Chapter 2: Hazard Recognition – Health Effects & Property of Chemicals

Chemical, physical, biological, and radiological hazards are found at hazardous waste sites. You need to know how to recognize hazards and the signs and symptoms of exposure in order to protect yourself, others, and the environment. This chapter covers health effects and hazardous properties of chemicals.

Chapter Objectives:

After completing this module, you will be able to:

1. Explain the types of symptoms and health effects caused by exposure to health hazards.
2. Explain information on the physical properties and characteristics of hazardous chemicals (i.e., vapor pressure/density, flashpoint, LEL/UEL, specific gravity).
3. Use measurements taken at work and occupational exposure limits to figure out if you have been overexposed to chemicals in the air.
4. Use health effects, chemical properties, and sampling and monitoring information to protect yourself (i.e., knowing what chemicals should not be mixed together).
Case Study

A worker at a hazardous waste cleanup site was instructed to combine half-full drums. Sampling tests showed that two drums both contained non-flammable materials, so he poured the contents of one drum into the other. The liquid started to spatter, bubble, and produce a yellow cloud and then it caught on fire. **Why did this happen?**

When combined, the chemicals reacted and gave off vapors and so much heat that they caught on fire. Chemicals that are dangerous to mix together are called “incompatible.” In this chapter, you will learn about properties of chemicals, including incompatibility, which can be used to recognize and prevent this kind of problem.
Section I – Health Effects

Toxicology is the study of poisons and their adverse health effects.

What are some examples of poisons and their health effects (toxic response)?

- The nausea, dizziness and eye, throat, and airway irritation caused by inhaling smoke from your first cigarette.
- Slurred speech, dizziness, nausea, and vomiting caused by too much alcohol.
- Diseases and difficulty in breathing caused by years of working with concrete that contains crystalline silica.
- Others? __________________________________________________________

Exposures can be brief, occur over many years, or somewhere in between. Adverse health effects may be immediate, not evident for many years, or somewhere in between.

Acute health effects appear immediately or shortly after (within 72 hours) exposure.

Acute effects are usually caused by short-term (acute) exposures, generally less than 24 hours. Acute health effects may disappear soon after the exposure ends or the damage may be permanent.

<table>
<thead>
<tr>
<th>Exposure To:</th>
<th>Acute Responses:</th>
</tr>
</thead>
<tbody>
<tr>
<td>carbon monoxide</td>
<td>headache, nausea, weakness, dizziness, unconsciousness and death</td>
</tr>
<tr>
<td>sulfuric acid</td>
<td>skin, eye, and throat burning</td>
</tr>
<tr>
<td>nitric acid</td>
<td>irritation of eyes, skin, and mucous membranes and pulmonary edema</td>
</tr>
<tr>
<td>phosgene (carbonyl chloride)</td>
<td>pulmonary edema 24 hours after exposure, death</td>
</tr>
</tbody>
</table>
Chronic health effects occur many months or years after exposure and are often the result of long-term, often low-level, exposure to a chemical. With some chemicals, chronic health effects can result from short-term exposures.

You may not notice any effects from exposure to a chemical with chronic health effects for many years. You generally do not feel the damage as it is being done. For example, long-term exposure to asbestos can cause asbestosis, lung cancer, and other cancers, but it does not scratch your throat or give you any early warning that it is dangerous.

<table>
<thead>
<tr>
<th>Exposure To:</th>
<th>Chronic Health Effects:</th>
</tr>
</thead>
<tbody>
<tr>
<td>asbestos</td>
<td>asbestosis, lung cancer, mesothelioma, and other cancers</td>
</tr>
<tr>
<td>benzene</td>
<td>leukemia, anemia, liver damage</td>
</tr>
<tr>
<td>formaldehyde</td>
<td>nasal and lung cancer, skin sensitization, asthma</td>
</tr>
<tr>
<td>fume from sulfuric and/or nitric acid</td>
<td>enamel erosion of front teeth</td>
</tr>
<tr>
<td>solvents</td>
<td>liver, kidney, skin damage, central nervous system effects</td>
</tr>
</tbody>
</table>

Chemicals get into the body by four routes of entry: breathing (inhalation), absorption through the skin, swallowing (ingestion), and injection.

Most chemicals can enter the body by more than one route of entry. The toxicity of a chemical may differ depending on how it entered your body and it may not be a hazard if it can’t get into your body. Of the four routes of entry, the lungs generally offer the least resistance to a chemical entering your body. For example, ingesting large amounts of vitamin D can be acutely toxic but skin contact does not present a hazard because vitamin D is not absorbed through the skin. Inhaling metallic mercury (also known as elemental mercury or quicksilver) is generally more hazardous than ingesting it. This is because 80 percent of inhaled metallic mercury enters the blood through the lungs while less 0.01 percent of what is ingested enters the blood via the stomach and intestines.
Inhalation, or breathing them in, is the most common way that chemicals get into your body. The vapors, particles, and fibers you inhale end up in the lungs and, in some cases, cross into the blood stream along with oxygen. The smaller particles and fibers are the deeper into the lungs they are likely to travel. Fewer large particles and fibers get into the lungs because they are trapped by mucous in the nose and upper airways, moved up by the small hair-like cilia, and spit out or swallowed. Smoking damages the cilia, preventing them from moving the mucous containing trapped dust and chemicals out of the lungs.

Absorption through the skin can also be a major route of exposure. Many chemicals (for example, solvents and liquid insecticides) can cross through intact skin into the bloodstream. Different areas of the body absorb chemicals at different rates. The rate of absorption varies with skin thickness, water content, and fat content. Some chemicals will pass through your skin more quickly if your skin has been exposed to water for an extended period of time (for example, wearing sweaty gloves all day). The rate of absorption will also increase if the skin has been irritated, damaged, punctured, or been exposed to chemicals that break down fat in the skin. The relative rate of absorption is compared to a part of the body with a low rate of absorption. This graphic compares the chemical absorption rate of some parts of the body to the absorption rate of the feet.

Chemicals may cause allergic or irritant dermatitis following skin contact (discussed later in this section).
Chemicals can be ingested, or swallowed, when you eat, drink, or smoke. Toxic particles are also ingested when you swallow the mucus that has trapped them. Do not eat, drink, smoke, or put on ChapStick© or other cosmetics in a contaminated area. Never bring food, cigarettes or cosmetics into contaminated areas.

Chemicals, bacteria, and other materials can be injected under your skin by contaminated tools, sharp objects, or pressurized air, gas, or hydraulic fluid.

How does your body react when exposed to chemical or physical hazards?

The resulting health effects include injuries and illnesses, temporary health effects and long-term diseases, minor symptoms to life-threatening conditions, and death. A few examples are provided below and specific types of health effects will be discussed in detail.

**Head (nervous system):** dizziness, headaches, stress nervousness, irritability, sleeplessness, tremors, speech changes

**Ears:** ringing, temporary deafness, hearing loss

**Teeth and Gums:** corrosion of enamel, blue/discolored gums

**Eyes:** redness, irritation, watering, grainy feeling, welder’s flash

**Nose and Throat:** sneezing, coughing, sore throat, nasal cancer

**Chest and Lungs:** wheezing, congestion, shortness of breath with mild exercise, flu-like symptoms (metal fume fever)

**Muscles, Tendons, and Joints:** soreness, inflammation, tendinitis

**Reproductive System:** miscarriage, irregularities in menstruation, damage to fetus or chromosomes, low sperm count, sterility

**Stomach and Intestines (gastrointestinal tract):** vomiting, diarrhea

**Skin:** redness, dryness, itching, ulcers, skin cancer
The dose response curve shows how people respond to toxic chemicals. A higher dose means a greater response by the body.

