gamma rays, x-rays, or neutrons, a quantity of radioactive material is expressed in terms of its radioactivity (or simply its activity), which represents how many atoms in the material decay in a given time period. The units of measure for radioactivity are the curie (Ci) and becquerel (Bq).

Can be thought of as the intensity of the source received in one hour at a specific location. Note: For emergency response, 1 hour is the most common rate referenced.

Dose

Dose is the accumulated radiation impact at a measuring point.

Absorbed dose describes the amount of radiation absorbed by an object or person (that is, the amount of energy that radioactive sources deposit in materials through which they pass). The units for absorbed dose are the radiation absorbed dose (rad) and gray (Gy).

Dose equivalent (or effective dose) combines the amount of radiation absorbed and the medical effects of that type of radiation. For beta and gamma radiation, the dose equivalent is the same as the absorbed dose. By contrast, the dose equivalent is larger than the absorbed dose for alpha and neutron radiation, because these types of radiation are more damaging to the human body. Units for dose equivalent are the roentgen equivalent man (rem) and sievert (Sv), and biological dose equivalents are commonly measured in 1/1000th of a rem (known as a millirem or mrem).

When a person is exposed to radiation source, they are considered to have received a “radiation dose”. A Radiation dose to individuals is usually measured in units called REM (Roentgen Equivalent Man). Units called RAD (Radiation Absorbed Dose) and Roentgen are technically not the same as REM, however, for radioactive accidents where gamma radiation is the main constituent, they can be considered equivalent terms.

Roentgen “R”

R is a unit of measurement for the exposure of X-rays and gamma rays, It is a measure of the ionization of particles produced in air. 1 R = 2.58 X 10^{-4} Coulumb/ kg

RAD

The RAD is defined as the deposition of 0.01 joule* of energy per kilogram (kg) of tissue. A RAD of X-rays, gamma rays, and beta particles are about equally damaging to tissue. However, a RAD of alpha particles or Neutrons, is more damaging to tissue than a RAD of gamma rays.

* The Joule or J is SI unit (SI = International Scientific System) for energy, heat or work. One Joule equals 6.24 X 10^{18} electronvolts. A common defibrillator’s maximum output is around 360 Joules or 360 Wattseconds.

REM

The primary unit of measure for human exposure, the REM was introduced to take into account this variation in tissue damage. This is important because a person may be exposed to more than one type of radiation. For example, it was found that 100 RAD of gamma and beta radiation produced the same effect as 100 RAD of X-rays. However, only 20 RAD of Neutrons and 5 RAD of alpha particles produced the same effect as 100 RAD of X-rays. Therefore, Neutron and alpha radiations were more potent and required fewer RAD to produce the same effect.

The unit milliREM (abbreviated mR) is 1/1000th of a REM, it is a more frequently encountered term because we more often encounter low to moderate levels of radiation.

A microREM (abbreviated μR) is 1/1,000,000th of a REM and is also a radiation measurement unit used on very sensitive radiation detection equipment. Typically, background levels of radiation are measured in microREMs.

Most modern radiation detection instruments automatically change scales between microREM, milliREM and REM as the intensity of the activity increases or decreases. This is called auto scaling. It is important for the hazardous materials emergency responder to readily recognize the symbols your meter uses to note or record readings accurately. Reporting an incident's rate as 15 REM has far different consequences than reporting the rate as15 microREM because the responder failed to observe the output correctly.

For practical purposes, 1 R (exposure) = 1 rad (absorbed dose) = 1 rem or 1000 mrem (dose equivalent).

Other Units of Measurement

Becquerel (Bq) The SI unit used to express the number of disintegrations of radioactive atoms in a radioactive material during one second. The Bq is equal to one disintegration (release of a wave or particle) per second.

A Curie (Ci) is a very large amount of radioactivity (37 billion disintegrations per second). Contamination of an individual will usually involve µCi to mCi quantities. Nuclear medicine patients are injected with µCi to mCi quantities of radioactive material for routine diagnostic exams.

The International Scientific System (SI) assigns different units to the quantities:

1 Gray (Gy) = 100 RAD
1 Sievert (Sv) = 100 Rem

Changing Terminology

The majority of radiation meters currently in use read in R, REM, RAD units of measurements. Most can be configured to read in SI units (Sv, Gy). Many military and radiological response teams have their units reading only in SI units. It is important to know the conversions and be prepared to change over to SI Unit system.

Exposure Limits

Radiation Exposure should be limited to the lowest achievable dosage for safety. Emergency Response personnel may be permitted higher exposure levels for mitigating a radioactive release or incidents to save the life of an injured or threatened person. However, there are regulations and guidance surrounding all of these activities and it is important to understand which regulations apply to your specific situation.

Exposure Limits (Whole body)

REM	Activity
0.5	Annual public exposure limit (NRC)
1.25	Workers in restricted areas (OSHA)
5	Annual occupational exposure limit for radiation workers (NRC)
10	Protect vital property or mitigate incident (EPA/FEMA)*
25	Lifesaving/protection of large population exposure limit (EPA/FEMA)*

**Protective Action Guides* and Planning Guidance for Radiological Incidents (USEPA) and Protective Action Guides for Radiological Dispersal Device (RDD) and Improvised Nuclear Device (IND) Incidents (DHS/FEMA)

According to the guidance cited above, if lifesaving emergency responder doses approach or exceed 50 REM (0.5 Sv) emergency responders *must* be made fully aware of both the acute and chronic (cancer) risks of such exposure. Exposure to radiation above 25 REM requires planning and consent by the responder. The issue is that responders cannot feel, smell or see radiation at levels that can cause the onset of cancers decades later. Asking a responder to consider their long term health and the possible loss to their family during an emergency is difficult at best. Serious consideration and accurate disclosure of the facts will help the responder make the right choice for them.

In all cases, the emergency responder should consult a Health Physicist and have an assessment completed for a planned exposure.

The ALARA Principle

The goal in responding to radiation incidents is to keep exposures “As Low as Reasonably Achievable” or ALARA. Because of background radiation and because different individuals show different biological effects, it’s difficult to determine what the effects of exposure to low levels of radiation really are. The regulations concerning radiation exposure are based upon the ALARA principle. Emergency responders should make every effort to maintain exposure of all personnel as low as reasonably achievable.

Application of ALARA in the Field

Emergency responders, and their supervisors, should develop response plans and follow the recommended guidelines to increase their ability to service the public. Below, are a few guidelines for dealing with radioactive incidents and reducing exposure.

Time

The less time spent near the source of radiation, the less radiation received. For example, if you were exposed to a source emitting 50 milliRem per hour for 30 minutes, your exposure would be 25 milliRem.

Prior to committing to the scene, take a minute to pre-plan and practice your mission or task as a team. Fire, rescue, hazardous materials and medical personnel should all participate in a “tailboard session” to make sure that everyone fully understands their specific tasks and responsibilities. Proper planning will make it possible to take in the appropriate medical and rescue equipment the first time, minimizing the need for additional entries and additional exposure to radiation. The stay times table (next page) provides a general planning tool that can be used to estimate how long an entrant can remain in the exposure zone before they reach or exceed permissible dosages.

When prolonged rescue and/or patient care is going to be required near the source of radiation, consider alternating equally qualified teams for entries in order to reduce individual exposure time.

The table below provides a guide to acceptable exposure times based on the radiation levels present and the desired maximum dose. For example, if you have a reading of 100 Rem/hour (or 100,000 mR/hr.), you would be able to stay in the control zone for a maximum of 15 minutes without exceeding the exposure limit allowed to save a life, 25,000 mR (25 Rem).

Note: ALL personnel entering the exclusion zone or contamination reduction zone should wear modern dosimeters that can accurately measure total dosage received over any period of time. Alarms can be set on these dosimeters to alert personnel to the total dosage received.

Radiation stay time chart

(Time to receive a dose or exposure – Complements of LA City Fire)

Gamma-ray Dose Rate			***Stay Time to Receive this Dose***						
Rate/hr	Rate/min	Rate/sec	1R	5R	10R	25R	100R	300R	500R
1 mR/hr	17 µR	0.3 µR	6 wk	30 wk	1 yr				
5 mR/hr	83 µR	1.4 µR	200hr	6 wk	12 wk	30 wk	2 yr		
100 mR/hr	1.7 mR	27 µR	10 hr	50 hr	100 hr	250 hr	6 wk	18wk	30 wk
1 R/hr	17 mR	270µR	1 hr	5 hr	10 hr	25 hr	100hr	300hr	500 hr
10R/hr	170 mR	2.7 mR	6 min	30 min	1 hr	2.5 hr	10 hr	30 hr	50 hr
100R/hr	1.7 R	27 mR	36 sec	3 min	6 min	15 min	1 hr	3 hr	5 hr
200R/hr	3.3 R	56 mR	18 sec	90 sec	3 min	7.5 min	30 min	1.5 hr	2.5 hr
500R/hr	8.3 R	140mR	7 sec	36 sec	72 sec	3 min	12 min	36 min	1 hr

Distance

Increasing your distance from a source will decrease the amount of radiation you receive. Distance is a very predictable and effective means of reducing your radiation exposure.

Equipment and personnel should be staged an adequate distance from the source of radiation. Keep all standby and support personnel not required at the time for fire suppression, rescue or medical functions out of the Contamination Reduction and Exclusion Zone(s) until their services are actually required. As soon as practicable, move patients and responders out of the contaminated area and into an area with an acceptable level of exposure. This may require passing through a decontamination area or simply movement into a Refuge Area for staging and safety.

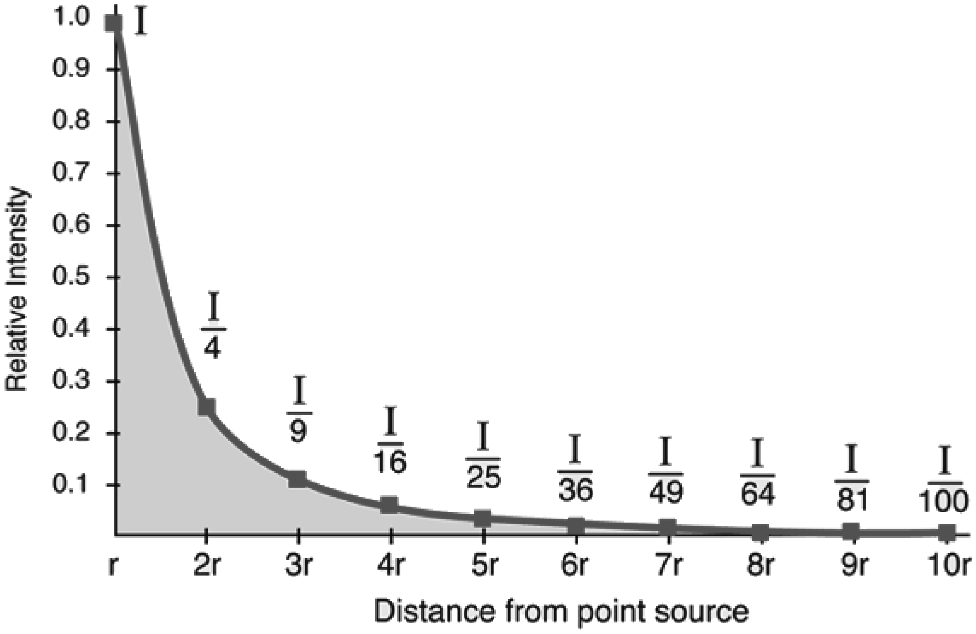
Inverse Square Law

One helpful tool for determining safe distances from a radioactive source is the "Inverse Square Law." Gamma radiation spreads out as it travels away from the source. Because of this, each time you double your distance from a radiation source you can divide the intensity by 4. For example, if you obtained a reading of 12 REM/hour at 10 feet from a source, by doubling your distance to 20 feet, the intensity will drop to 3 REM/hour, one quarter the intensity at 10 feet.

Another example would be if you had a reading of 100 Rem at 20 ft, and you moved to 100 ft what would the approximate reading be?

100 ft divided by 20 ft = 5. Inverse of 5 is 1/5, square that = 1/25 times the original reading getting an answer of 4 Rem at 100 feet. It represents a huge reduction in exposure to personnel! Again, because members move about during an incident, all members should wear dosimeters to accurately assess total dosage received.

Figure: 5.1: Graph of Inverse Square Law

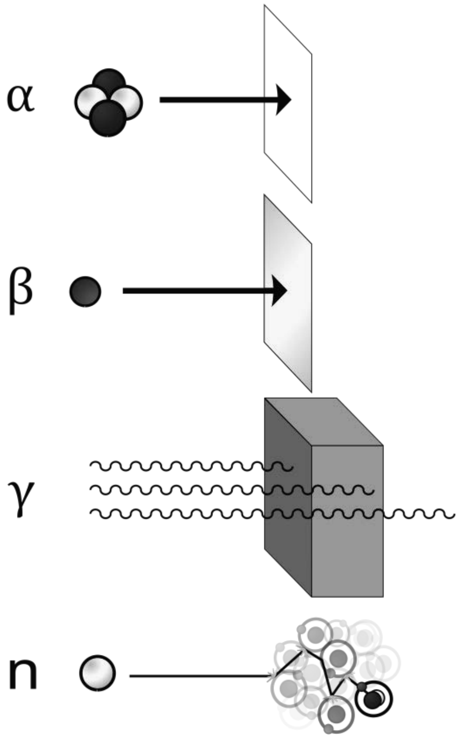


STAY TIME TABLE

Gamma Dose Rate on Meter		Time to Receive This Dose (Times rounded off. Table only calculates dose from external sources.)									
		All Emergency Responder Activities Under the Emergency Conditions				Protect Property	Life-Saving	Life-Saving Volunteers Only		Potentially Lethal	
		100 mrem 0.1 rem	1 rem	2 rem	5 rem	10 rem	25 rem	50 rem	100 rem	300 rem	500 rem
	10 µR/hr	1 year									
	50 µR/hr	12 week	2 year								
	100 µR/hr	6 week	1 year								
	500 µR/hr	8 days	12 week	24 week	1 year						
	750 µR/hr	5.5 days	8 week	16 week	40 week	1.5 year					
SET UP HOT LINE CAUTION	1000 µR/hr 1 mR/hr	4 days	6 week	12 week	30 week	1 year					
	2 mR/hr	50 hr	3 week	6 week	15 week	30 week	74 week				
	5 mR/hr	20 hr	8 days	16 days	6 week	12 week	30 week	1 year			
	7.5 mR/hr	13 hr	5.5 days	11 days	4 week	8 week	20 week	40 week	80 week		
	10 mR/hr	10 hr	4 days	8 days	3 week	6 week	15 week	30 week	1 year		
WORK IN HOT ZONE CAUTION	20 mR/hr	5 hr	2 days	4 days	10 days	3 week	7 week	15 week	30 week	2 year	
	30 mR/hr	3.3 hr	33 hr	3 days	1 week	2 week	5 week	10 week	20 week	60 week	
	40 mR/hr	2.5 hr	1 day	2 days	5 days	11 days	4 week	8 week	15 week	1 year	
	50 mR/hr	2 hr	20 hr	40 hr	4 days	8 days	3 week	6 week	12 week	35 week	1 year
	75 mR/hr	80 min	13 hr	1 days	3 days	5.5 days	2 week	4 week	8 week	24 week	40 week
DANGER	100 mR/hr	1 hr	10 hr	20 hr	2 days	4 days	10 days	3 week	6 week	18 week	30 week
	200 mR/hr	30 min	5 hr	10 hr	1 day	2 days	5 days	11 days	3 week	9 week	15 week
	300 mR/hr	20 min	3 hr	7 hr	18 hr	32 hr	3 days	1 week	2 week	6 week	10 week
	400 mR/hr	15 min	2.5 hr	5 hr	12 hr	1 day	2.5 days	5.5 days	11 days	31 days	52 days
	500 mR/hr	12 min	2 hr	4 hr	10 hr	19 hr	2 days	4 days	8 days	25 days	40 days
DANGER	750 mR/hr	8 min	78 min	2.6 hr	6.5 hr	13 hr	33 hr	3 days	5.5 days	16 days	4 week
	1000mR/hr 1 R/hr	6 min	1 hr	2 hr	5 hr	10 hr	25 hr	50 hr	4 days	12 days	3 week
	1.5 R/hr	3 min	40 min	78 min	3.5 hr	6.5 hr	16.5 hr	33 hr	3 days	8 days	14 days
DANGER	2 R/hr	3 min	30 min	1 hr	2.5 hr	5 hr	13 hr	25 hr	2 days	6 days	11 days
	3 R/hr	2 min	20 min	40 min	100 min	200 min	8 hr	16 hr	1.5 days	4 days	1 week
	4 R/hr	90 sec	15 min	30 min	75 min	2.5 hr	6.5 hr	13 hr	1 days	3 days	6 days
	5 R/hr	72 sec	12 min	24 min	1 hr	2 hr	5 hr	10 hr	20 hr	2.5 days	4 days
	7.5 R/hr	48 sec	8 min	16 min	40 min	78 min	200 hr	6.5 hr	13 hr	40 hr	3 days
LIFE-SAVING ONLY DANGER	10 R/hr	36 sec	6 min	12 min	30 min	1 hr	2.5 hr	5 hr	10 hr	30 hr	50 hr
	20 R/hr	18 sec	3 min	6 min	15 min	30 min	75 min	2.5 hr	5 hr	15 hr	1 days
	30 R/hr	10 sec	2 min	4 min	10 min	20 min	50 min	96 min	3 hr	10 hr	17 hr
	40 R/hr	9 sec	90 sec	3 min	7.5 min	15 min	38 min	75 min	2.5 hr	7.5 hr	12 hr
	50 R/hr	7 sec	72 sec	80 sec	6 min	12 min	30 min	1 hr	2 hr	6 hr	10 hr
	75 R/hr	5 sec	50 sec	100 sec	4 min	8 min	20 min	40 min	80 min	4 hr	6.5 hr
	100 R/hr	4 sec	30 sec	1 min	3 min	6 min	15 min	30 min	1 hr	3 hr	5 hr
	200 R/hr	2 sec	18 sec	30 sec	90 sec	3 min	7 min	15 min	30 min	90 min	2.5 hr
VOLUNTEERS GRAVE DANGER	300 R/hr	1 sec	10 sec	20 sec	1 min	2 min	•	10 min	20 min	1 hr	100 min
	400 R/hr	1 sec	9 sec	15 sec	45 sec	90 sec	•	7.5 min	15 min	45 min	75 min
	500 R/hr	1 sec	7 sec	15 sec	30 sec	72 sec	•	6 min	12 min	36 min	1 hr
	750 R/hr	1 sec	5 sec	9 sec	24 sec	48 sec	•	4 min	8 min	24 min	40 min
	1000 R/hr	1 sec	3 sec	7 sec	18 sec	36 sec	90 sec	3 min	6 min	18 min	30 min