Several factors influence each person’s response to a certain dose, or amount, of a chemical. This is true whether the chemical is the alcohol we drink, the medicine we take, or a solvent used at work.

Factors that affect an individual’s response to a toxic chemical include:

- Body weight
- Occupation
- Physical and health condition
- Exposure to other chemicals (now or in the past)
- Gender
- Heredity
- Age
- Lifestyle (smoking, nutritional status)
Your body processes chemicals in three ways:

1. **Metabolize**, or break down, the chemical into a form that is more easily separated and removed from the body. Most chemicals are metabolized in the liver but other organs, including the lungs, kidneys, skin, stomach, and intestines can be involved in metabolizing chemicals too. Often the chemical is altered to be more water soluble (easier to excrete) and less toxic.

2. **Excrete** the chemical or the byproducts of its metabolism in urine, feces, sweat, exhaled air, or hair.

3. **Store** the chemical or byproducts of its metabolism in the bones, fat, or other tissues

**Chemicals are often classified by how they harm us.** We’re going to talk about the following classes of chemical hazards.

- Asphyxiants
- Irritants
- Sensitizers
- Systemic toxins
- Blood system
- Nervous system (neuro) toxins
- Liver (hepato) toxins
- Kidney (renal or nephron) toxins
- Reproductive toxins
- Carcinogens
- Teratogens
- Mutagens

**Asphyxiants are chemicals that interfere with getting oxygen to body tissues and can cause suffocation.** There are two kinds of asphyxiants: simple asphyxiants and chemical asphyxiants.

**Simple asphyxiants take the place of (displace) oxygen in the air so that there is less oxygen available to be brought into the body.** There are many simple asphyxiants that may be found on construction and hazardous waste sites. Carbon dioxide, ethane, helium, hydrogen, methane, neon, krypton, acetylene, nitrous oxide, argon, propane, and nitrogen are simple asphyxiants.
An atmosphere with less than 19.5% oxygen by volume is considered oxygen deficient and immediately dangerous to life and health. The health effects experienced depend on duration of the oxygen deficiency, work rate, breathing rate, temperature, health, and age. Adverse health effects, such as reduced reaction times, may begin at 19.0% oxygen but not be immediately noticeable or recognized. These percentages are for measurements taken at sea level; adjustments must be made for higher elevations.

Chemical asphyxiants reduce your body’s ability to provide oxygen to its tissues, even when there is plenty of oxygen in the air. Chemical asphyxiants interfere with:

1. Oxygen getting into the blood
2. Oxygen being transported to body tissues
3. Oxygen being taken up by tissues
4. A combination of the three
Even at low levels or following brief exposures, chemical asphyxiants can cause collapse, unconsciousness, and death. Carbon monoxide, hydrogen cyanide, hydrogen sulfide, and methylene chloride are chemical asphyxiants.

An irritant causes inflammation by direct contact with the skin, eyes, nose, mouth, or respiratory system. Irritants can also be allergens.

• **Respiratory tract irritants can cause injury to the nose, mouth, throat and lungs.** Inhaled irritants can harm any part of the respiratory tract but their water solubility determines where they will do the most damage. Materials that are more water-soluble (e.g., ammonia, formaldehyde, and sulfur dioxide) affect mainly the upper respiratory tract as they contact moist tissues in the nose and throat. Less water-soluble materials (e.g., nitrogen dioxide and phosgene) act deeper in the lungs (lower respiratory tract). Chlorine and ozone are examples of chemicals that often affect both the upper and lower respiratory tract.

Respiratory tract irritation can be relatively minor, such as a tightening of the chest or bronchitis. But it may also be very serious, as in the case of pulmonary edema (fluid in the lungs), and cause death.

• **Skin irritants can cause redness, itching and drying of the skin, which is known as contact dermatitis.** Organic solvents and detergents are examples of skin irritants. Some acids, such as sulfuric acid, are irritants at low concentrations but can cause burns and destroy tissue at higher concentrations.

After repeated exposures to chemicals known as allergic sensitizers, some people become allergic and develop a reaction to even small exposures of those chemicals. **Allergic sensitizers generally affect the skin and respiratory tract and the reaction may get worse with each exposure.** The symptoms are often the similar to those caused by irritants but they can occur at locations other than where the chemical came in contact with the body. An example of such symptoms is asthma (inflammation and narrowing of the airways in the lungs) following skin contact with isocyanates. As with irritants, the response can be very serious, and may even cause death. Sensitizers include isocyanates, formaldehydes, phenol resins, epoxy resins, chromium, and nickel.
Systemic toxins affect body systems that are removed from the body part of original contact. This is different from local health effects, such as skin irritation or burns from contact with an acid, which occur at the point of contact with the chemical. An example of systemic toxicity is the central nervous system (brain) depression caused by exposure to alcohols. Like many chemicals, alcohols can also cause local health effects such as irritation at the site of contact (skin, eyes, and lungs).

Blood system toxins damage blood cells or interfere with blood cell formation. Examples include benzene, methylene chloride, arsine, phosphorus, and naphthalene.

Nervous system (neuro) toxins damage the central nervous system (brain) or peripheral nervous system. Symptoms include dullness, muscle tremor, restlessness, convulsions, loss of memory, epilepsy, and loss of muscle coordination. Examples include mercury, insecticides, hexachlorophene, and lead.

Liver (hepato) toxins cause liver damage and produce symptoms including jaundice and liver enlargement. Examples include alcohols, carbon tetrachloride, and nitrosamines.

Kidney (renal or nephro) toxins damage the kidneys. Examples include halogenated hydrocarbons, heavy metals, ethylene glycol.

Reproductive toxins damage the reproductive cells (egg and sperm) or interfere with their formation. Examples include DBCP, lead, cadmium, cellosolves, and vinyl chloride.

Carcinogens cause cancer and must be listed on an SDS equal or greater than 0.1 percent of the product. Cancer is the uncontrolled growth of malignant (harmful) cells at any site in the body. Cancer can take 20 to 30 years after the exposure to develop. Carcinogens include vinyl chloride, asbestos, methylene chloride, and toluene-2, 4-diisocyanate. Other chemicals must be listed on an SDS if the amount is 1.0 percent of the product.
Teratogens cause birth defects in the developing fetus. Examples include thalidomide, anesthetic gases, methyl ethyl ketone, xylene, methylene chloride, lead, methyl mercury, cigarette smoke, ionizing radiation. Many teratogens can affect the fetus even before the woman knows she is pregnant.

Mutagens cause a change (mutation) in your genetic material. Mutation of the reproductive cells may cause birth defects in future children. Mutation of other cells in the body may cause cancer. Examples of mutagens include ethylene oxide (a sterilizing chemical used in hospitals), benzene, hydrazine, and ionizing radiation. Many mutagens are also carcinogens.

How do we describe how much of a chemical we might be exposed to?

Concentration is the amount of a substance (the chemical we’re concerned about) in a given amount of another material (when we’re talking about workplace exposure, the other material is often air). Concentration is different from weight because 5 mg/m3 is not 5 milligrams of arsenic, it is 5 milligrams of arsenic in every cubic meter of air.

Concentration of gases and vapors is often measured in parts per million (ppm) or parts per billion (ppb). Concentration of particulates is usually measured in weight per volume of air (i.e., mg/m3 [milligrams per cubic meter of air] or ug/m3 [micrograms per cubic meter of air]).

Parts per million (ppm) means the number of parts of one substance per million parts of another substance. The concentration of gases and vapors in air is often measured in ppm or ppb. 1 ppm is equivalent to 1 inch in 16 miles or 1 drop in 14 gallons.

\[
100% = 1,000,000 \text{ ppm} \\
10% = 100,000 \text{ ppm} \\
1% = 10,000 \text{ ppm} \\
0.1% = 1,000 \text{ ppm}
\]

Parts per billion (ppb) is 1,000 times smaller than ppm so 1 ppb is 1 inch in 14,000 miles or 1 drop in 14,000 gallons.
mg/m³ means milligrams of substance in each cubic meter of air (a cubic meter = 39 inches x 39 inches x 39 inches or about 1.25 cubic yards). These units are commonly used for concentrations of dusts, metal fumes, or other particles in the air. For example, one crushed aspirin in a cubic meter of air is 325 mg/m³.

f/cc means the number of fibers in each cubic centimeter of air. These units are used for substances such as asbestos and fiberglass. In the asbestos standard (29 CFR 1926.1101), OSHA defines a fiber as the “particulate form of asbestos, 5 micrometers or longer, with a length-to-diameter ratio of at least 3 to 1.”

mg/kg means milligrams of one substance per kilogram of another substance. This unit is often used to indicate the amount of chemicals in milligrams per kilogram of body weight to produce a toxic response. It is also used to indicate the amount of a chemical in milligrams per kilogram of contaminated soil.

For many chemicals, the NIOSH Pocket Guide lists a conversion factor from ppm into mg/m³ for many chemicals.

Micrograms (µg), milligrams (mg), grams (g), and kilograms (kg) are metric units of mass or weight. A grain of sugar weighs approximately 1 milligram. A gram is one thousand (1,000) milligrams and approximately the mass of a dollar bill or a paper clip. A kilogram is one million (1,000,000) milligrams and about 2.2 U.S. pounds.

2.2 pounds = 1 kg = 1,000 g = 1,000,000 mg = 1,000,000,000 µg

1 gram (g) = Weight of a dollar bill

or

Weight of 1 Packet of Sweet ‘N Low
Micrometers (µm), millimeters (mm), centimeters (cm), and meters (m) are metric units of length. There are approximately 2.5 centimeters in an inch.

3.3 ft = 39.4 in = 1 m = 100 cm = 1,000 mm = 1,000,000 µm

Cubic centimeter (cc or cm³) and cubic meter (m³) are common metric units of volume. A cubic centimeter is the volume of a cube that is 1 centimeter long, 1 centimeter high, and 1 centimeter deep. A sugar cube is approximately one cubic centimeter.

A cubic meter is the volume of a cube that is 1 meter long, 1 meter high, and 1 meter deep. The volume of a blue public mailbox is approximately 1/4 cubic meter and 250,000 times larger than a cubic centimeter.

Exposure limits describe the maximum amount or concentration of chemical you can be exposed to. The term occupational exposure limit (OEL) is a term that includes all workplace exposure limits. Some OELs are legally enforceable and some are recommendations.

Permissible Exposure Limits (PELs) are enforceable exposure levels set by OSHA. Employers must keep exposures below the PELs. NIOSH and non-governmental agencies (such as the American Conference of Governmental Industrial Hygienists) also establish limits, but these recommendations are not legally enforceable.
Threshold Limit Values (TLVs) are recommended exposure limits set by the American Conference of Governmental Industrial Hygienists (ACGIH), a private, non-governmental organization. In general, TLVs are not legally enforceable. Contractors on Department of Energy (DOE) sites are required to meet the 2005 TLVs when they are more protective (lower) than the OSHA PELs. TLVs are reviewed and updated annually and are usually more protective of human health than PELs.

Recommended Exposure Levels (RELs) are set by NIOSH and are not legally enforceable. RELs are usually more protective of human health than PELs.

Most PELs and TLVs are defined as average exposures over an 8-hour work shift. RELs are set for 10-hour days so they don’t need to be adjusted when working 10-hour days. Some PELs, TLVs, and RELs have a “skin” notation, which means that the material is readily absorbed through the skin.

Short-Term Exposure Limits (STELs) are a maximum average concentration to which a person may be exposed for a short period of time, usually 15 minutes. It is legally enforceable if set by OSHA. NIOSH and ACGIH also have recommended STELs for some chemicals.

The ceiling limit is an exposure level that must not be exceeded at any time. It is legally enforceable if set by OSHA.

**Your Exposure Limits: Important Points to Remember**

Most OSHA Permissible Exposure Limits (PELs) and ACGIH Threshold Limit Values (TLVs) are 8-hour averages.

- STELs are set for very few compounds
- STELs and Ceiling limits provide protection from the effects short-term exposure to high concentrations (acute effects)
- You can submit a written request to your employer for exposure monitoring results under the OSHA Standard on Access to Employee Exposure and Medical Records (29CFR1910.1020)
Exposure Limits – Time-Weighted Averages (TWA’s)

Most PELs are 8-hour time-weighted averages (TWA) and are expressed as either mg/m3 or ppm.

There are also shorter TWAs. Short Term Exposure Limits (STELs) are TWAs that are averaged over a 15-minute period.

### How a Time-Weighted Average is Calculated

You are exposed to acetone at 80 ppm for 6 hours and 60 ppm for 2 hours. What is your average exposure for the 8-hour shift?

\[
TWA = \frac{(\text{concentration } \#1 \times \text{time } \#1) + (\text{concentration } \#2 \times \text{time } \#2)}{(\text{time } \#1 + \text{time } \#2)}
\]

\[
TWA = \frac{(80 \text{ ppm \times 6 hours}) + (60 \text{ ppm \times 2 hours})}{(6 \text{ hours} + 2 \text{ hours})}
\]

\[
TWA = \frac{480 + 120}{8} \text{ ppm}
\]

\[
TWA = 75 \text{ ppm}
\]

The OSHA Permissible Exposure Limit (PEL) for acetone is 1,000 ppm. The PEL has not been exceeded.
You are working with methyl alcohol (methanol). You know that the OSHA Permissible Exposure Limit (PEL) for methyl alcohol is 200 ppm and want to determine if you are being overexposed. Monitoring results show that you are exposed to 250 ppm for 4 hours and 25 ppm for 4 hours in one day. Determine your average exposure for the 8-hour shift?

\[ TWA = \frac{(\text{concentration #1} \times \text{time #1}) + (\text{concentration #2} \times \text{time #2})}{(\text{time #1} + \text{time #2})} \]

\[ TWA = (\quad \text{ppm} \times \quad \text{hours}) + (\quad \text{ppm} \times \quad \text{hours}) \]

\[ \quad \text{hours} + \quad \text{hours} \]

\[ TWA = \quad (\quad + \quad ) \quad \text{ppm} \]

\[ TWA = \quad \text{ppm} \]

Does your exposure exceed the PEL?