Shielding

Shielding a radioactive source may be desirable if radiation levels are high and because of work missions; people are likely to be exposed for extended periods of time (over 1 hour). Denser materials, such as lead and steel, make the best shielding.



Some form of shielding should be used whenever possible. How much and the type of shielding needed will depend on the type of radiation involved. Alpha particles travel a very short distance in air and shielding can be as little as a piece of paper. Beta particles are small enough to pass through paper, but are easily stopped by a sheet of aluminum or full turnout gear. Gamma radiation will require something much thicker like lead shielding. If you don't have lead, you can still protect yourself by staying behind some kind of "mass" whenever possible. Keep other objects such as fire engines, buildings, natural terrain or involved wreckage between yourself and the radiation source. Remember if you can see the radiation source, you are being exposed!

Radiation Detection Instruments

Radiation can only be sensed or measured by specialized detection instruments. You cannot smell, touch, taste, or feel radiation. You can only feel its aftereffects. Yet with the proper equipment, radiation can be easily detected. The instruments work by detecting charged atoms, atomic fragments, or nuclear particles. The following instruments are used to measure quantity, intensity and accumulation of radiation.

Types of Radiation Detection Equipment

Type	Description
Survey Meter	A portable device used to establish whether radioactive material is present and to measure the amount of that radiation. They are a handheld instrument which typically measures the amount of radiation present and provides this information on a numerical display in units of counts per minute, counts per second, or microroentgen (µR) or microrem (µrem) per hour. Most of these devices detect beta and gamma radiation only. However, some models can detect alpha, beta, gamma, and/or neutron radiation emitted from radioactive materials.
Fixed Area Detector	A fixed instrument that measures energy (in counts per minute) and is used to monitor an area to establish whether or not a radioactive material is present.
Self-Reading Dosimeter	A device that measures the accumulated radiation exposure of the wearer. It can be read at any time, but only measures gamma radiation.
Film Badge	A light-tight package of photographic film that measures the accumulated radiation exposure of the wearer. The exposure of the individual is calculated by the degree of darkness of the film after it is developed. A film badge can only be read in a laboratory. It measures both gamma and beta radiation.
Multi Channel Analyzer	A fixed or portable device that measures the energy spectra emitted by a radiological source. The energy signature or peaks are then assessed and the "Specific" Isotope involved can be determined. Most of these meters also measure activity like a survey meter.

Radiation Isotope Identification Device (RIID)	A radiation detector with the ability to analyze the energy spectrum of radiation to identify the specific radioactive material (radionuclide) that is emitting the radiation. In addition, these devices can be used as survey instruments to locate radioactive material.

Components Common to Survey Instrumentation

Detection technology varies from manufacturer to manufacturer and can be based on specific or unique needs. Specifically, how these instruments work is beyond the scope of this course, however a basic understanding of some of the components will be helpful in the interpretation of readings.

Gas-Filled Detectors

These include Geiger-Mueller counters, ionization chambers and proportional counters.

Geiger-Mueller Tube

Geiger-Mueller Tubes are filled with an inert gas. An electrical field is generated across the gas volume and within the tube is a positively charged electrode (anode) and a negatively charged electrode (cathode). When radiation enters the tube, it is interacts with the gas and creates ions. The negative and positive ions are collected on their respective electrodes. The result is a reading on the meter.

Ionization Chambers

An instrument that detects and measures ionizing radiation by measuring the electrical current that flows when radiation ionizes gas in a chamber, making the gas a conductor of electricity.

Proportional Counters

A radiation instrument in which an electronic detection system receives pulses that are proportional to the number of ions formed in a gas-filled tube by ionizing radiation.

Scintillator

A popular method for the detection of gamma-rays involves the use of crystal scintillators. The general description of a scintillator is a material that emits low-energy (usually in the visible range) photons when struck by a high-energy charged particle. When used as a gamma-ray detector, the Scintillator does not directly detect the gamma-rays. Instead, the gamma-rays produce charged particles in the Scintillator crystals which interact with the crystal and emit photons. These lower energy photons are subsequently collected by photomultiplier tubes (PMTs).

Radiological Isotope Identification Detectors (RIID)

There are several models and configurations on the market currently. These instruments can use a variety of crystals and sensitivities to obtain varying levels of sensitivity. The units will detect radiation, quantify the intensity and then can be programmed to determine the specific isotopes involved by measuring the energy signatures emitted by the elements. Each element emits a characteristic energy pattern that can be compared to a database to determine the specific isotope. Most manufacturers have a reach back capability where the responder can upload the spectrum for their scientists to verify the field readings.

Luminescent Detectors

These utilize solids which store radiation energy; when processed, the solid material emits a quantity of light proportional to the original amount of energy. These detectors must be processed in order to obtain a measurement. These are very rarely used by first responders or hazmat teams.

Dosimeters

Several types of dosimeters are available on the market today. These units can range from a simple film badge, to direct reading pocket dosimeters, and ultimately to electronic instruments that are capable of providing important functions, including total dosage, exposure alarms, rate meter, rate alarms and data logging all in one instrument.

Instrument Readouts

Radiation meters are manufactured to meet a variety of specifications, both military and civilian. For this reason, the configuration and readout can differ from one instrument to another. The key is to learn how the meter is configured before going into the field. Some readouts are analog and have an arched shaped scale. A needle in the center of the scale indicates the reading. These tend to be older units as most manufactures make readouts which are digital and display numbers and units of measurements.

Counts per minute (CPM or counts per second CPS) are simply the number of hits or strikes recorded by the probe. Every time a photon hits the mylar cover of a pancake probe, the instrument adds one count. If there are 45 hits in one minute, then the instrument will read 45 CPM (assuming it is in the CPM scale). A complex mathematical formula must be applied to convert CPM/CPS into rem or another usable measurement. For emergency responders, this is too time consuming and unnecessary. It is simpler to change probes. It is important however, to understand that a Scintillation counter does not accurately measure dosimetry, it is an approximation.

CPM tells you how many emissions the source is putting out, but not how hazardous it is. REM or mR (or Severt and etc.) will give you the potential damaging dosage.

In emergency response, CPM is useful for finding radiation with a pancake probe. In decontamination situations it can locate low intensity sources which may be missed by a Scintillator with a metal cover. CPM should not be used for determining Zones.

Instrument Configuration

There are four basic types of instruments a responder might use to conduct a survey for radiation:

1. Contamination Survey Instruments
2. Radiation Exposure Survey Instruments (Set in uR/mR/R per hr or Sieverts/Hr or Greys/Hr)
3. Dosimeters
4. Radiological Isotope Identification Detector

Each manufacturer wants to configure their instrument to have the most desirable functions. Below is a partial list of the functions which could be included in your radiation detector.

Functions may include:

1. Readings in Roentgen, Rem, Rad, Sieverts, Gray and/or other scales.
2. Readings in the Counts per Minutes (CPM) or Counts per Second.
3. Auto Scaling.
4. Datalogging (recorded readings, downloadable results).
5. Dosimeter function – Stores accumulated dosage since it was last cleared.
6. Probe Switch – To switch between pancake and Scintillator probes.
7. Fast/Slow Switch – Fast reading, although not as accurate or slower reading – which is more accurate.
8. Alarm settings.
9. Check Source On the side of the instrument
10. Signal Transmission – Transmits readings to a receiver (usually a computer) in the safe zone.
11. Digital or Analog read out.
12. Isotope identification capability in the field.

Calibration

Radiation instruments must be calibrated by qualified personnel. Many of these instruments are gas filled and the gas can leak out over time. Without calibrations being performed, this leakage may not be detected and the accuracy of the instrument becomes suspect. Generally, these instruments are returned to the manufacturer or a manufacturer’s authorized/certified third party for calibration. It is critical that instrument owners follow the manufacturer’s calibration guidelines.

Equipment Maintenance

During an incident, equipment maintenance and protection is critical. Protecting the probe from contamination and impact will help assure a longer instrument life. One microscopic particle, lodged in a mylar membrane is enough to render the piece of equipment useless until re-calibrated. Read and follow the manufacturer's guidelines for care and maintenance.

Summary

Radiation incidents are rare. However, it's important for response personnel to understand how to deal with these incidents in order to prevent needless exposures.

You need to know at a glance, what scale your instrument is reading and where you are in relation to your stay times and turn-back rates. Understand how the instrument operates; know the alarm set points and the scale(s) of the instrument. Know and understand the difference between reading in mR per hour and Counts Per Minute. Be able to recognize auto scaling changes and adapt to the consequences of the new scale.

Review Questions

List three units of measurement commonly used to measure the effect of ionizing radiation on people.

What does the “R” in the acronym “ALARA” stand for?

1. Reliably
2. Redundantly
3. Reasonably
4. Responsibly

Which form of radiation is/are the most penetrating and difficult to shield?

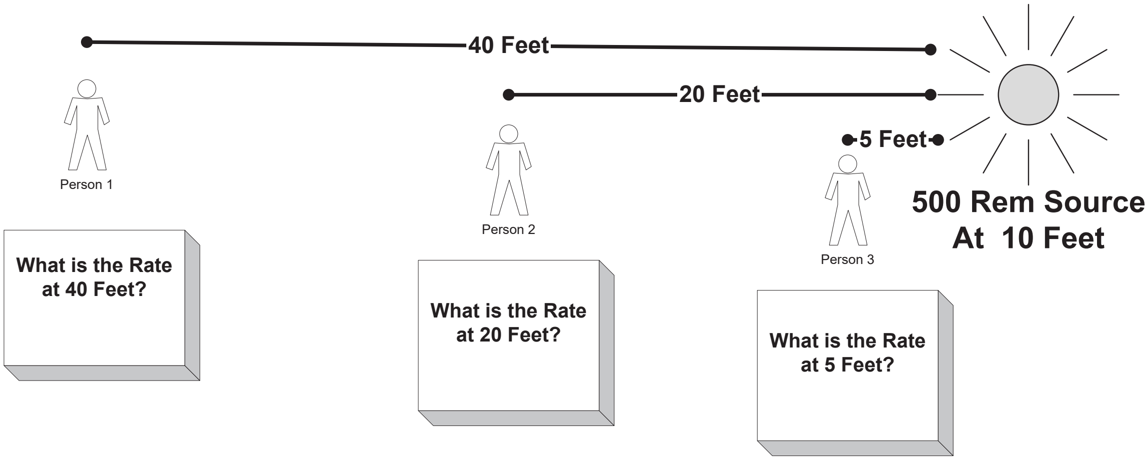
1. Gamma
2. Beta
3. Alpha
4. Omega

The basic factors to employ to lower your exposure to radiation are ___________, distance and shielding.

Which of the following is the accumulated radiation impact at a measuring point?

1. Exposure
2. Accumulated energy
3. Counts per minute
4. Dose

Using the inverse square law, calculate the potential dosages for each distance. (Show your work.)



Person #1:

Person #2:

Person #3:

Chapter 6: Colorimetric Indicator Tubes

Introduction

Colorimetric gas detector tubes are used for detecting the presence of gases/vapors and are available from several manufacturers. Colorimetric gas detector tubes are a glass tube filled with a chemical reagent granulate, which discolors when it comes in contact with a specific gas. They are used for spot sampling for gases and vapors and measuring their concentration in the atmosphere.

In a typical colorimetric gas detector tube a known volume of air is drawn through a glass tube by a pump. The pumps can be piston pumps, bellows pumps or automatic type pumps. The tube has a layer of reagent which indicates the presence of the analyte by changing color. The length-of-stain discoloration may indicate the concentration of the measured substance. The further the discoloration of the reagent, the higher the gas concentration is. The tube has a printed scale allowing a direct reading of the concentration.

A limitation of colorimetric detector tubes is that they were designed to detect a single known gas or vapor. Advancements in the design and capability of detector tubes came with the introduction of specialty kits that are designed to allow the user to sample for multiple gases simultaneously.

Colorimetric detector systems have many advantages over other monitoring systems.

1. Most tubes don’t require oxygen to function properly.
2. Colorimetric tubes are highly selective and can identify scores of different gases or vapors.
3. They can identify the gas/vapor present *and* measure the concentration.
4. Tubes are available to measure a wide range of concentrations for the same substance.
5. Most tubes aren’t affected by normal variations in humidity.
6. There are tubes available for several hundred substances including many that are “specialty” or “exotic” gases.
7. You can use them in combination with multiple tubes to sample for multiple substances simultaneously.

Detector Tubes

The glass tube tips are fused at both ends to prevent inadvertent exposure of the reagent. The user breaks off the tube tips just prior to use. Since the reagent is only used once and isn’t exposed to the atmosphere until just prior to use there is no need to calibrate the system.

Figure 6.1: Colorimetric Detector Tubes

To use a detector tube, select the tube that is appropriate for the pump and the suspected contaminant. Break off the ends of the tube and insert the tube into the pump so the arrow on the tube points toward the pump. The manufacturer's instructions will specify the number of pump strokes necessary for the tube chosen. Many tubes also have the required number of strokes printed on the tube itself.

Different tubes are used to detect whether a certain contaminant is present (qualitative indicators) or how much of a known contaminant is present (quantitative indicators). Tubes are available in different concentration ranges for and individual contaminants. This is very useful depending upon the suspected concentration present. For example, ammonia tubes come in a range of 1-10 ppm, 10-50, 50-100, and 100 -2000 ppm. Since the mechanism works the same despite what is placed inside the tube, these devices can detect a wide range of gases and vapors qualitatively and quantitatively, including acids, bases, organic amines, unsaturated hydrocarbons, halogenated hydrocarbons, and aromatic hydrocarbons.

Each box of tubes comes with instructions that describe how to interpret tube responses. Indicators of chemical concentrations include a specific color change (e.g., from white to blue), change in color intensity (such as from pink to red), or the length of color change (e.g., from 0 to 4 inches down the tube). For these quantitative measurements, compare tube readings with the manufacturer's instruction sheet for concentration calculation.

Indicator tubes are normally chemical specific. However, some tubes can detect multiple chemical substances. These are known as Polytest tubes. Polytest tubes usually only indicate when air contamination is present, but they do not define the concentration of the contaminant. Some polytest tubes are designed to look for a specific range of specified chemicals. These will produce multiple-colored rings if more than one class of chemicals is present. One polytest tube, the GASTEC brand Polytech IV Rainbow Detector Tube Number 27, is designed to react with eight different contaminants: ammonia, hydrogen chloride, hydrogen sulfide, chlorine, sulfur dioxide, nitrogen dioxide, carbon monoxide, and carbon dioxide. This may be a useful tube for the responder because it can replace eight individual tubes (most indicator tubes are normally packaged ten to a box). Indicator tubes have a limited shelf life, which means you may be throwing away tubes that were never opened because you didn't encounter the particular gas before they expired. You're less likely to have that problem with polytest tubes. The Polytec tubes can be used to determine multiple unknown substances with a single test. There are 1 to 8 reaction layers in each Polytec tube which will evaluate up to 15 gases simultaneously. Because these tubes are looking for eight gases simultaneously, only one tube need be expended to determine the presence or absence of specific gases detected.

Figure 6.2: GASTEC brand Polytech IV Detector Tube

Common Polytech Tubes and Reagents

Detecting Layer	No. Name Original color	1 NH_3 Purple	2 HCl Yellow	3 H_2S White	4 SO_2 Blue	5 NO_2 Yellow	6 CO Yellow	7 CO_2 Blue
Substances		Measurement Results						
Ammonia, Amines		Yellow						
Hydrogen chloride			Red					
Hydrogen sulfide				Brown			Dark brown	
Chlorine					Yellow	Yellow		
Sulfur dioxide					Yellow			
Nitrogen dioxide					Purple	Orange		
Acetylene							Brown	
Carbon monoxide							Brown	
Ethylene							Brown	
Phosphine							Dark brown	
Hydrogen							Grey	
Methyl mercaptan							Yellow/ orange	
Propylene							Grey	
Carbon dioxide								Brown

Cross Sensitivities

Although a tube may be intended for detecting a specific contaminant it may also react to other contaminants, especially those in the same chemical family. The manufacturer's instruction sheet will often list such "cross-sensitivities" and indicate the various color changes you can expect. For example, the Dräger hydrogen chloride (HCl) detector tube is designed to discolor from blue to yellow and will indicate nitric acid, hydrogen bromide, formic acid, acetic acid, and propionic acid. The presence of oxidizing substances, such as chlorine, will produce a blue-gray discoloration. The manufacturer's instruction sheet for the specific contaminant should specify cross-sensitivities and related color changes.

The Dräger acetic acid tube and the Dräger ammonia tube are both very useful because of their cross-sensitivities. In fact, although the acetic acid tube is designed for acetic acid, the tube is useful for detecting qualitatively other acidic contaminants (see table below). The ammonia tube is useful for detecting most amines.

Acetic Acid Detector Tube Cross-Sensitivities

Contaminant	**Color Change**
Acetic Acid (CH_3COOH)	Yellow
Sulfur Dioxide (SO_2)	Yellow
Chlorine (Cl_2)	White
Inorganic Acids (HCl, HF, H_2SO_4)	Red
Nitric Acid (HNO_3)	Orange-gray
Hydrogen Sulfide (H_2S)	Lavender

Range of Deviation

Even if colorimetric tubes are within the expiration date and have been stored properly the tube reading and the actual concentration can still deviate from ± 5% to ± 30%. Check the tube's instructions for the range of deviations applicable to that tube's results.

Use Considerations

It is important to read, understand, and follow the manufacturer's instructions. Pumps and tubes are not interchangeable between manufacturers. Procedures for use will vary between manufacturers (e.g. number of pump strokes required). The color changes and the time it takes for a color change to occur will often vary from one manufacturer from another. Instructions also warn of specific factors such as interfering gases that can affect tube response. Interfering gases can give a false positive or can mask the presence of another gas. For example, the indication of phosgene by the Dräger phosgene tube is completely inhibited by high concentrations of chlorine.

Like all chemical reactions, the reaction that occurs inside a detector tube may be affected by temperature extremes, temperature changes, excessively high or low humidity, atmospheric pressure, sunlight, or the presence of other interfering gases or vapors. The manufacturer's instructions should indicate temperature and humidity limitations and list some common interfering gases and vapors. However, never assume there are no interfering chemicals even if none are listed. In addition, it is important to note the expiration date on the box of tubes you will be using. Expired tubes should not be used because their results may not be accurate.

There are several potential downsides to the use of colorimetric tubes on an emergency scene. Most tubes will take between 2-10 pump strokes to obtain a reading, but some may require a larger number of strokes. For example, the Dräger sulfuric acid tube requires 100 strokes per tube. (Since the vapor pressure of Sulfuric acid is .001 mmHg at 25^0 C. there are almost no vapors present for the tube to detect.)

One disadvantage of colorimetric tubes is the relatively small sample that they draw. It may not be possible to draw statistically significant samples from the very small amounts of air sampled by colorimetric tubes. The results represent only an air sample at a particular place at a particular time. They are *not* an air monitor.

The specificity of the tube can also be a drawback. Although there may be over a hundred tubes available, the hazmat team should have a good idea which contaminant may be present or, there is a good chance that they will not have the correct tube. The tubes should be used for to rule out or confirmation the presence of a suspected contaminant, not just a random sample. Since many colorimetric tubes have a relatively short shelf life it's not practical and cost effective to maintain a large inventory of tubes.

There are several popular brands of colorimetric tubes (e.g., Dräger, Gastech, MSA, Kitigawa, and Matheson). Each is designed to be used with the corresponding brand of pump. Interchanging brands of pumps and tubes has been shown to cause erroneous results.

When taking a sample with a colorimetric tube you should watch for a color change at each pump stroke and not wait until you complete the required number of strokes. An immediate color change can indicate a concentration that may be in excess of the maximum concentration listed on the tube. (Note: don't stop the pump strokes prematurely. You must follow the manufacturer's protocol to ensure accurate results.)

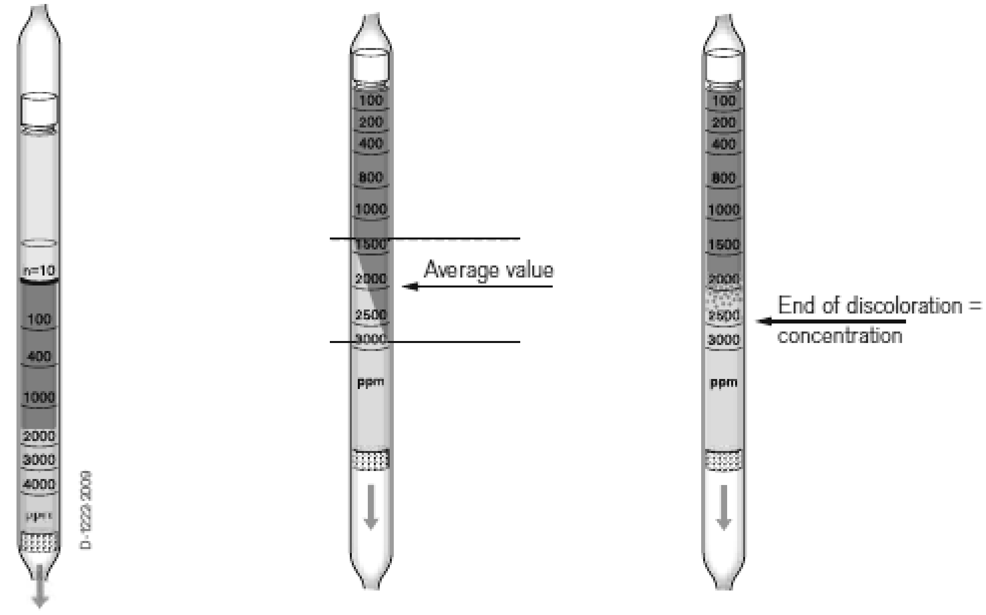
Interpretation of Results

Detector tubes are read according to the manufacturer's instructions for each tube. The manufacturer's information should also give a range of accuracy for each type of tube. This range indicates how much the actual air concentration may differ from the detector tube results. In emergencies, it is prudent to use the value calculated from the highest range. For example, if a measurement of 100 ppm is obtained and the instructions indicate that the actual concentration may be ±15%, use a value of 115 ppm for decision-making (100 plus 15% of 100).

It can sometimes be difficult to observe the color changes due to factors such as insufficient lighting or obscured vision. You should try to observe the color change (if any) as soon as possible and in adequate lighting but at the same time you should avoid exposing the tube to direct sunlight. If it's difficult to adequately assess the color change you can hold the tube up to something such as a white paper. You can also compare the tube to an unused tube.

The color changes may be ambiguous or indistinct. When the color indication is at a right angle to the tube's longitudinal axis the concentration can be read directly against the scale (see example 1). If the color indication is oblique (i.e. runs in a slanting direction to the tube's longitudinal axis), then a long and a short discoloration can be observed. In this case the average reading indicates the concentration (see example 2). If the color indication become progressively diffuse, the end of the discoloration may be difficult to evaluate. In this case the final edge of the discoloration must be read at the point where a faint discoloration is just visible (see example 3).

Figure 6.3: Examples of Different Color Changes



Example 1 Example 2 Example 3

As with all monitoring systems, "zero" doesn't mean nothing is there. It means your tube didn't detect anything. There's a difference between the two!

Colorimetric Indicator Tubes and WMD

Colorimetric Indicator tube systems are designed for sampling airborne concentrations or the evolution of gas or vapor from the surface of a substance. The ability to detect a gas or vapor is a basic tenant of hazard assessment and is dependent on the volatility of a substance and the environmental conditions (humidity, wind, rain, ambient temperature and distance from the source). Many WMD chemicals have low vapor pressures, making them difficult to detect, others are gases and, depending on the distance from the source, may be diluted and, again, difficult to detect.

Most WMD chemicals are Toxic Industrial Chemicals (TICs) and can be detected using colorimetric tubes. Most tube manufacturers make tubes for Chlorine, Hydrogen Cyanide, Cyanogen Chloride and Phosgene gas. Other WMD chemicals such as Sarin and Nitrogen Mustard may have specific tubes, or the manufacturer may make a polytest tube which indicates several agents. For example, the MSA Chemical Warfare (CW) Agent Tube (part # 10007654) for Nerve Agent includes: Sarin, VX, GA (Tabun), GD (Soman), etc. in one tube. This tube detects characteristics common to all the “Nerve Agents” listed. The sensitivity of this tube is 1x10-5 mg/l and gives a go / no-go response.

Another manufacturer, Dräger, offers a Civil Defense Simultest (CDS) Kit which detect nerve, blood, lung, nose and throat irritating agents using Simultest Sets.

Colorimetric systems are useful in WMD incidents as one component of a detection and monitoring strategy.

Summary

There are several detection instruments available for emergency response. As with all sampling and monitoring devices, this is not a stand-alone system, nor is it interchangeable with other colorimetric manufacturers systems. The chemical agent characteristics, threat and the availability of the proper colorimetric tubes will dictate how useful colorimetric tubes are in an incident. Their effectiveness is derived from a well-conceived sampling and monitoring plan.

Emphasis is placed on each responder’s expertise with the equipment available within their departments. They must not only know how to use their equipment and understand their limitations, but also know how to interpret the results.

Review Questions

Describe the process for using a colorimetric detection device.

How do colorimetric tubes indicate the presence of a contaminant?

What is meant by a “polytest tube”? What are they able to detect?

What is meant by “cross-sensitivities”?

List some of the things that can affect the accuracy of a colorimetric tube?

What are some of the disadvantages associated with colorimetric tubes?

How many tubes should be taken in to monitor an atmosphere where contaminants are suspected?

Information sheet for exercise.

Dräger Tube Petroleum Hydrocarbons 100/a

11th Edition • November 2001 (Reprinted from Dräger Instruction Sheet)

Application Range

Determination of petroleum hydrocarbons in air and technical gases.

The calibrated scale of the tube is applicable to n-octane.

Measuring Range: 100 to 2500 ppm to n-octane.

Number of Strokes (n): 2

Time of Measurement: approx. 30 s

Standard Deviation: ± 10-15%

Color Change: White → green

Ambient Conditions

Temperature: 0˚C to 40˚C

Humidity: <30 mg/L (corresponding 100% r.h. at 30˚C)

Atmospheric pressure: for correction of the reading, multiply by factor F = 1013

Actual atmospheric pressure (hPa)

Cross-Sensitivities

Many hydrocarbons are indicated, however all of them with differing sensitivity.

Differentiation is not possible.

Aromatics are indicated with minor sensitivity only.

CO in the range of 100 to 1000 ppm is indicated with approximately half the sensitivity.

Colorimetric Detector Tube Exercises

Refer to information on the previous page when answering these questions.

An underground fuel leak from a gasoline service station has caused fuel vapors to intrude into the basements of nearby homes and businesses. Can a Dräger 100/a, petroleum hydrocarbon, detector tube be used to survey these buildings for gasoline vapors? If so, what is the margin for error?

What type of response should be expected in terms of the number of pump strokes and color change?

Gasoline has a LEL of 1.4%. Can a Dräger petroleum hydrocarbon 100/a detector tube be used to determine if the atmosphere is explosive?

Chapter 7: Introduction to Advanced Detection Technologies

Introduction

This chapter describes the nature and basic functions of advanced instrumentation. The instructor will provide details on instrumentation which is increasingly used in your jurisdiction. This chapter will cover chemical and some biological detection capabilities.

Advanced detection instruments include:

1. Infrared Spectroscopy
2. Laser Technology
3. Gas Chromatography
4. Flame Ionization Detectors
5. Ion Mobility
6. Mass Spectrometry
7. Surface Acoustic Wave

Some advanced detection instruments/systems are used in CBRNE response. They include:

CBRNE Chemical Agent Instrument Technologies

- Ion Mobility Spectroscopy (IMS)
- Surface Acoustic Wave Frequency Analysis (SAW)
- Infrared Spectroscopy
- Flame Spectrophotometry
- Military Chemical Agent Detection Materials

CBRNE Biological Agent Instrument Technologies

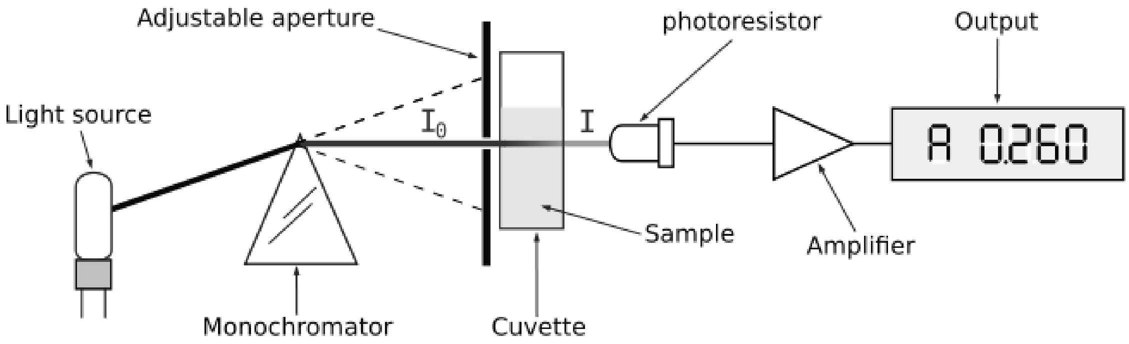
- Handheld Immunochromotographic Assays (HHAs)
- Microscopic Analysis
- Polymerase Chain Reaction (PCR)

Infrared Spectroscopy

Infrared spectroscopy (IR) is an analytical technique used for analyzing samples with covalent bonds. They may measure either the range of wavelengths in the infrared spectrum that are absorbed by a substance or the infrared waves that are emitted by excited atoms or molecules. Those devices that measure how much of the infrared energy (IR) is absorbed give either a percentage reading of the IR absorbed or the concentration of the substance in ppm.

An infrared spectroscopy instrument will pass infrared light through a sample. The molecules vibrate in response to the infrared radiation. These vibrational movements create bands in a spectrum that occur at specific wavelengths (called spectra). The instrument processes the infrared light that is absorbed or transmitted to generate a graph of those wavelengths (frequencies). The resulting spectra help identify which types of bonds are present in the test specimen.