**Exposure to all chemicals in a mixture must be considered, especially if the health effects of the chemicals are similar.** For example, if you work on a hazardous waste site cleaning up acetone, xylene, and toluene, it is important to consider your exposure to all three because they all affect the central nervous system.
This example shows how to combine exposures to chemicals that have similar effects. Air monitoring shows that acetone levels are at 500 ppm, xylene levels are at 50 ppm, and toluene levels are at 100 ppm.

\[
\begin{align*}
\text{TWA acetone} & \quad + \quad \text{TWA xylene} & \quad + \quad \text{TWA toluene} \\
\text{PEL acetone} & \quad + \quad \text{PEL xylene} & \quad + \quad \text{PEL toluene} \\
500 \text{ ppm} & \quad + \quad 50 \text{ ppm} & \quad + \quad 100 \text{ ppm} \\
1,000 \text{ ppm} & \quad + \quad 100 \text{ ppm} & \quad + \quad 200 \text{ ppm} \\
= & \quad = \quad = \\
\frac{1}{2} & \quad + \quad \frac{1}{2} & \quad + \quad \frac{1}{2} \\
& \quad = \quad 1.5
\end{align*}
\]

In this example, the result was 1.5 meaning that additional controls to reduce exposures are needed.

Some exposures can be measured in blood, urine, or exhaled breath. This is called biological monitoring.

Examples include:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Measured In</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead</td>
<td>Blood</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>Breath or blood</td>
</tr>
<tr>
<td>n-hexane</td>
<td>Breath or urine</td>
</tr>
<tr>
<td>Parathion (pesticide)</td>
<td>Urine</td>
</tr>
<tr>
<td>Perchloroethylene</td>
<td>Blood, urine, breath</td>
</tr>
</tbody>
</table>
Summary: Toxicology and Health Effects

A high concentration (dose) of a toxic chemical for a short period (minutes) of time is called an **acute exposure**. Acute exposures can be very dangerous to your health now (acute effect). Exposure to a chemical over a long period of time (days, months, years) is called a **chronic exposure**. Some chronic exposures cause cancer, permanent nerve or brain damage, lung, liver, or kidney disease (chronic effect).

Some toxic chemicals only harm you at the point of contact with your body (skin, eyes, and lungs)—this is called a **local effect**. Other chemicals enter your body and harm tissues or organs in parts of the body that are not near the point of contact or entry. These are called **systemic effects**.

Chemicals can get into the body by **absorption** (soaking through the skin), **inhalation** (breathing in), **ingestion** (getting in your mouth when you eat or smoke), and **injection** (with a needle, splinter, tool, compressed air, etc.). These are called **routes of entry**. In addition, chemicals can harm us at the point of contact (skin, lungs, etc.).

When the dose, or amount of a toxic chemical the body is exposed to, increases, the body’s response increases. This is called the **dose-response relationship** for the chemical. In other words, the dose-response relationship is the amount the harm or effect that a certain exposure causes increases as the dose increases. Each worker has a slightly different response to the same dose of a chemical.

Chemicals can be dangerous to both people and the environment. You should be able to identify these hazards and protect yourself.

**Solvents** often irritate the skin, eyes, nose, throat and lungs. When solvents get into the blood, the brain and nerves are often affected. Long-term exposure to some solvents can cause damage to the liver and kidneys.

**Acids** and **bases** (also known as caustics or alkalis) are corrosive chemicals that can damage the skin, eyes, and airways.
Chemicals exposures and radiation that damage the blueprint (DNA) of the cell are called **mutagens**. Substances (like asbestos) and radiation that cause cancer, usually many years after the exposure, are called **carcinogens**. Chemicals and radiation that cause birth defects are called **teratogens**. Chemicals that cause problems, such as infertility, low sperm count, changes in hormones, and menstrual problems, making it difficult or impossible for men and women to have children are called **reproductive toxins**.

When lead, mercury, or other **heavy metals** get into the body the brain and nerves are affected. Even at low levels, lead can cause anemia. Cadmium and uranium are poisons that can cause kidney damage and lung cancer.

**Section II – Properties of Chemicals**

**What will we clean up?**

ATSDR (Agency for Toxic Substances and Disease Registry) states that “this priority list is not a list of “most toxic” substances, but rather a prioritization of substances based on a combination of their frequency, toxicity, and potential for human exposure at NPL (National Priority List) sites.”
ATSDR/EPA 2013 Substance Priority List

1. Arsenic
2. Lead
3. Mercury
4. Vinyl Chloride
5. Polychlorinated Biphenyls (PCBs)
6. Benzene
7. Cadmium
8. Benzo(A)Pyrene
9. Polycyclic Aromatic Hydrocarbons
10. Benzo(b)fluoranthene
11. Chloroform
12. Aroclor 1260
13. DDT, PP’
14. Aroclor 1254
15. Dibenzo(A, H)anthracene
16. Trichlorethylene
17. Chromium, hexavalent
18. Dieldrin
19. Phosphorus, white
20. Hexachlorobutadiene

Beryllium is also common on hazardous waste sites.

Source: ATSDR Web Site http://www.atstdr.cdc.gov/spl/
Chemical formulas

All chemicals are made up of atoms that can come together to form molecules. There are approximately ninety-two types of atoms, or elements, that appear in nature. Each element has a chemical symbol. Carbon’s symbol is C, oxygen’s symbol is O, and silicon’s symbol is Si but this pattern doesn’t always hold true. Iron’s symbol is Fe and potassium’s symbol is K. Chemical formulas indicate what atoms a molecule is made of. Each formula lists the symbols of the atoms in the molecule and how many of those atoms are in each molecule. For example, carbon monoxide (CO) has one carbon atom and one oxygen atom; carbon dioxide (CO2) has one carbon atom and two oxygen atoms.
Elements commonly found in hazardous chemicals or at hazardous sites

<table>
<thead>
<tr>
<th>NON-METALS</th>
<th>METALS</th>
<th>INERT GASES</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELEMENT</td>
<td>SYMBOL</td>
<td>ELEMENT</td>
</tr>
<tr>
<td>Carbon</td>
<td>C</td>
<td>Sodium</td>
</tr>
<tr>
<td>Oxygen</td>
<td>O</td>
<td>Potassium</td>
</tr>
<tr>
<td>Hydrogen</td>
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<td>Aluminum</td>
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<td>Nitrogen</td>
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<tr>
<td>Chlorine</td>
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<td></td>
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<td>Uranium</td>
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<td></td>
<td></td>
<td>Plutonium</td>
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<td></td>
<td></td>
<td>Silica</td>
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</table>

* radioactive elements

Organic chemicals always contain a carbon atom, usually bonded to a hydrogen atom, but not all chemicals with a carbon atom are organic. Do not confuse organic chemicals (many are poisonous) with organic vegetables (no pesticides). Many solvents are organic chemicals. Petroleum, coal, oils, vegetation and all animals are made of organic chemical compounds. Some organic compounds are listed below.

- Benzene (C6H6)
- Chloroform (CHCl3)
- Glucose (C6H12O6)
- Carbon tetrachloride (CCl4)
- Ethyl alcohol (CH3CH2OH)

Inorganic chemicals generally do not contain carbon atoms. Examples are provided below.