Figure 7.1: Infrared Photospectrometer



Generally, to use this equipment, a person looks up the chemical they would like to monitor. Some characteristic of the compound is picked. For instance, if a person wants to monitor acetone, they would pick the carbonyl group (C=O), then set on the machine the frequency absorbed by the carbonyl group. When the machine is calibrated, it will respond to fluctuations in acetone. Another, more sophisticated method for using this device is to run through all of the frequencies that it can detect and see where there is absorption. If an unknown gas absorbs at wavelengths that correspond to C=C bonds and C=O bonds, the compound contains each of these components. The gas could be acrolein, which has both bonded compounds.

The equipment can be linked to a computer to analyze the IR light information from a sample and compare it with data stored in an internal IR Spectral Library. When analyzing unknown solid, liquid, or gaseous materials using IR the IR spectrometer software will generate a graph representing all the covalent bonds and functional groups that are IR active. This graph is then compared against an internal library of thousands of known chemical spectral graphs. The software then produce a list of “best matches” in the library with the graph generated from the unknown, often expressed as “percent similar”.

This system works very well for single-component gases or vapors. However, a mixture of gases or vapors can be difficult to interpret. They often generate complex IR spectral graphs that may or may not be stored in the software system’s libraries. Another challenge to IR Spectroscopy is the presence of water in the sample and/or dilution. The high covalent nature of water can cause the IR spectral graph of water to cover up or mask other significant bonds and/or functional groups.

The response time for an IR instrument can be 1-2 minutes, depending on the precision that the user selects for analysis. IR Spectroscopy can be used to confirm results from other analytical testing systems as well as for the selection of proper correction factors when precise atmospheric monitoring results are needed. Another valuable application of IR Spectroscopy is useful in screening potential white powder incidents for biological materials due to its ability to differentiate the protein, lipid, and carbohydrate functional groups present in biological materials and cell walls, as opposed to the absence of such groups in materials such as sugar, baking soda, talc, etc.

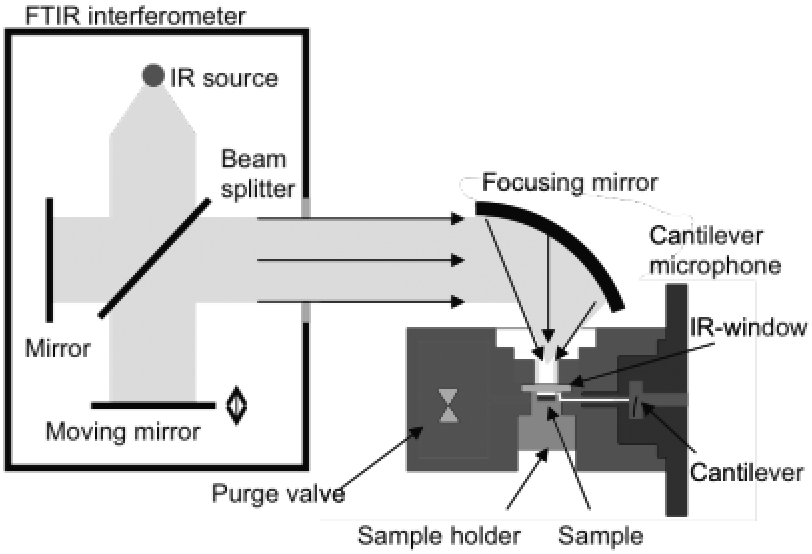
FTIR spectroscopy

Fourier Transform Infrared (FTIR) technology is used in a hazardous materials response to identify unknown materials.

An FTIR instrument exposes a sample to infrared (IR) radiation. The molecules of the sample will absorb some of the IR radiation and allow some to pass through. The wavelengths of the IR radiation passing through and absorbed by the sample are unique to the molecules present. The instrument collects data from the spectral range. That data undergoes a Fourier transform (a mathematical operation) to convert the raw data into an infrared absorption spectrum (i.e. fingerprint).

FTIR identifies chemical bonds in a molecule and produces a distinctive molecular fingerprint that can be used to screen and scan samples for many different components. FTIR is an effective analytical instrument for detecting functional groups and characterizing covalent bonding information.

Figure 7.2: FTIR Spectroscopy



The system can identify multiple unknown gases simultaneously. Thousands of hazardous substances can be identified in a matter of minutes. This includes Chemical Weapons, Narcotics, Toxic Industrial Chemicals, Precursor chemicals, commonly used hazardous substances, and commonly spilled items. FTIR is effective for detecting functional groups.

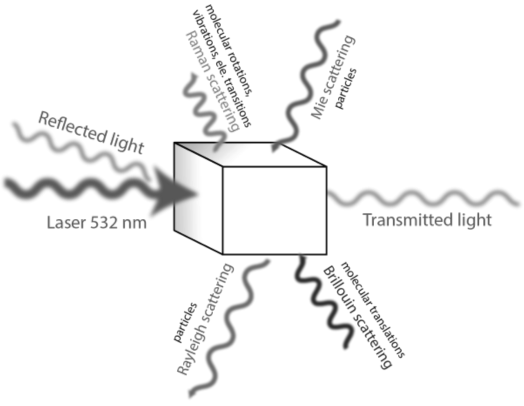
These devices may be unable to detect trace level substances and substances in less than 10% solution in water. They may also not be able to identify substances that do not have any covalent bonding structure such as diatomic acids (i.e. HCl, HF), pure ionic bonded materials (i.e. NaCl, KI, etc.), metals, and elements.

Raman Spectroscopy

Raman spectroscopy is an optical measurement technique based on inelastic scattering of monochromatic light, usually from a laser source. Inelastic scattering means that the frequency of photons in monochromatic light changes upon interaction with a sample. Photons of the laser light are absorbed by the sample and then reemitted. The frequency of the reemitted photons shifts up or down in comparison with original monochromatic frequency, which is called the Raman effect. This shift provides information about vibrational, rotational and other low frequency transitions in molecules.

Raman, like FTIR, can identify liquid and solid chemicals. The significant advantage Raman has over FTIR is its ability to identify thousands of chemicals without making direct contact with the chemical of interest and many chemicals can be analyzed directly through transparent and semi-transparent containers. This reduces contamination and exposure.

Figure 7.3: Raman Scattering



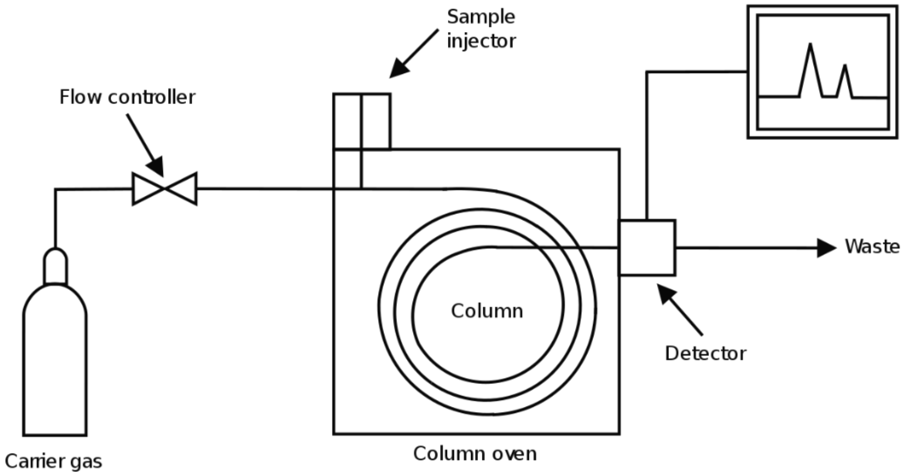
There are additional cautions in using Raman based systems in that they typically employ class 3B lasers which can have detrimental effects on dark colored substances such as gun powder, which can easily burn or ignite.

These two technologies can rapidly identify the characteristics of a liquid substance which may have a vapor or may be producing a gas through a chemical reaction. These technologies are able to specifically identify a substance and provide valuable information about its effect on air monitoring devices or even if the air monitoring devices are capable of detecting the chemical of interest.

Gas Chromatography

"Gas chromatography" is a term used to describe the group of analytical separation techniques used to analyze volatile substances in the gas phase. In gas chromatography, the components of a sample are dissolved in a solvent and vaporized in order to separate the analytes by distributing the sample between two phases: a stationary phase and a mobile phase. The mobile phase is a chemically inert gas that serves to carry the molecules of the analyte through a heated column. (The column is a narrow metal tube.)

Figure 7.4: Diagram of Gas Chromatograph



Using the instrument: a small amount of the sample is placed in a syringe and injected into the machine. The components of the sample are heated and instantly vaporize. A carrier gas (a neutral gas such as hydrogen or helium) moves the gases in the sample through the column. Carrier gas must be dry, free of oxygen and chemically inert. The column is a thin glass or metal tube usually filled with a liquid that has a high boiling point. As the mixture travels through the column, it's adsorbed and separates out into its components. Each component emerges in turn from the end of the column and moves past an electronic detector (sometimes a mass spectrometer), which identifies it and prints a peak on a chart. The final chart has a series of peaks that correspond to all the substances in the mixture.

These instruments don't provide instantaneous results. Some contaminants can take a long time to get through the column. Toluene, for instance, can take twelve minutes to get through the column used by the FID/gas chromatograph before the device produces a result.

By using chromatography in front of other sensors and measuring the retention times (the time it takes for a substance to get through the column), the concentration of one compound can be measured in relation to the presence of any other compounds.

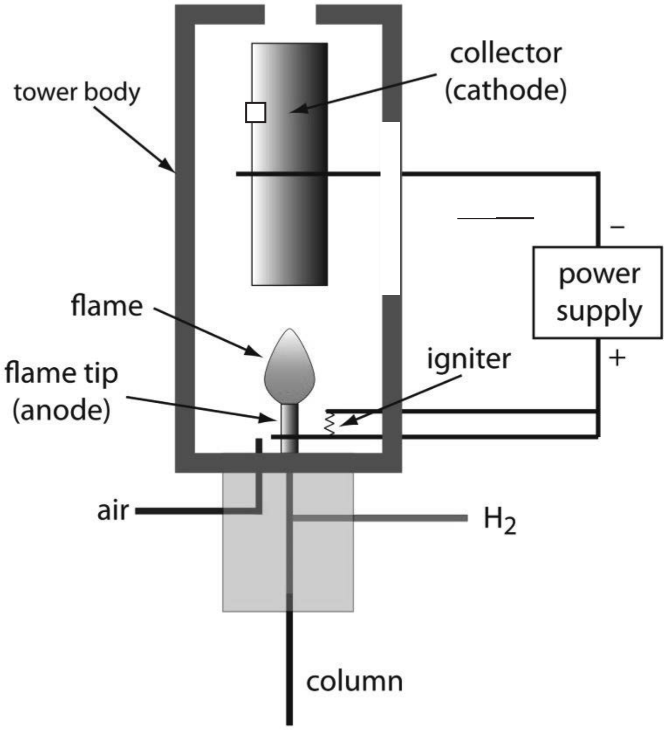
The detection methods discussed next (FID and ion mobility) and PIDs (discussed in the last chapter) may or may not be used in conjunction with a gas chromatograph.

Flame Ionization Detectors

Flame ionization detectors (FIDs), as the PIDs mentioned previously, use charged particles or ions to detect chemicals in the air. However, while PIDs use high-energy UV light to displace electrons from contaminants in the air, FIDs use a hydrogen flame to burn organic (carbon-containing) materials in air. As they burn, the positively charged carbon-containing ions are produced and collected, and a current is generated similar to that of the PID process. The hydrogen flame has sufficient energy to ionize organic materials with ionization potentials up to12.4 eV. Whereas the PID is blind to carbon monoxide and methane, the FID is very sensitive to both. This is why FIDs are so commonly used by the gas companies.

Like PIDs, FIDs display meter readings relative to the calibrant gas. FIDs do not burn, or ionize, all organic materials with the same efficiency. The FID meter reading, therefore, does not reflect the total concentration of carbon-containing materials in air. A FID has a more generalized response due to the nature of breaking chemical bonds with the energy supplied by the flame.

Figure 7.5: Flame Ionization Detector



All FIDs can be used as survey instruments, detecting relative concentrations of air contaminants. In addition, some FIDs may be operated in the gas chromatograph (GC) mode. FIDs with a GC attachment and a strip chart recorder can be used to separate and measure the relative concentrations of known contaminants in air. This requires injecting known standard concentrations of each contaminant and observing the meter response on the strip chart recorder. If unknowns are present, however, it is very difficult to determine their identity using an FID. (Note: GC attachments and strip chart recorders may not be approved for use in explosive atmospheres.) FIDs are also referred to as organic vapor analyzers (OVAs).

Use Considerations

The most useful FID for emergency response is a meter operating in the survey mode. In this mode, the meter continually draws in sample air and gives a reading in response to the level of contamination present. There are survey mode FIDs available that can read 0 to 1000 ppm or up to 10,000 ppm.

Only an intrinsically safe FID should be used. FID models are available with Class 1, Division 1, Groups A, B, C, and D approvals. Intrinsically safe FIDs are equipped with flash arrestors and are safe for flammable atmospheres. As an added safeguard, the FID is designed so that the supply of hydrogen is temporarily interrupted when flammable vapors increase the height of the hydrogen flame; this interruption extinguishes the flame. FIDs that are not intrinsically safe must not be used for hazardous materials emergency response.

As with the other monitors, the FID has limitations. These include: hydrogen fuel, oxygen supplies, temperature, humidity, flameout, nonionizing gases and no response curves or conversion charts.

Ion Mobility Spectroscopy

Instruments that utilize Ion Mobility Spectroscopy (IMS), operate in a similar way to PIDs. IMS instruments analyze collected samples gases by typically using a radioactive source to ionize the molecules of the gaseous sample, most commonly radioactive Nickel. Other ionization sources include ultraviolet light, corona discharge, and electron spraying, however radioactive sources, such as Nickel 63 (Ni^{63}) are typically preferred due to their low radioactivity, longer life than batteries (100 years), and low signal to noise ratios thereby reducing interference with IMS generated spectra.

In place of ultraviolet light (as used by a PID) or combustion (as used by the FID), compounds entering an ion mobility device are ionized via a radioactive isotope. Once in the ionization chamber with the radioactive nickel, the compounds will become positively charged (cationic) or negatively charged (anionic), depending upon the class of the substance. The contents of the ionization chamber are then sent through a diffusion tube (chromatography) to a detector. Retention time is the primary determiner of the compound. However, this device identifies very few compounds.

There are a few unique aspects to this device, which are in place mostly to limit the number of compounds to which the device responds. (It’s designed to detect potential CBRNE agents.)

Very large molecules that are of a high covalent nature can be easily ionized and thereby overwhelm the ionizing capability of the ionization source. A moisture barrier prevents water vapor from entering the instrument by. Organic vapors are removed from the air stream by a semi-permeable membrane. Suspect vapors enter the instrument through the moisture barrier and then pass by the ionization source and are given either a positive or negative charge.

At this point, the ions are in the drift tube of the instrument where they migrate, based on their size and charge, toward an ion collector plate. The time it takes the charged particles to reach the ion collector plate is based on the magnitude and polarity of their charge, their size, the types of collisions they have with other ions in the drift tube, and their concentration.

At the ion collector plate, the ions lose their charge and then impart an electric current. An ion mobility spectrum is then generated by utilizing the time it took each ion to reach the ion collector plate and the respective charge generated at the collector plate. This spectrum is then compared against numerous internal library spectra built into the instrument.

IMS instruments are capable of detecting nerve, blister, choking and riot control agents. Their ability to identify compounds is limited by the size and number of reference IMS spectra stored within the instruments internal libraries for comparison. While many of the CWAs have ultra-low vapor pressures, the CWAs that present an inhalation exposure hazard readily generate vapors that can be detected by IMS.

Rapid detection of such gases at very low concentrations is needed to adequately protect incident personnel. IMS is capable of rapidly ionizing and detecting many of the most hazardous CWAs in the parts per billion range.

Mass Spectrometry

Mass spectrometers ionize a sample then sort the ions according to their mass and charge. The instrument measures the ions, calculates the ratio between the mass and charge of the sample and displays the results as a vertical bar graph. A mass spectrometer uses the resulting spectra to identify the components of the sample. It’s capable of identifying mixtures as well as pure samples. Mass spectrometry units are often combined with gas chromatography instruments to quickly identify an unknown substance.

Surface Acoustic Wave Monitors (SAW)

Surface Acoustic Wave, (SAW), monitors utilize substrate plates bonded to natural crystals to measure concentrations of contaminant gases. These substrate complexes are called piezoelectric plates.

The monitors use a pair of piezoelectric plates to detect the mass of absorbed materials. Materials enter the detection chamber and are absorbed into a sensor surface coating. As samples of vapor enter the collection chamber of the instrument, moisture is prohibited from entering and chemicals to be analyzed are concentrated on the surface of a charcoal pre-concentrator. The charcoal surface is then heated to liberate the absorbed molecules which are then driven by a flow of carrier gas to the piezoelectric plates. On each end of the plates, an Interdigital Transducer, (IDT), is attached. At the input IDT, electric current is applied, which causes the piezoelectric plate to expand and contract, thereby causing a vibrational wave to move across the surface of the bonded crystal. The output IDT than measures the electrical energy as the wave is now converted back to an electric current. Anytime that a contaminant comes in contact with the sensor crystal, the mass of the piezoelectric substrate changes, and causes a subsequent change in the frequency and amplitude of the wave generated across the crystal surface.

The absorption of substances on the surface coating causes a resonance frequency change in the instrument. A pair of surface acoustic wave microsensors (piezoelectric crystals) act as sponges for these changes. These microsensors are extremely sensitive to minute changes in the mass of the coatings producing a measurable voltage. The changes are compared to the stored algorithm of substances stored in the monitor's sensors. Any detectable comparison causes the monitor to alarm.

In order to detect for specific CWAs polymers are applied to the surface of the piezoelectric crystal surface to absorb targeted compounds. This prevents compounds that are not of interest in a potential CBRNE incident from causing the SAW instrument to alarm. However, even with specific polymer coatings, a single piezoelectric sensor can still absorb multiple chemical compounds and/or CWAs. For this reason, three or more piezoelectric sensors with different polymer coatings are utilized.

When a compound is absorbed on the surfaces of the different polymers, their respective wave frequency and amplitude changes are compared to identify the compound and reduce the occurrence of false-positive alarms. Once the analysis cycle has been completed, the contaminated sensors are then cleaned by heating the polymers which then drives off the compound that was absorbed.

While SAW technology provides the capability of detecting CWAs in the high ppb to low ppm range the piezoelectric crystals can detect a broad range of compounds. Consequently, many industrial and environmental compounds that could be expected at the scene of a CBRNE incident have the ability to mask targeted CWAs as well as causing a high concentration of the agent in order for positive identification. SAW sensors are also easily contaminated by materials such as smoke, steam, and other organic vapors.

Flame Spectrophotometry

Flame Spectrophotometry uses a flame to heat a chemical. Elements give off specific colors (light spectrum) due to this thermal excitation. These colors (called "spectral lines") are distinct enough that elements can be easily distinguished from one another. An instrument using Flame Spectrophotometry analyzes the visible light from the flame. Elements such as Phosphorus, Sulphur, Arsenic, H-N=O chemical liaison, Potassium, Sodium, Calcium give off a distinct light spectrum. The instrument uses those spectra to identify elements present in Chemical Warfare Agents (CWA) so the instrument can identify various CWAs.

Light Spectra of Various Elements

Name of Element	Observed Color of Flame
Potassium (K)	Violet
Lithium (Li)	Red
Calcium (Ca)	Orange
Sodium (Na)	Yellow
Barium (Ba)	Lime Green

Handheld Immunochromotographic Assays (HHAs)

HHAs are a device that is used to detect biological organisms and their toxins. A liquid sample (or its extract) containing the analyte of interest flows laterally through various zones of polymeric strips. The strips have molecules attached that can interact with the analyte. The strips have a series of capillary beds, such as pieces of porous paper, microstructured polymer, or sintered polymer. Each of these elements has the capacity to transport fluid spontaneously across the polymeric strips. (Home pregnancy tests are an example of HHAs.)

HHA technology detects biowarfare agents by detecting their antigens. It employs a variety of biochemical tests to qualitatively identify the presence or absence of biological antigens or antigen specific analytes. (An antigen is a molecule on an infectious bacterial or viral agent that is capable of inducing an immune response.)

They are simple devices intended to detect the presence (or absence) of a target analyte in sample (matrix) without the need for specialized and costly equipment. This allows responders to quickly detect and identify many biological agents. (Note: HHAs can identify an agent but they can’t measure the amount or concentration of the agency present.)

One common method uses different “tickets” for each different type of biological agent. To use this system, the responder places a prepared liquid sample of the material in question on one end of the ticket where antibodies specific to a selected pathogen are located. If antigens are present that match the antibodies of the ticket, they combination is carried to the opposite end, a color change indicates a positive result, and an electronic reader analyzes the results.

Another HHA system utilizes a sandwich of antibodies, separated by a substrate. The presence of an antigen that matches the two antibodies causes a color change when a matching antigen is present.

Chemical Warfare Agent Detector (CAD) Papers and Kits

The most likely CWA CADs that HazMat team personnel are likely to encounter are M8 and M9 papers, pesticide tickets and M256A1 kits. These test papers and kits use a color change to indicate the presence of chemical warfare agents (CWA). The color changes are specific to certain CWAs so they can identify the agent.

M8 CAD Paper

M8 CAD paper are small rectangular sheets that come in a packet of 25. They are used to detect the presence of G and VX nerve agents and blister agents (in the liquid state only). Using three different indicator dyes, the presence of VX causes the paper to bleed to a dark green color, G agents cause a yellow color change, while blister agents induce a red color to appear. If such agents are present, a color change can be expected within 30 seconds. Additionally, the US Army Office of the Surgeon General recommends against using M8 paper for determining the completeness of decontamination operations as interferants for this test system include common materials including sodium hydroxide and many petroleum products.

M9 CAD Paper

M9 CAD paper is typically used as a passive system for monitoring the presence of many nerve and blister agents on personnel and equipment. M9 CAD paper comes in 2 ½” wide, 30 foot long rolls with a Mylar coating and an adhesive backing for affixing the tape to different objects. While M9 paper has a much lower level of detection (LOD) than M8 paper, M9 paper does not specify which CWA it has detected. Rather, if one of several color changes is observed, (pink, red, reddish-brown, or reddish-purple), the presence of a CWA is indicated. Similar to M8 paper, M9 paper can also generate false positive by interferants such as hydrocarbons, brake fluid, aircraft cleaning solutions, insect repellant, defoliants, and anti-freeze.

M256A1 CAD Test Kit

The M256A1 kit utilizes colorimetric indicators consisting of several different enzymatic substrates. They can identify the relative concentrations of many nerve, blister, and some blood and choking agents. An advantage this system has is that it also detects CWAs in the vapor state. Each M256A Test Kit comes with 12 tickets per case, 1 booklet of M8 CAD paper, and printed instructions. While this kit detects a broad range of CWAs, the response time is approximately 15 minutes as there are several steps that take some time prior to moving on to multiple liquid ampoules that must be broken. Although the M256A1 kit detects a wide range of CWAs they are subject to interferants such as various smoke products, hydrocarbons, and high temperatures that can cause false positives. Also, this system is not able to detect the presence of CWAs that have been placed into solution with water.

Table 7.1, M256A1 Test Kit LODs

Agent	LOD Concentration
VX	0.0018 ppm
G Series	0.005 mg/m^3
HD	0.462 ppm
L	1.65 ppm
CK	4 ppm

Microscopic Analysis

Field microscopy is a qualitative bacterial and viral identification technique. Bacteria and viruses can be identified based on their shape, size (length, width, diameter), and Gram staining characteristics. For example, Bacillus anthracis is identified by its rod shape and positive Gram Stain. One limitation that must be considered is the power and resolution of available microscopes to be used in order to identify organisms down to tenths of microns.

A Hazmat Technician with specific training in field based microscopy could visually analyze suspected samples and screen for the presence of various biological agents. Personnel must remember that proper identification requires specialized training and should always be used to complement other detection systems.

Polymerase Chain Reaction (PCR)

PCR works by taking a sample of a biological material and separating out any DNA materials that are present. The PCR instrument then heats the material which untwists (denatures) the DNA and exposes the various amino acid sequences of the associated strands. Then using a polymerase substrate, the amino acid sequences are matched to the original DNA of the sample, and doubles the amount of the original DNA sequence with each cycle. Field systems that detect for specific biological warfare agents search this very long strand of DNA for very specific and unique sequences of DNA.

Summary

There are a number of detection instruments available for emergency response. This chapter covered a variety of instruments including: colorimetric detector tubes, electrochemical sensors, flame ionization detectors (FID), gas chromatographs, mass spectrometers, infrared spectroscopy, and ion mobility. Again, responders must be familiar with the particular equipment available within their departments. They must not only know how to use them and understand their limitations, but also know how to interpret the results.

Review Questions

Which analytical technique discussed in this chapter can be used for analyzing samples with covalent bonds?

1. Ion Mobility
2. Infrared spectroscopy
3. Surface Acoustic Wave Frequency Analysis
4. Pi Bond analytics

The response time for an IR instrument can be __________ minutes, depending on the precision that the user selects for analysis.

Which instrument/system identifies chemical bonds in a molecule and produces a distinctive molecular fingerprint that can be used to screen and scan samples for many different components?

1. FTIR
2. FID
3. PCR
4. SPQR

What is a limitation of Gas Chromatography?

1. It requires frequent calibration.
2. Interfering gases can obscure results.
3. Samples may take several minutes to be analyzed.
4. It's sensitive to changes in pH.

PIDs use high-energy UV light to displace electrons from contaminants in the air, FIDs use a _____________________________ to burn organic (carbon-containing) materials in air.

SAW sensors can be easily contaminated. What type of material can do this?

1. Organic vapors.
2. Sintered polymers.
3. Hypochlorite solutions.
4. Radioactive isotopes.

Which type of detection technology can detect bio warfare agents?

1. SAW
2. HHA
3. FID
4. GC/MS

What is the average response time for a M256A Test Kit?

1. 2 minutes.
2. 15 minutes.
3. 1 hour.
4. 3 hours.

Chapter 8: Introduction to Field Identification of Unknowns

Introduction

In an emergency response, the Technical Specialist—Hazardous Materials Reference determines which type of chemical protective equipment (suit, gloves, boots and etc.) are needed; what level of respiratory protection is needed; how to decontaminate the material (suits, monitors, equipment and people); evacuation distances and a host of other safety factors, based on the Field Identification of known or unknown chemical. Determining the identity of an unknown solid or liquid can be relatively simple or very complex. The level of complexity is based on how much information is need about the chemical make-up; is it a pure chemical or a mixture, how many chemicals are mixed together and is the result a mixture or did/or will it react?

The most accurate method for determining the identity of an unknown solid, liquid or gas, is to send it to a laboratory for analysis. Unfortunately, lab analysis takes time and most Hazardous Materials Teams do not have that luxury. Most teams use a variety of methods to analyze the product. The method used is directly related to the level of information required. In other words, does the responder need to know the full chemical make-up, or are the general characteristics sufficient?

Field Identification consists of a variety of qualitative and quantitative tests. Each test is designed to give responders a piece of the puzzle. The key is to use the right tests, *in the correct sequence* to produce a valid conclusion. This chapter will discuss strategies for the use of Field Identification to determine the identity or category of a given chemical.

Regulatory Justification

Field Identification ties together the A-Week Chemistry theory with B-Weeks practical application to give the participant a well-rounded understanding of chemicals. This component provides the training specified:

- NFPA 472 requires that the hazmat emergency responder be able to identify at least three hazardous materials, one solid and one liquid unknown using field techniques.
- Title 19 California Code of Regulations (CCR) §2520 (l)(1)(F) requires each student to test two solids and three liquids during training.
- Title 8 CCR 5192 (q)(6)(c)(2) and 29 CFR 1910.120 (q)(6)(iii)(b) which states that a hazmat technician must know how to classify, identify, and verify unknown materials using field equipment.

Field Identification: Purpose

There are many reasons why a Hazmat Technician may need to identify an unknown material. A few of the reasons, in addition to those previously mentioned, are listed here:

1. Establish protective actions and distances
2. Determine methods of detection
3. Selection of personal protective equipment
4. Determine decontamination solution
5. Provide medical treatment of exposures and contamination
6. Make notification to medical facilities
7. Provide notification to responders and those on-scene
8. Classify the chemical for containerization and shipping

The Local, State and Federal Environmental Health agencies may require identification for:

1. Assignment of EPA and RCRA waste characteristics
2. Assignment of DOT Hazard Class
3. *Assignment of DTSC Hazardous Waste Class*
4. Rapid assessment of hazards
5. Selection of mitigation measures
6. Bulking materials into consolidated waste streams
7. Public health risk assessment

The most valuable aspect of a field identification class is that it provides hands-on familiarity with hazardous and non-hazardous chemicals. The participant learns to relate a given chemical's appearance and behavior to its chemical structure and gains a crucial understanding of the difference between organic and inorganic chemistry. This practical information is highly pertinent to all emergency response personnel.

In the chemistry field, the identification of unknown solids and liquids is called "Qualitative Analysis", and it is one of the oldest branches of chemistry. It is the branch of chemistry that is concerned with the principles, methods, and techniques used in establishing the identity of a substance. Qualitative Analysis seeks to find the elemental composition of compounds. It uses standard methods to test for reactions characteristic of certain ions, which may cause color change, solid forming and other visible changes

The System

The need to develop a Field Level Chemical Identification System (Field ID) for Hazmat Teams was clearly recognized as the result of previous HazMat incidents involving unknown chemicals. An example was the closure of the San Francisco Bay Bridge in 1980 for twelve hours due to a spill of an unknown white powder. The material was later identified as Microtalc™, an inert, non-hazardous substance used in food, pharmaceutical and personal care applications. An enormous amount of money, time and manpower was spent because, at that time, they had to consider a spilled substance as hazardous until it is identified. As a result of this incident Robert Turkington, then a CalOSHA employee, developed a protocol for field ID and classification of commonly spilled materials. This system later became known as HazCat™.

Field identification systems are designed to enable the emergency responder to perform tests at the incident site, reducing the need to send samples to a lab. The system is intended to identify and/or categorize the most commonly spilled hazardous and non-hazardous materials, usually single or pure chemicals. The tests utilize standard qualitative analytical techniques that allow responders to use easily observed chemical reactions to identify and/or categorize the substances and/or their components. These field identification tests utilize properties such as water reactivity, pH, flammability, specific gravity, and viscosity to identify pertinent hazardous characteristics of unknown materials.

Substances that produce similar test results to the desired one or which keep the test from functioning properly are called interferences. The only way to eliminate these interferences is to apply the tests *systematically*. This process progressively eliminates/rules out compounds not identical to the unknown material being analyzed. Over the years these methods have become increasingly efficient and accurate.

Field identification, when properly performed and applied, can be used to confirm other identification technologies, technical reference research results, and incident atmospheric monitoring data. The observed physical and chemical behaviors uniquely identified and designed into field identification systems compliment the aforementioned identification techniques. There are kits commercially available that perform these tasks.

Training and Practice

Responders performing Field Identification must have a good understanding of chemistry and the tools at their disposal. Training in each of the components of an agencies field ID method is critical to both safety and accuracy. Commercially available kits generally have training available to purchasers.

Misinterpretation of test results is a common error and can bring the analyst to an improper conclusion, which can cascade into bad response decisions. Skill must be developed in the method required for conducting each individual test. A key element to accuracy is reproducibility. Given the same sized sample of the same material, performing the same test: the results must be the same. This sounds simplistic, however a miscall on the results can be dangerous. Miscalling a “sinker”, as a “swimmer”, can lead the analyst down the wrong path and to a decision with long term medical and legal implications. Practice, on a regular basis, improves skill and accuracy.

Refresher training is required to maintain competency in the method or system and may be a legal requirement, depending on the job description. In addition, vendors update and improve their systems, requiring users to also update.

Common Errors

Taking a laboratory wet chemistry system and equipment into the field to perform qualitative analysis on an unknown sample is a recipe for the implementation of Murphy’s Law (Anything that can go wrong...).