- Hydrochloric acid (HCl)
- Sulfuric Acid (H2SO4)
- Water (H2O)
- Silica (SiO2)
- Ammonia (NH3)
- Sodium Chloride - table salt (NaCl)
- Sodium Hydroxide (NaOH)
Chemical and Physical Properties: How Do Chemicals Act?

How chemicals act depends upon their physical and chemical properties. Understanding how chemicals behave can help you anticipate the hazards.

The following properties of chemicals are explained below. The next chapter will discuss where to find this information for chemicals on your job site.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Freezing Point</td>
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<td>2.</td>
<td>Melting Point</td>
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<tr>
<td>3.</td>
<td>Boiling Point</td>
</tr>
<tr>
<td>4.</td>
<td>Corrosiveness</td>
</tr>
<tr>
<td>5.</td>
<td>pH</td>
</tr>
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<td>6.</td>
<td>Solubility in Water</td>
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<tr>
<td>7.</td>
<td>Specific Gravity</td>
</tr>
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<td>8.</td>
<td>Viscosity</td>
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<td>9.</td>
<td>Relative Gas Density (vapor density)</td>
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<td>10.</td>
<td>Vapor Pressure</td>
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<td>15.</td>
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<tr>
<td>16.</td>
<td>Shock Sensitivity</td>
</tr>
</tbody>
</table>

Chemicals can exist in three states: solid, liquid, or gas/vapor. Solids have fixed volume and shape and are not compressible. Liquids are compressible, have a fixed volume, and change shape with the container. Gases are compressible and have an undefined shape and volume (they expand to fill the container).
We often use the terms gas and vapor interchangeably because they behave similarly, but they are actually slightly different. The difference is that a vapor is a gas that is normally a liquid or solid at room temperature. When a liquid evaporates it produces vapors. Some solids, such as iodine and carbon dioxide, are capable of subliming (going directly from a solid to a gas) at atmospheric pressure and room temperature; thus, such solids also have significant vapor pressures under these conditions.

It is important to know what phase (solid, liquid, or gas) a chemical is in to understand the risk. For example, a solid block of lead can’t harm you unless you swallow it or grind it into small particles and inhale it. But if it is heated, the lead will turn into a liquid which can burn you. If heated more, the lead will turn into a fume that can be inhaled. The state of substance affects the type of hazards (burn or health effects from lead exposure) and the degree of the hazards (it is easier to be exposed to lead fume than a lead block).

**Freezing Point**

**Definition:** Temperature at which a liquid becomes a solid

**Examples:** Water left in your freezer (less than 32°F) changes to a solid (ice)

**Melting Point**

**Definition:** Temperature at which a solid becomes a liquid.

**Examples:** Ice (solid water) left at any temperature above 32°F changes to a liquid (water).

<table>
<thead>
<tr>
<th></th>
<th>Melting Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tin</td>
<td>449°F</td>
</tr>
<tr>
<td>Lead</td>
<td>620°F</td>
</tr>
<tr>
<td>Copper</td>
<td>1,985°F</td>
</tr>
<tr>
<td>Iron</td>
<td>2,800°F</td>
</tr>
</tbody>
</table>
Sublimation

**Definition:** The process by which certain solids become gases (sublimes) without ever being a liquid

**Example:** Dry ice (CO₂) changes from a solid to a gas at temperatures above -109°F

Boiling Point

**Definition:** The temperature where a liquid rapidly changes into a vapor or gas. At this temperature, the vapor pressure of the liquid is equal to atmospheric pressure.

**Examples:**
- PCBs: 617-691°F
- Water: 212°F (100°C)
- Acetone: 133°F
- Chlorine: -29°F

**Importance:** If you know the freezing, melting, sublimation, and boiling points, you can then figure out the form or state a compound will be in at the temperature you are working in.

Corrosive

**Definition:** A compound that can damage skin, eyes, other tissues, metal, and other solids. For example, strong acids (low pH) and bases (high pH) are corrosive.

**Examples:**
- **Corrosive Acids**
  - Sulfuric acid (oleum)
  - Nitric acid
  - Hydrochloric (muriatic) acid
- **Corrosive Bases**
  - Sodium hydroxide
  - Lime
  - Sodium hydroxide (also known as lye or caustic soda)
**Importance:** Corrosives are health hazards and must be stored in glass or special plastics. **pH**

**Definition:** *pH* is a measure of how strong an acid or base a substance is. A pH of 1 is very acidic; a pH of 14 is very alkaline. A pH of 7 is neutral—neither acid nor base. A change in **pH of one unit** (for example, from 3 to 4) represents a **10-fold change** in acidity or alkalinity.

**Importance:** Compounds with high and low pH values will cause burns, irritate eyes, nose and lungs. **Wastes with a pH of less than 2 or greater than 12 are legally defined as hazardous.**
How will a chemical act in the air or water?

Knowing a material’s chemical properties can help you to understand where it is most likely to go in the air and water. This information is important in determining where to do air monitoring and deciding how to protect the environment.

Solubility: Will it Dissolve in Water?

Definition: Solubility is the ability of a substance to be dissolved in a solvent (often water). Solubility is usually expressed as a percentage, by weight or mass, that can be dissolved in a certain mass of solvent.

Examples: Methylene chloride has a solubility of 2% in water. This means that up to 2 grams of methylene chloride can be dissolved in 100 grams of water.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Solubility in Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>100% or miscible</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>2%</td>
</tr>
<tr>
<td>Toluene</td>
<td>0.07%</td>
</tr>
<tr>
<td>PCBs</td>
<td>Insoluble</td>
</tr>
</tbody>
</table>

Importance: Soluble compounds mix with water. A substance is said to be immiscible if it is not at all soluble in water and miscible if it is fully soluble in water. If a liquid that is immiscible (not soluble) spills into a waterway, most of it will either float to the top or sink to the bottom. A chemical’s solubility helps determine how to clean up wastes.
Specific Gravity (Sp. Gr.): Will a Liquid Float on Water or Sink?

**Definition:** Specific gravity is the density of a liquid compared to water (water = 1). If specific gravity is less than one, the chemical tends to float. If the specific gravity is greater than one, the chemical tends to sink. If the water is moving then the chemicals will mix.

**Specific gravity (Sp. Gr.),** sometimes called relative density, is the ratio of the density (mass of a unit volume) of a substance to the density of a given reference material. Specific gravity usually means relative density with respect to water. Temperature and pressure must be specified for both the sample and the reference. Specific gravity is usually measured at 1 atm and a temperature of 68 °F.

**Examples:**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Sp. Gr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toluene</td>
<td>0.87</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>1.33</td>
</tr>
<tr>
<td>PCB</td>
<td>1.39</td>
</tr>
<tr>
<td>Light diesel oil</td>
<td>0.86</td>
</tr>
</tbody>
</table>

**Importance:** By quantifying buoyancy, specific gravity helps you determine where a chemical spilled in water is likely to be found (floating on the surface or sunk down to the bottom) and to identify clean-up methods (like pillows or booms on the surface).

**Specific gravity of water is 1**

Specific gravity less than 1 (floats)  Specific gravity greater than 1 (sinks)
Viscosity: How thick is it?

**Definition:** Viscosity is the measure of a material’s resistance to flow, which decreases as temperature increases and independent of pressure (except at very high pressure)

**Importance:** This viscosity of a substance impacts how quickly it will spread if spilled.

**Relative Gas Density (RGasD)**

**Definition:** Relative gas density, also known as vapor density, is the weight of a vapor or gas compared to an equal volume of dry air at the same temperature and pressure. Relative gas density is unit-less. Air has a relative gas density (RGasD) of 1. If RGasD is greater than 1.0, the vapor or gas is heavier than air and tends to concentrate in low places. If less than 1.0, the vapor or gas tends to rise.

**Examples:**

<table>
<thead>
<tr>
<th>Substance</th>
<th>RGasD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia</td>
<td>0.60</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>0.97</td>
</tr>
<tr>
<td>Air</td>
<td>1.0</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>1.19</td>
</tr>
<tr>
<td>Methylene chloride</td>
<td>2.90</td>
</tr>
<tr>
<td>Gasoline</td>
<td>3.79</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>4.50</td>
</tr>
</tbody>
</table>

**Importance:** Tells you where to expect and monitor for released gases and vapors. Heavy gases and vapors will tend to collect in low-lying areas. Any air movement will mix gases and vapors so you can’t assume that an area is safe based on relative gas density.
RGasD of air is 1

RGasD greater than 1 (tends to sink)

RGasD less than 1 (tends to rise)

Hint: If you do not know the relative gas density of a chemical, look up its molecular weight (MW) in the NIOSH Pocket Guide. If the MW is more than 29 (the molecular weight of air) then the vapor or gas is heavier than air. If the MW is less than 29, the vapor or gas is lighter than air.
Vapor Pressure (VP): How Fast Will a Liquid Release Vapors?

Definition: Vapor pressure (VP) is a measure of a liquid’s ability to evaporate or give off vapor. The higher the VP, the faster a liquid will become a vapor. Vapor pressure is measured in millimeters of mercury (mmHg). One atmosphere of pressure (1 atm) equals 760 mmHg. Any chemical with a VP of 760 mmHg or more will be a gas at room temperature.

Liquids release some vapor all of the time but chemicals with high vapor pressures release a large amount of vapor at room temperature. Vapor pressure increases as temperature increases. The boiling point is the temperature where the vapor pressure of the liquid is as high as atmospheric pressure, and a lot more vapor is released. A chemical with a high boiling point will have a low vapor pressure – it needs more heat to become a vapor. The lower the boiling point, the higher the vapor pressure will be.

Examples:

<table>
<thead>
<tr>
<th></th>
<th>VP (mmHg) at 68°F</th>
<th>BP (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chlorine</td>
<td>5,168 (6.8 atm)</td>
<td>-29</td>
</tr>
<tr>
<td>Methylene Chloride</td>
<td>350</td>
<td>104</td>
</tr>
<tr>
<td>Acetone</td>
<td>180</td>
<td>133</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>58</td>
<td>189</td>
</tr>
<tr>
<td>Water</td>
<td>24</td>
<td>212</td>
</tr>
<tr>
<td>o-Xylene</td>
<td>7</td>
<td>292</td>
</tr>
<tr>
<td>PCBs</td>
<td>.001</td>
<td>617 - 691</td>
</tr>
</tbody>
</table>

Importance: Chemicals with high vapor pressure are gases or enter the air quickly and can be more easily inhaled. Also, a sealed vessel containing a chemical with a high vapor pressure is more likely to become pressurized and explode as the temperature rises.
**Evaporation Rate**

**Definition:** Evaporation rate is the rate at which a material will vaporize compared to the rate of vaporization of a specific material. Whenever a relative evaporation rate is given, the reference material must be stated and is usually ether or butyl acetate.

**Importance:** Evaporation rate determine how much of a liquid will vaporize and be present in the air. Evaporation rate increases as temperature, surface area (size), and air movement (wind) increase.

**Flammability**

**For a fire to burn, there must be a proper combination of four things: fuel, oxygen, heat (above the ignition temperature), and a chain reaction.** For example, even if you have enough fuel, enough oxygen, and an ignition source, there is no fire without a chain reaction producing enough heat to sustain the fire. Likewise, with enough fuel and an ignition source, but too little oxygen, there is no fire. These four items make up the fire tetrahedron.

To put out a fire, you must remove one of the four elements shown in the fire tetrahedron.
What we were taught in science class about the fire triangle was not quite right. Chain reaction was added because enough heat must be produced to sustain the fire (reaction). Think about holding the flame of a cigarette lighter beneath a 2 by 4 for a second. There is heat, oxygen and fuel, but no chain reaction. If the 2 by 4 was ground into sawdust, the reaction would go forward because the ratios were right.

**Flash Point (Fl. P.): Can the vapors burn?**

**Definition:** The lowest temperature at which a liquid will give off enough vapor to form an ignitable mixture with air near the surface of the liquid if there is a source of ignition. Liquids do not burn, vapors burn.

**Examples:**

<table>
<thead>
<tr>
<th></th>
<th>Flash Point</th>
<th>Classification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>-45°F</td>
<td>Category 2</td>
</tr>
<tr>
<td>Acetone</td>
<td>0°F</td>
<td>Category 2</td>
</tr>
<tr>
<td>Methyl ethyl ketone</td>
<td>16°F</td>
<td>Category 2</td>
</tr>
<tr>
<td>Toluene</td>
<td>40°F</td>
<td>Category 2</td>
</tr>
<tr>
<td>Turpentine</td>
<td>95°F</td>
<td>Category 2</td>
</tr>
<tr>
<td>Stoddard solvent</td>
<td>102-110°F</td>
<td>Category 3</td>
</tr>
<tr>
<td>Diesel</td>
<td>126-205 °F</td>
<td>Category 3</td>
</tr>
<tr>
<td>Cresol</td>
<td>187°F</td>
<td>Category 4</td>
</tr>
</tbody>
</table>

**Why are some of these ranges?**

**Importance:** The flash point is used to classify the relative fire hazards of liquids. **OSHA (29CFR1910.106) defines a flammable liquid as any liquid having a flashpoint at or below 199.4 °F and divides them into four categories based on the following:**

Category 1 shall include liquids having flashpoints below 73.4 °F and having a boiling point at or below 95 °F.

Category 2 shall include liquids having flashpoints below 73.4 °F and having a boiling point above 95 °F.
Category 3 shall include liquids having flashpoints at or above 73.4 °F and at or below 140 °F (60 °C). When a Category 3 liquid with a flashpoint at or above 100 °F is heated for use to within 30 °F of its flashpoint, it shall be handled in accordance with the requirements for a Category 3 liquid with a flashpoint below 100 °F.

Category 4 shall include liquids having flashpoints above 140 °F and at or below 199.4 °F. When a Category 4 flammable liquid is heated for use to within 30 °F of its flashpoint, it shall be handled in accordance with the requirements for a Category 3 liquid with a flashpoint at or above 100 °F.

When liquid with a flashpoint greater than 199.4 °F is heated for use to within 30 °F of its flashpoint, it shall be handled in accordance with the requirements for a Category 4 flammable liquid.

**Oxidizer: Can it start a fire?**

**Definition:** Chemical that can start or promote burning of other materials.

**Examples:**
- Perchloric acid
- Ozone
- Hydrogen peroxide
- Household bleach
- Peroxides
- Chlorine

**Importance:** Oxidizers can react chemically with fuels and can start fires or explosions. Store oxidizers away from flammables and combustibles.
Flammable Vapor—Explosive Limits

Definitions:  
Explosive range (flammable) is the concentration of a substance in air between the LEL and UEL. In this range, the substance will readily ignite.