Here are a few examples of common errors:

1. Inadequate Safety Equipment (eg: “I don’t need chemical goggles, I have eyeglasses”).
2. Using too large a sample (no bucket chemistry!).
3. Dirty glassware and equipment (Leads to false readings and can react).
4. Lack of understanding of the variables within each test. (For example the color change and subsequent bleach out of the Ki Starch paper when exposed to a strong oxidizer.
5. Skipping tests or adding additional tests, not listed on the protocol you are using.
6. Misreading a result and following the wrong path.
7. Poor or hurried technique resulting in cross contamination of equipment or samples.
8. Failure to read, understand, and *follow* instructions.

Summary

Field Identification is the “science” part of responding to hazardous materials emergencies. Whether it is used for identifying unknowns or verification of a known material, the emergency responder must be well trained, practiced and equipped.

Field identification of unknown substances can be a dangerous process. The materials involved are hazardous chemicals! Understand the processes involved for your own safety and that of others.

Examples of Field Identification Tests

Volatility Test for Vapor Pressure

No Reagents or Strip Papers required - Only pure water

Procedure

- Place watch glasses on 2 beakers, 250 ml size.
- On one watch glass, place 2-4 drops of pure water.
- On the other watch glass, place 2-4 drops of the unknown liquid.
- Monitor both watch glasses for a few minutes and see if your unknown evaporates (volatilizes) faster than the water.
- Use your magnifier.
- This is simply a comparative test. A rough estimate is all you need. Watch for a possible residue.

Summary and Conclusions

This test is greatly influenced by temperature. The higher the temperature, the faster the evaporation. Should your unknown sample evaporate much faster than the water, air contamination becomes a major factor. Monitoring devices should be used to determine toxic, corrosive, and flammable atmospheres.

Testing pH in Water:

Procedure

- Pour a sample of water into a container (test tube).
- Open up your container of pH testing strips with dry hands in a relatively dry environment; make sure you never expose unused pH testing strips to water, otherwise the color-coding on these strips will activate, and the strips will be useless for future testing
- Dip the pH test strip into the water; avoid stirring or splashing the water if at all possible.
- Hold the pH test strip under the water for several seconds. Depending on the brand of test strip you are using, submersion times will vary; consult the packaging for exact guidelines.
- Remove the pH strip after submersing for the recommended duration. Hold the test strip level and wait a 5 to 10 seconds for the strip's color swatches to brighten.
- Compare the colors on the strip to the guide printed on the pH testing strip container. Different color shades indicate different acidity or basicity levels.
- Rinse and throw away the used pH test strip once you are finished. Testing strips are designed for single-use only.

Beilstein Test Procedure

Procedure

Heat the tip of a copper wire in a burner flame until there is no further coloration of the flame. Let the wire cool slightly, then dip it into the unknown (solid or liquid and again, heat it in the flame. A green flash is indicative of chlorine, bromine, and iodine; fluorine is not detected because copper fluoride is not volatile. The Beilstein test is very sensitive, thus halogen-containing impurities may give misleading results.

Positive Test

A green flash indicates the presence of chlorine, bromine, and iodine, but *not* fluorine.

Chapter 9: Safety and Personal Protection

The following safety rules apply to the Field Identification Section of this course.

General Guidelines

1. Conduct yourself in a *responsible manner* at all times. Horseplay, practical jokes, and pranks are dangerous and prohibited.
2. *Know what you are doing* and why you are doing it. Follow all written and verbal instructions carefully. If you do not understand a direction or part of a procedure, ask the instructor before proceeding.
3. *No eating, drinking, gum chewing, or tobacco products* around chemicals or potentially hazardous environments. **Do not purposely inhale vapors!**
4. *Keep hands away* from face, eyes, mouth and body while using chemicals. Wash hands thoroughly; at breaks, and before eating, drinking, or smoking.
5. *Do not perform any unauthorized experiments*. This is grounds for dismissal from the course. Use only chemicals provided by the instructor.
6. *Be neat!* Keep your table or bench space clean and orderly. Unnecessary books or class materials should be stored elsewhere in the room during experiments. Clean up spilled materials immediately. Remember not to rest your arms on the work table.
7. Learn the location of and how to use available *safety equipment:* eyewash fountain, first aid kit, fire extinguisher, etc.
8. Notify an instructor immediately of any *spill, accident, or unsafe condition*.
9. Use extreme care when *handling chemicals.* If any chemical is accidentally splashed or comes in contact with your body, immediately use your decontamination dishpan and rinse thoroughly with water. Return caps securely on bottles and jars after use.
10. When obtaining chemicals, understand and use the proper *safe method for carrying* them back to your table.
11. *Dispose of all chemical waste properly*. Solid material such as matches, pH paper, etc. should be disposed of in the solid waste container. Only liquids should be in the liquid waste container.

Protective Clothing

12. *All members* of the team are required to wear protective clothing, regardless of who is actually handling the chemicals.
13. *Safety glasses* or other eye protection must be worn at all times in the training area. **There are no exceptions.**
14. A *splash apron* or other type of protective barrier shall be in place to prevent chemicals from getting on your clothes and/or your skin.
15. *Disposable gloves* shall be worn as minimum protection against touching chemicals or contaminated tools and glassware. Use gloves that fit properly.

16. *Head protection* shall be worn to prevent chemicals from getting into your body through the hair follicles or being unnecessarily lodged in the hair itself.
17. *Shoes* must completely cover the foot. Open-toed footwear is not acceptable.

Accidents and Injuries

18. *Report any accident* (spill, breakage, etc.) *or injury* (cut, burn, etc.) to the instructor immediately, no matter how trivial it may appear.
19. *If a chemical should splash in your eye(s)* or on your skin, immediately flush with water from the eyewash station or safety shower for at least 20 minutes. Notify the instructor immediately.

Handling Chemicals and Equipment

20. Be particularly cautious when using the *propane flame*. Be aware of powders and dust that can become airborne when introduced into the flame. Take care that hair, clothing and hands are a safe distance from the flame at all times. Never reach over an exposed flame. Never leave a lit propane torch unattended.
21. Heated metals, torch tips and glass *remain very hot* for a long time. They should be set aside to cool and picked up with caution.
22. *Check the label* on chemical bottles before use.
23. *Never return unused chemicals* to their original containers. It may contaminate the material.
24. *Conserve materials and energy.* Extinguish flames when not in use. Do not run water taps continually when washing glassware. When using chemicals for analysis, take small amounts only out of the container.
25. *When transferring chemicals* from one container to another, hold the containers away from your body.
26. *Fill wash bottles* only with distilled water and use only as intended, e.g., rinsing glassware and equipment, or adding water to a container.
27. *Examine glassware* before each use. Never use chipped or cracked glassware. Never use dirty glassware.
28. *Do not immerse hot glassware* in cold water; it may shatter.
29. If you *do not understand* how to use a piece of equipment or test procedure, ask the instructor for assistance.

Remember: *All* chemicals can be hazardous!

Remember: It’s concentration *and* the dose!

Please sign and turn in the safety policy agreement to your instructor.

Safety Policy Agreement

I, ________________________________ (printed name) have read and agree to follow all of the safety rules set forth in this policy. I realize I must obey these rules to insure my own safety, and that of my fellow students and instructors. I will cooperate to the fullest extent with my instructor and fellow students to maintain a safe lab environment. I will also closely follow the oral and written instructions provided by the instructor. I am aware that any violation of this safety policy that results in unsafe conduct in the laboratory or misbehavior on my part may result in being removed from the laboratory, and/or dismissal from the course.

____ __________

Signature Date

Chapter 10: Technical Specialist; Hazardous Materials Reference

Introduction

The Technical Specialist-Hazardous Materials Reference (commonly called “Tech Ref”) is part of the Hazardous Materials Group. This position provides technical information and assistance to the Hazmat Group. Individuals filling this position must have the expertise to identify and assess hazards and determine environmental impacts of hazardous substance releases/or potential releases. Personnel in this position must be able to provide technical data, technical assistance, strategic and tactical information to safely mitigate the incident. The FIRESCOPE ICS Mutual Aid system requires the Technical Specialist-Hazardous Materials Reference on a Mutual Aid Typed Team in California to be trained, at a minimum, to the Hazardous Materials Technician Level. Additional training may be required, based on departmental standards. Note: in a large or prolonged incident more than one person may fill this position.

Major Responsibilities of the Technical Specialist-Hazardous Materials Reference

The major responsibilities of the Tech Ref position are listed in the ICS Field Operations Guide (FOG) and stated below. Listed with each responsibility are procedures for implementing the responsibility. Remember, these are only the major responsibilities, and once you have gained experience in the position, you may want to augment this list as you see necessary. It is also important to remember that some activities are one-time actions, while others are ongoing or repetitive for the duration of the incident.

Check in and obtain a briefing

Once the Tech Ref person has completed his or her check-in process, request a briefing from the Hazardous Materials Group Supervisor or Hazardous Materials Branch Director (if activated). This initial briefing should include initial instructions concerning work activities, plus identify resources assigned and requested for the Hazardous Materials Group or Branch. The Tech Ref person should obtain an incident action plan when available. After receiving a briefing, the Technical Specialist-Hazardous Materials-Reference should start a unit log (ICS Form 214) to record significant events or actions taken during the shift.

Provide technical support to the Hazardous Materials Group

The Tech Ref position provides technical support and assistance to the Hazardous Materials Group Supervisor, Assistant Safety Officer—Hazardous Materials and the Planning Section (if activated).

Maintain communications and coordinate operations with the Hazmat Entry Leader

Using environmental monitoring, hazard assessment, geography, and other factors, Tech Ref should coordinate with the Hazardous Materials Group Supervisor to recommend control line locations. Tech Ref should provide technical support to the Decontamination Leader on decontamination procedures. This can include information on special washing agents, if needed, as well as wash/rinse sampling equipment, analysis information on decontamination effectiveness and recommendations. Safety-related technical assistance and information should also be provided to the Assistant Safety Officer-Hazardous Materials.

Provide and interpret environmental monitoring information and modify the monitoring plan as necessary as incident conditions change.

Tech Ref will provide or coordinate environmental monitoring as needed and will designate monitors, sensors and detectors which are appropriate for the chemical hazard, site monitoring, the Entry and/or Decon team and the environment in which they will be used. While Tech Ref may not use the equipment, he or she will review the environmental monitoring data and provide hazard assessment and risk/benefit information to the Entry Leader and the Assistant Safety Officer-Hazardous Materials. He or she should also track weather data and forecasts from the Weather Observer (if appointed) and obtain or arrange for weather monitoring equipment as needed.

Provide product identification, characteristics, and hazard information to incident personnel

Determine personal protective equipment compatibility to hazardous materials

Tech Ref can analyze the chemical and determine compatibility with PPE. He or she will make recommendations to the Hazardous Materials Group Supervisor, Assistant Safety Officer-Hazardous Materials, Entry Leader and Decontamination Team Leader on which PPE/equipment is appropriate.

Obtain technical information from public and private sources

Technical information sources include resources such as the Poison Control Center, Tox Center, CHEMTREC, State Department of Food and Agriculture, and the Regional Response Team. Industry, government representatives, or response teams can also provide technical information and should be requested through the Hazardous Materials Group Supervisor as needed. For example, the Regional Response Team can assist Tech Ref in obtaining computer modeling to predict the spread of contaminants. Tech Ref may be asked to provide an interpretation of technical data for dissemination by the Public Information Officer.

Provide technical information to the incident for documentation

Another responsibility of Tech Ref is to provide technical information on the incident for the required documentation. This information may require documentation duplication equipment and other services which should be planned in advance. Photographic equipment and services, such as video recording and still photography, should also be secured. All documentation will be forwarded to the Documentation Unit.

Assist in projecting the potential environmental effects of the release

Tech Ref is responsible for assisting the Planning Section with projecting the potential environmental effects of the release. This involves providing an assessment of environmental impacts and forecasting the environmental impact from estimated/measured continued substance release.

Participate in the preparation of the Site Safety and Control Plan (ICS Form 208)

The Tech Ref position plays a key role in drafting the Site Safety Plan. This position will provide information about the properties of the substance(s) involved for hazard analysis. Tech Ref will participate in making decisions about hazard monitoring, decontamination and safe work practices.

Technical Reference Briefing

In addition to helping to draft a Site Safety Plan, Tech Ref will deliver a briefing on the hazards of the material involved. This briefing will answer four questions:

What is the material?

In many cases responders may not know the name of the material involved in the incident. If that is the case then Tech Ref should try to provide as much information as possible about the material such as hazard class or the general type of material as determine by field identification methods.

What will it do?

Can the material harm us? If so, how? Will it do something bad right now? How can we protect ourselves?

Where will it go?

Will it evaporate and/or spread? Will the material rise or sink? Can we monitor its spread or detect where it has gone with instruments available to us?

What will it do when it gets there?

Will it harm anyone? Will it harm the environment? Will it dissipate on its own?

Summary:

The Technical Specialist-Hazardous Materials Reference position reports to the Hazardous Materials Group Supervisor. However, he or she may also be asked to provide technical information in the development of the incident action plan to the Planning Section and the Information Officer. The Tech Ref position must also work directly with facility representatives and product specialists. This position requires an individual who not only possesses analytical skills but also has strong interpersonal skills.

Review Questions

The Technical Specialist - Hazardous Materials Reference reports to:

1. The Incident Commander
2. The Operations Section Chief
3. The Hazardous Materials Group Supervisor
4. The Logistics Section Chief

What ICS form must, at a minimum, the Tech Spec - HM Reference maintain?

1. ICS Form 201
2. ICS Form 202
3. ICS Form 208
4. ICS Form 214

Job Aid for Tech Ref Briefings

What is the material?

Name(s): ______________________

Hazard class: ______________________

Major Hazard(s): ______________________

____

____

What will it do?

Explode?

Burn?

Evaporate quickly?

Polymerize?

Incompatibilities?

Where will it go?

Evaporate?

Spread?

Rise or sink in air?

Float or sink in water?

Can we monitor for this?

What will it do when it gets there?

Will it harm anyone?

Will it harm the environment?

Will it dissipate on its own?

Introduction to Reference Sources

Chapter 11

Introduction

- Information is key
  - Verified
  - Accurate
  - Reliable

Reference Sources

- Must be…
  - Easy to access
  - Accurate
  - Understandable

Types of Reference Sources

- Printed
- Electronic

Types of Printed Sources*

- Database
- Guidebook
- Specialty Reference
- Regulatory

*How the SEL categorizes them

Database Sources

Twelfth Editions

SAX'S
DANGEROUS
PROPERTIES
OF
INDUSTRIAL
MATERIALS

Richard J. Lewis, Sr.

- Dangerous Properties of Industrial Materials (Sax Manual)

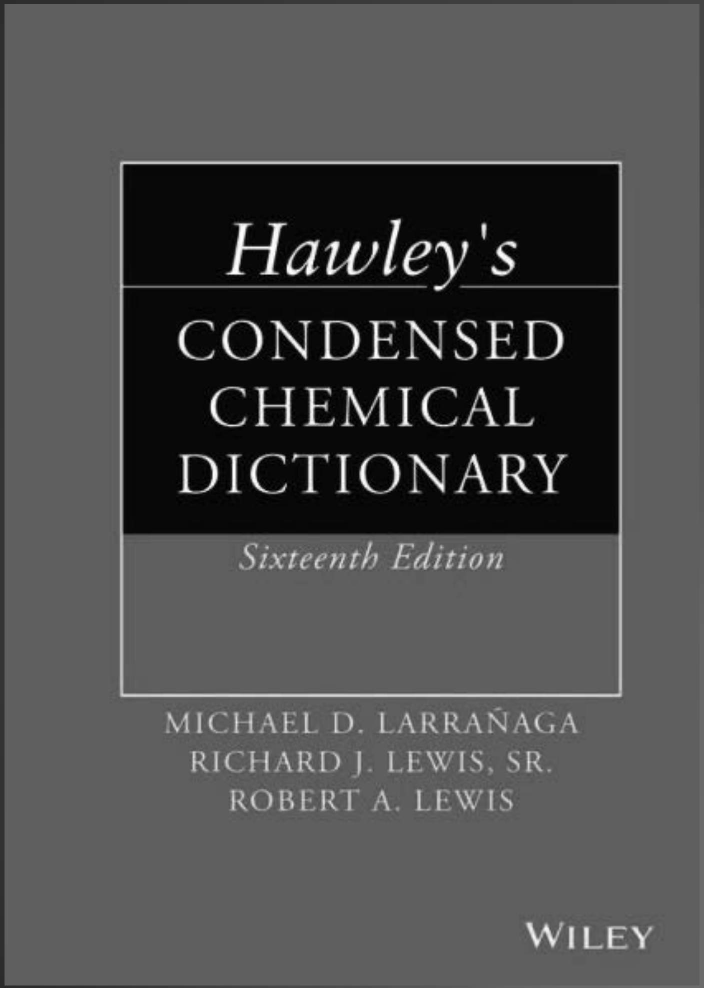
Question (Sax Manual)

- What's the LD50 of methanol?