Lower Explosive Limit (LEL) is the lowest concentration (% in air) of a substance that will burn if ignited. Concentrations below the LEL are “too lean” to ignite.

Upper Explosive Limit (UEL) is the maximum concentration (% in air) of a substance that will burn if ignited. Concentrations above the UEL are “too rich” to ignite.

Importance: Evacuate the area if the concentration of a flammable vapor or gas is greater than 10% of the LEL. Do not enter or stay in an area that is above 10% of the LEL unless you are trained and properly equipped.

Concentrations above the UEL are not safe because the concentration can quickly drop into the explosive range when air is added or mixed.

The concentration of flammable gases and vapors can change rapidly, so constant air monitoring is essential. Methyl alcohol’s (also known as methanol) explosive range is between 6 and 36 percent and is illustrated below.
Flammable ranges (shown below with shading) vary widely.

**Ammonia (refrigerant)**
- 0%  
- LEL 15%  UEL 28%

**Acetone (solvent)**
- 0%  
- LEL 2.5%  UEL 12.8%

**Benzene (solvent) also causes cancer at much lower levels**
- 0%  
- LEL 1.2%  UEL 7.8%

**Gasoline (fuel)**
- 0%  
- LEL 1.4%  UEL 7.6%

**Ethylene Oxide (disinfectant) also causes cancer at much lower levels**
- 0%  
- LEL 3%  UEL 100%
Would you enter a space containing 0.5% acetone? Why or why not?

____________________________________________________________________
____________________________________________________________________
____________________________________________________________________

Combustible dust fires and explosions

Fire is a rapid chemical process that produces heat and light. An explosion is a rapid chemical process that produces heat and light and violent expansion of gases.

Combustible dust is a finely divided combustible particulate solid that presents a flash fire hazard or explosion hazard when suspended in air or the process-specific oxidizing medium over a range of concentrations.

The ease of ignition and the severity of a combustible dust explosion is influenced by:

1. particle size;
2. moisture content;
3. ambient humidity;
4. oxygen available for combustion;
5. the shape of dust particles; and
6. the concentration of dust in the air.
Five conditions are necessary for a deflagration, explosion, or fire from combustible dust.

1. Oxygen
2. Combustible dust
3. Dispersion/ideal dust concentration
4. Confinement of the dust cloud
5. Ignition source

Incompatibilities and Reactivities:
What will happen if these chemicals are mixed?

Incompatible chemicals react violently when they come in contact with each other and may result in:

- fire;
- explosion; and/or
- toxic gas release.

Incompatible chemicals must be prevented from coming into contact with each other. Store containers of incompatible chemicals away from each other so that they won’t come into contact if the containers leak or rupture.

When strong acids and bases (alkalis) are mixed, heat and spattering occur and can damage eyes and skin. Acids added to cyanides produces hydrogen cyanide gas, which can cause death.

Water-reactive chemicals can create heat, spattering and toxic fumes upon contact with water.
Examples of water reactive compounds are:

**Oxides, hydroxides, and hydrides, of:**
- Lithium
- Sodium
- Potassium

**Halogens**
- Fluorine
- Iodine
- Chlorine
- Bromine

**Strong acids**
- Sulfuric acid (oleum)
- Hydrochloric acid
- Hydrofluoric acid
- Nitric acid

**Strong bases**
- Sodium hydroxide (lye)
- Potassium hydroxide
- Calcium hydroxide (lime)

<table>
<thead>
<tr>
<th>Strong Oxidizers Such As:</th>
<th>React Violently With:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chromic acid</td>
<td>Acetaldehyde</td>
</tr>
<tr>
<td>Chromic anhydride</td>
<td>Acetonitrile</td>
</tr>
<tr>
<td>Sodium peroxide</td>
<td>Acrylonitrile</td>
</tr>
<tr>
<td>Nitric acid</td>
<td>Benzene</td>
</tr>
<tr>
<td>Dry bleaches</td>
<td>Butyl alcohol</td>
</tr>
<tr>
<td>Disinfectants</td>
<td>Carbon disulfide</td>
</tr>
<tr>
<td>Chlorates</td>
<td>Cresol</td>
</tr>
<tr>
<td>Bromates</td>
<td>Cyanides</td>
</tr>
<tr>
<td>Nitrates</td>
<td>2,4-D</td>
</tr>
<tr>
<td>Peroxides</td>
<td>DDT</td>
</tr>
</tbody>
</table>

Do not store these chemicals near each other.

A further listing of incompatible chemicals is found at the end of this chapter.
Polymerization

**Definition:** Polymerization is a reaction that causes molecules to link together to form chains and produces heat in the process. Heat and toxic chemicals are often produced during the reaction.

**Importance:** Knowing the reactive properties of chemicals you are working with can help you understand if they are dangerous to your skin and eyes or can start a fire.

**Hazardous Breakdown Products**

Some materials that do not burn may release hazardous materials in a fire or during welding.

**Examples:** Chlorinated hydrocarbons produce phosgene (mustard gas). PCBs produce a soot containing the powerful carcinogens dibenzofurans and dibenzodioxins.

Shock-sensitive chemicals can explode if dropped, shaken, or moved.

**Examples:** Ethyl ether can form peroxides, which are shock-sensitive and explosive. Picric acid and perchloric acid become unstable over time and can explode if moved.

**Importance:** Do not handle bulging drums or containers if crystals have formed around the lids. Explosion containment devices and blast shields are needed to handle these chemicals. OSHA requirements for shock-sensitive chemicals are in 1910.120(j)(5) and 1926.65(j)(5).
Where can I look up this information?

The *NIOSH Pocket Guide to Chemical Hazards* is an important source of information on the hazards of 677 chemicals in use today. Safety data sheets contain information on specific products or chemicals and the DOT Emergency Response Guide provides information on groups of chemicals. These, and other information sources, will be discussed in Chapter 3.
Summary: Properties of Chemicals

Chemical reactions can cause harm to people and the environment by:

1. releasing toxic gases;
2. producing out large amounts of heat; and/or
3. causing a fire or explosion.

The terms used to describe the chemical and physical properties of substances help you anticipate the hazards that may be present.

Knowing the upper and lower explosive limits helps you figure out if an atmosphere could explode. If the concentration of a flammable vapor or gas is greater than 10% of the LEL, then the area must be evacuated immediately if you are neither trained nor equipped to work in an explosive atmosphere.

The fire tetrahedron illustrates the four items necessary for a fire to burn:

1. fuel (can be solid, liquid, or a flammable vapor);
2. oxygen in the air ignition source;
3. heat (above the ignition temperature); and
4. a chain reaction.
It is very important for you to know which chemicals are incompatible for your own safety. You can consult the NIOSH Pocket Guide to Chemical Hazards (discussed in Chapter 3) to identify chemicals that react violently with water, oxidizers, degreasing solvents, bases (alkalis), and acids.

**Partial List of Incompatible Chemicals**

Substances in the right-hand column should be stored and handled so they will not come in contact with the substances in the corresponding row of the left-hand column.

<table>
<thead>
<tr>
<th>Substance</th>
<th>Incompatible Substances</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetic acid</td>
<td>Chromic acid, nitric acid, hydroxyl containing compounds, ethylene, perchloric acid, peroxides, and glycol permanganates</td>
</tr>
<tr>
<td>Acetone</td>
<td>Concentrated nitric and sulfuric acid mixtures</td>
</tr>
<tr>
<td>Acetylene</td>
<td>Chlorine, bromine, copper, silver, fluorine, and mercury</td>
</tr>
<tr>
<td>Alkaline and alkaline earth metals</td>
<td>Carbon dioxide, and carbon tetrachloride. Prohibit water, foam, and dry chemicals on fires involving these metals.</td>
</tr>
<tr>
<td>Ammonia (anhydrous)</td>
<td>Mercury, chlorine, calcium hypochlorite, iodine, bromide, and hydrogen fluoride</td>
</tr>
<tr>
<td>Ammonium nitrate</td>
<td>Acids, metal powders, flammable liquids, chlorine, nitrites, sulfur, and finely divided organics or combustibles</td>
</tr>
<tr>
<td>Analine</td>
<td>Nitric acid and hydrogen peroxide</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Substance</th>
<th>Reactions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromine</td>
<td>Ammonium salts, acetylene, butadiene, butane and other petroleum gases, sodium carbide, turpentine, benzene, and finely divided metals</td>
</tr>
<tr>
<td>Calcium carbide</td>
<td>Water (see also acetylene)</td>
</tr>
<tr>
<td>Calcium oxide</td>
<td>Water</td>
</tr>
<tr>
<td>Chlorates</td>
<td>Ammonium salts, acids, metal powders, sulfur, and finely divided organics or combustibles</td>
</tr>
<tr>
<td>Chlorine</td>
<td>Ammonia, acetylene, butadiene, butane and other petroleum gases, hydrogen, sodium carbide, turpentine, benzene, and finely divided metals</td>
</tr>
<tr>
<td>Chlorine dioxide</td>
<td>Ammonia, methane, phosphine, and hydrogen sulfur</td>
</tr>
<tr>
<td>Chromic acid</td>
<td>Acetic acid, naphthalene, camphor, glycerine, turpentine, alcohol, and other flammable liquids</td>
</tr>
<tr>
<td>Copper</td>
<td>Acetylene and hydrogen peroxide</td>
</tr>
<tr>
<td>Fluorine</td>
<td>Isolate from everything</td>
</tr>
<tr>
<td>Hydrocarbons (benzene, butane, propane, gasoline, turpentine, etc.)</td>
<td>Fluorine, chlorine, bromine, chromic, acid, sodium peroxide</td>
</tr>
<tr>
<td>Hydrocyanic acid</td>
<td>Nitric acid and alkalis</td>
</tr>
<tr>
<td>Hydrofluoric acid, anhydrous. (Hydrogen fluoride)</td>
<td>Ammonia (aqueous or anhydrous)</td>
</tr>
<tr>
<td>Substance</td>
<td>Reactants</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Hydrogen peroxide</td>
<td>Copper, chromium, iron, most metals or their salts, any flammable liquid, combustible materials, aniline, nitromethane, caustic soda, and other strong alkalis</td>
</tr>
<tr>
<td>Hydrogen sulfide</td>
<td>Fuming nitric acid and oxidizing gases</td>
</tr>
<tr>
<td>Iodine</td>
<td>Acetylene, ammonia (anhydrous or aqueous)</td>
</tr>
<tr>
<td>Nitric acid (concentrated)</td>
<td>Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulfides, flammable liquids, flammable gases, and nitritable substances</td>
</tr>
<tr>
<td>Nitroparaffins</td>
<td>Inorganic bases</td>
</tr>
<tr>
<td>Oxalic acid</td>
<td>Silver and mercury</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Oils, grease, and hydrogen, flammable liquids, solids or gases</td>
</tr>
<tr>
<td>Oxygen (compressed or liquid)</td>
<td>Oils, grease, hydrogen, flammable liquids, solids, or gases</td>
</tr>
<tr>
<td>Perchloric acid</td>
<td>Acetic anhydride, bismuth and its alloys, alcohol, paper, wood, grease and oils, any hydrating agents</td>
</tr>
<tr>
<td>Peroxides</td>
<td>Combustibles, magnesium, zinc, or aluminum powders</td>
</tr>
<tr>
<td>Peroxides, organic</td>
<td>Acids (organic or mineral) and avoid friction</td>
</tr>
<tr>
<td>Phosphorus (white)</td>
<td>Air, oxygen, nitric acid, nitrates, nitrites, chlorates, perchlorates</td>
</tr>
</tbody>
</table>
### Phosphorus oxychloride
- Water, alcohol

### Phosphorus pentoxide
- Water

### Picric acid
- Metals

### Potassium
- Carbon tetrachloride, carbon dioxide, water, lower aliphatic alcohols

### Potassium chlorate (see also chlorates)
- Sulfuric acid, other acids, sulfur, sulfites, hypophosphites, finely divided organics, or combustibles

### Potassium ferricyanide or
- Halogen with ammonia mercuricyanide

### Potassium perchlorate
- Sulfuric acid, other acids, finely divided (see also chlorates) organics or combustibles

### Potassium permanganate
- Glycerine, ethylene glycol, benzaldehyde, sulfide acid, alcohols, ether, flammable gases, and combustible materials

### Prussic acid
- Acetylene, oxalic acid, tartaric acid, fulminic acid, ammonium compounds, picric acid

### Silver
- Acetylene, oxalic acid, tartaric acid, ammonium compounds

### Sodium
- Carbon tetrachloride, carbon dioxide, water

### Sodium chlorate
- Combustible materials, sulfur, acids

### Sodium chlorite
- Combustible materials, sulfur, acids

### Sodium hypochlorite
- Water
<table>
<thead>
<tr>
<th>Substance</th>
<th>Reactants or Precautions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium nitrate</td>
<td>Ammonium nitrate and other ammonium salts</td>
</tr>
<tr>
<td>Sodium oxide</td>
<td>Water</td>
</tr>
<tr>
<td>Sodium peroxide</td>
<td>Any oxidizable substance (such as ethanol, methanol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerine, ethylene glycol, ethyl acetate, methyl acetate, and furfural)</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Chlorates, nitrates, other oxidizing material</td>
</tr>
<tr>
<td>Sulfuric acid</td>
<td>Sulfides, nitrates, nitrites, fluorides, bromides, iodides, fulminates, saltpeter, metallic powders, carbides, picrates, chlorates, perchlorates, permanganates, and other combustible materials. Potassium chlorate, potassium perchlorate, potassium permanganate (or such compounds with similar light metals, as sodium, lithium, etc.)</td>
</tr>
<tr>
<td>Titanium</td>
<td>Do not use water, carbon tetrachloride foam, or dry chemical on titanium fires</td>
</tr>
<tr>
<td>Water</td>
<td>Alkali metals and oxides, alkali metal hydrides, sulfuric acid, oleum, sulfur trioxide, phosphorus pentachloride, acetyl chloride, phosphorus pentoxide</td>
</tr>
<tr>
<td>Zinc powder or dust</td>
<td>Acids, sodium hydroxide, potassium hydroxide, moisture</td>
</tr>
<tr>
<td>Zirconium</td>
<td>Prohibit water, carbon tetrachloride foam, and dry chemical on zirconium fires</td>
</tr>
</tbody>
</table>