Question (Sax Manual)

- How hard/easy was it to look up?

Database Sources



Hawley's

CONDENSED
CHEMICAL
DICTIONARY

Sixteenth Edition

MICHAEL D. LARRAÑAGA
RICHARD J. LEWIS, SR.
ROBERT A. LEWIS

WILEY

- Hawley’s Condensed Chemical Dictionary

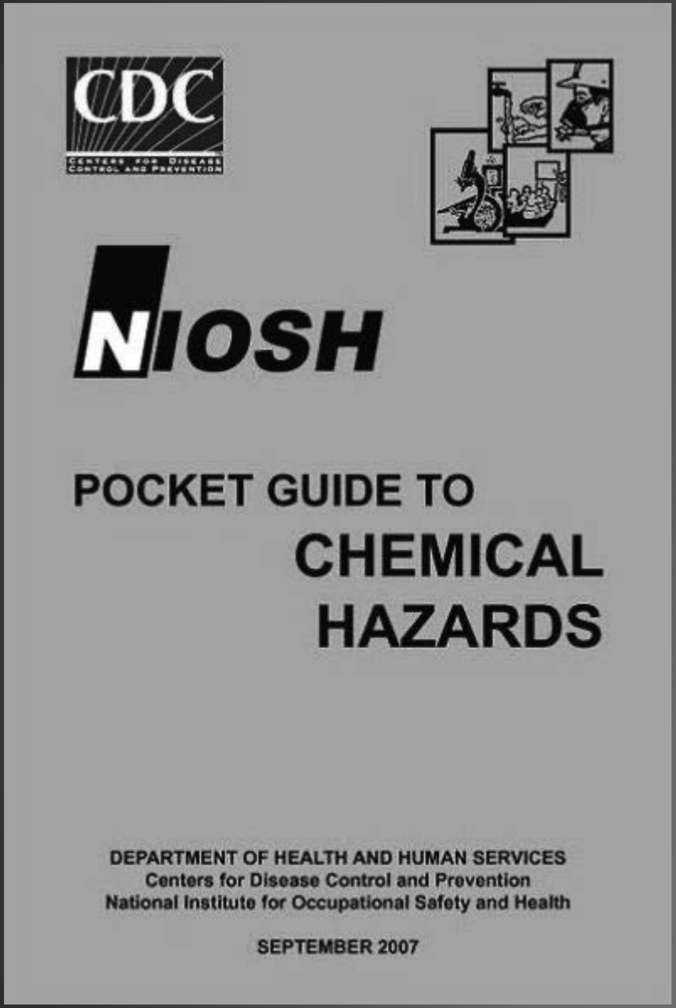
Question (Hawley's)

- What is sulfur dioxide used for?

Question (Hawley's)

- How hard/easy was it to look up?

Database Sources



CDC

CENTERS FOR DISEASE CONTROL AND PREVENTION

NIOSH

POCKET GUIDE TO
CHEMICAL
HAZARDS

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

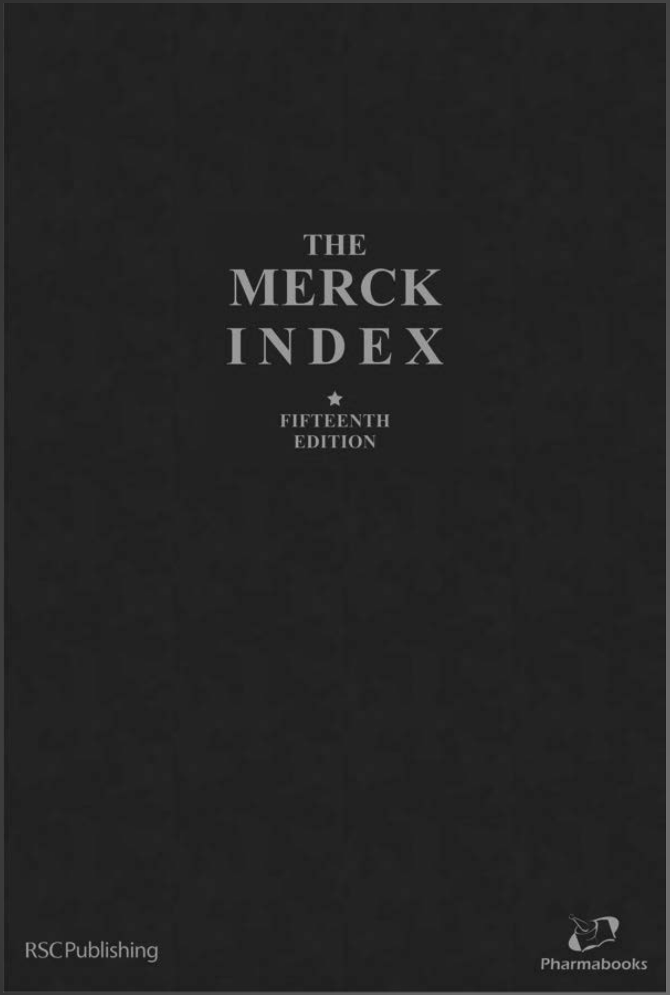
SEPTEMBER 2007

- NIOSH Pocket Guide to Chemical Hazards

Questions (NIOSH)

- Can you detect vinyl acetate with a PID that has a 10.6 eV bulb?
- Is benzene a carcinogen?
- What is the IDLH of turpentine?

Database Sources


THE
MERCK
INDEX
★
FIFTEENTH
EDITION

RSC Publishing

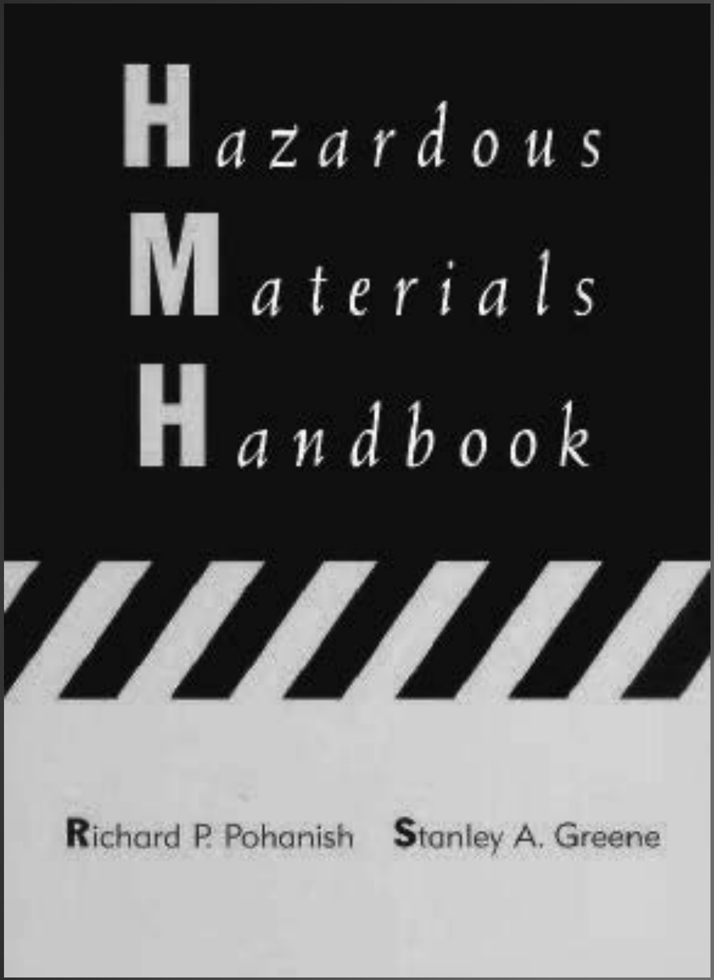
Pharmabooks

- Merck Index

Question (Merck)

- How will sodium hydroxide hurt you?

Database Sources

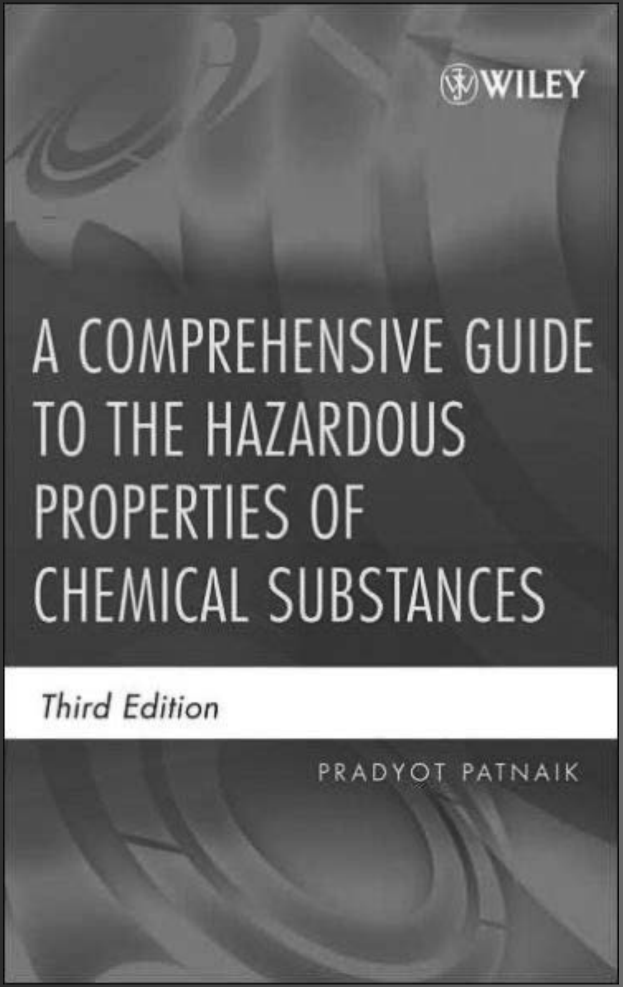


- Hazardous Materials Handbook (Pohanish)

Question (Pohanish)

- CAS # = 109-89-7
- What is it?

Database Sources



WILEY

A COMPREHENSIVE GUIDE TO THE HAZARDOUS PROPERTIES OF CHEMICAL SUBSTANCES

Third Edition

PRADYOT PATNAIK

- A Comprehensive Guide to the Hazardous Properties of Chemical Substances

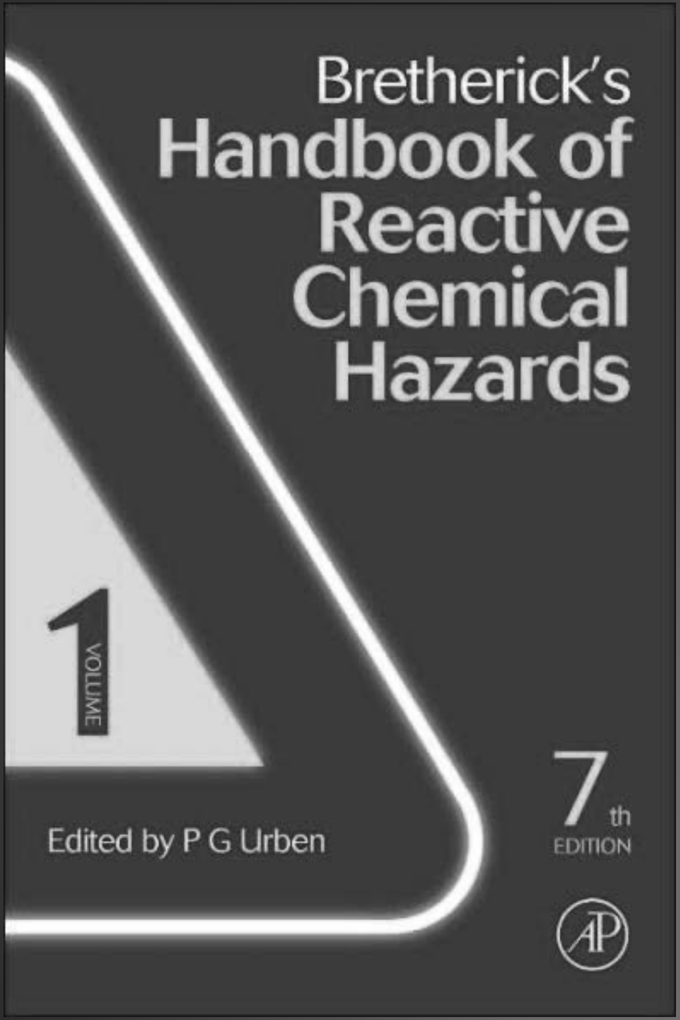
Question (Comprehensive Guide)

- Which chapter is nicotine in?
- What is ethane used for?

Database Sources

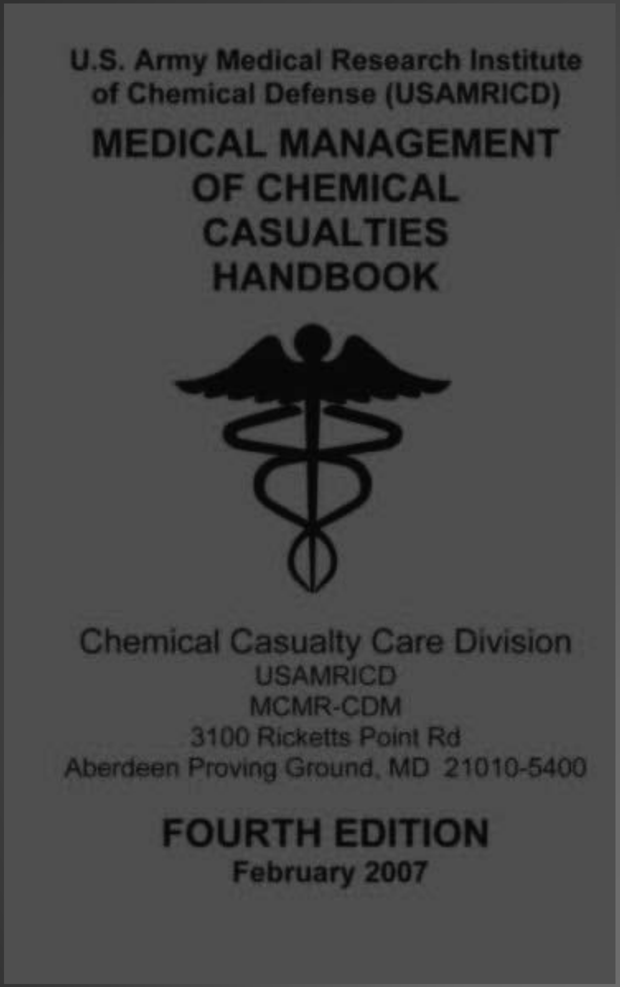
- CHRIS Manual
  - No longer published
  - Incorporated into CAMEO Chemicals

Specialty Sources



- Handbook of Reactive Chemical Hazards

Specialty Sources



U.S. Army Medical Research Institute
of Chemical Defense (USAMRICD)

**MEDICAL MANAGEMENT
OF CHEMICAL
CASUALTIES
HANDBOOK**

Chemical Casualty Care Division
USAMRICD
MCMR-CDM
3100 Ricketts Point Rd
Aberdeen Proving Ground, MD 21010-5400

FOURTH EDITION
February 2007

- Medical Management of Chemical Warfare Casualties

Specialty Sources

- Crop Protection Guide*
- Farm Chemical Book*

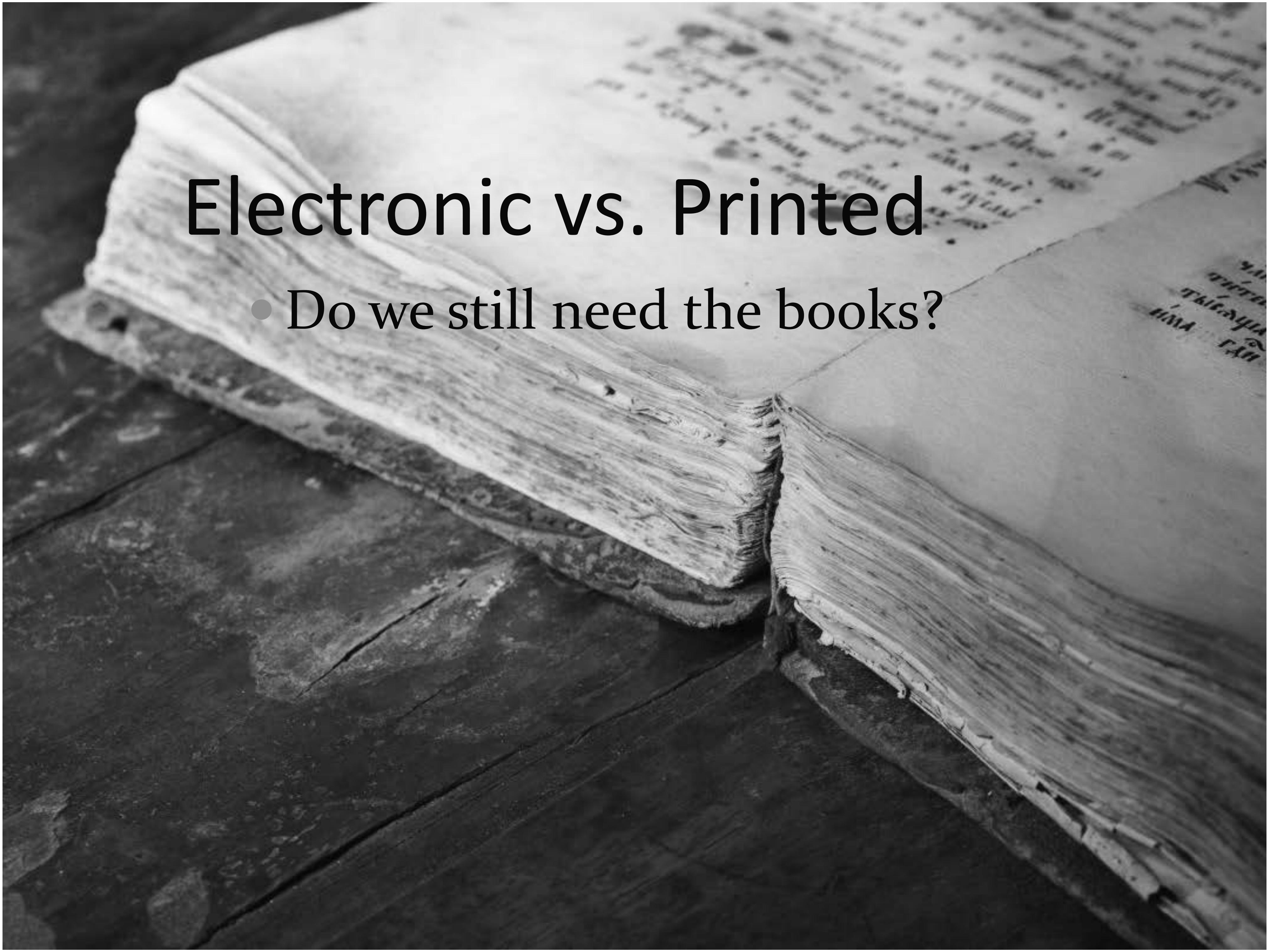
*Same thing, only different

Technical Information Centers

- See the ERG

CHEMTREC®

The right information at the right time



Electronic vs. Printed

- Do we still need the books?

Electronic vs. Printed

- Maybe!
  - Crashes?
  - Dropped signal?
  - Operator error?

Disasters

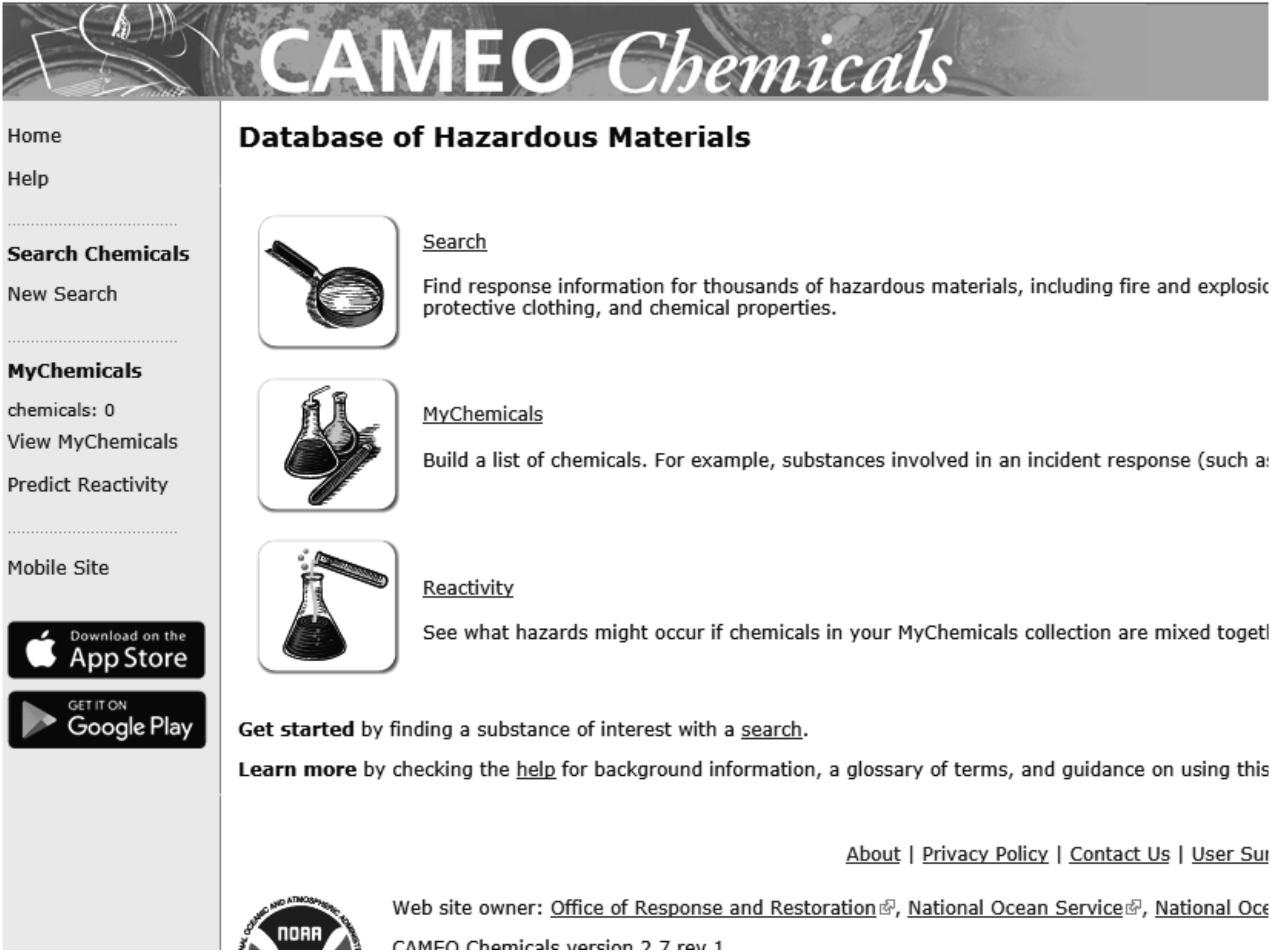
- Cell service?
- WiFi?

Cell Phones?

- Puerto Rico: 83% down
- NorCal fires: 77 sites down

Electronic Sources

- CAMEO Chemicals



Database of Hazardous Materials

Search

Find response information for thousands of hazardous materials, including fire and explosi
protective clothing, and chemical properties.

MyChemicals

Build a list of chemicals. For example, substances involved in an incident response (such a

Reactivity

See what hazards might occur if chemicals in your MyChemicals collection are mixed toget

Get started by finding a substance of interest with a search.

Learn more by checking the help for background information, a glossary of terms, and guidance on using this

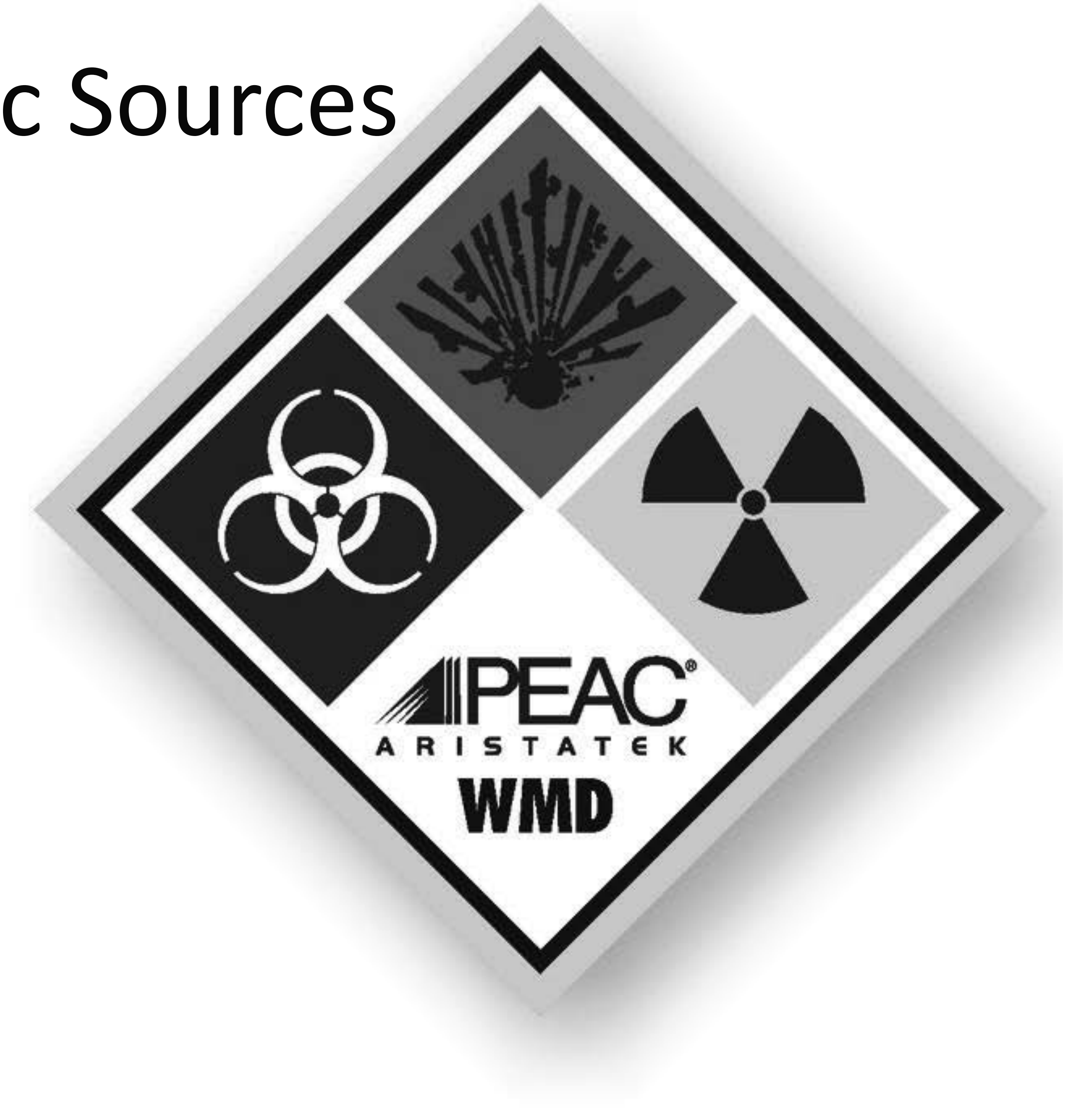
About | Privacy Policy | Contact Us | User Su

Web site owner: Office of Response and Restoration, National Ocean Service, National Oc

CAMEO Chemicals version 2.7 rev 1

Electronic Sources

- PEAC

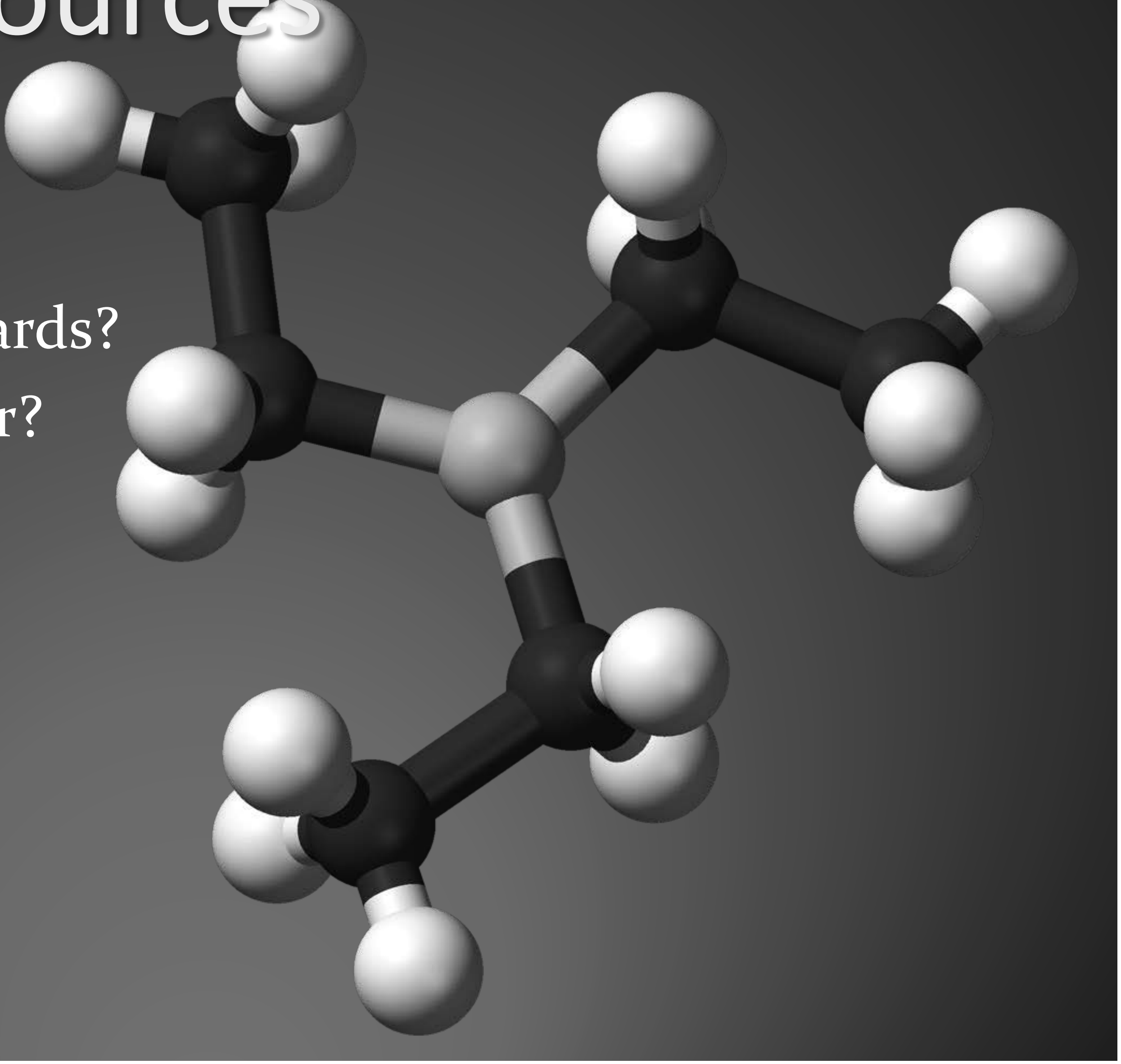


Electronic Sources

- Wikipedia?
  - Is it accurate?
  - You might be surprised…

Electronic Sources

- Triethylborane
  - What is it?
  - What are the hazards?
  - What is it used for?



Electronic Sources

- Internet!

Using the Information

- Will it do something bad right now?
- Will it hurt me?
- How can I protect myself?

Summary

- Know how to use them
- Know their limitations
- Use multiple sources