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Continued on page 136
After reading this chapter, students will be able to:

1. Identify states of matter as they relate to hazardous materials. (5.2.1)
2. Explain physical properties that aid in identifying potential hazards and predicting behavior of hazardous materials. (5.2.1)
3. Explain chemical properties that aid in identifying potential hazards and predicting behavior of hazardous materials. (5.2.1)
4. Define the hazard classes. (5.2.1)
5. Describe actions taken to gather sufficient information to identify the hazardous material(s)/substance(s) involved in a hazmat incident. (5.2.1)
Chapter 4
Analyzing the Incident: Identifying Potential Hazards

This chapter explains the following topics:

- States of matter
- Hazard classes
- Physical properties
- Additional information
- Chemical properties

States of Matter
An uncontrolled hazmat release from a container can create many problems. The material’s physical and chemical properties affect how it behaves, determine the harm it can cause, and influence the effect it may have on all it contacts, including people, other living organisms, other chemicals, and the environment. A material’s physical and chemical properties also influence how a container will behave if it is damaged or ruptured.

First responders need to know how to collect hazard and response data that provide information about the substance’s physical and chemical properties. The proper resources can greatly assist the responder in determining the present hazards, estimating the potential harm, and predicting how the incident may progress.

Matter is found in three states (Figure 4.1, p. 138):

- **Gas**
- **Liquid**
- **Solid**

At a hazmat incident, try to identify the material’s physical state as early as possible, because gaseous, liquid, and solid hazardous materials behave differently. This behavior influences the material’s potential hazards. Once you understand how matter behaves in each state, you can better predict where the hazardous material is going, what exposures it may affect, and what those effects may be (Figure 4.2, p. 138). The material’s state of matter will indicate how mobile that material may become and can help determine if there will be far-reaching hazardous properties. Awareness of hazardous material mobility helps rescuers determine control zones and evacuation distances. The *Emergency Response Guidebook* establishes separate initial isolation distances based solely on the involved product’s state of matter:

- **Solids** – 75 feet (25m)
- **Liquids** – 150 feet (50m)
- **Gases** – 330 feet (100m)
In general, solids are the least mobile and gases have the greatest mobility. Liquids may be mobile depending on the properties of the substance. A substance’s state may change if the temperature changes. A solid may change to a liquid if the temperature increases. You should consider the temperature’s effect on a substance if the incident is located outside because air temperature and weather factors can strongly influence a substance’s state of matter and subsequently its behavior (Figure 4.3).
Is It a Solid, Liquid, or Gas? Industry Terms to Describe Air Contaminants.

A first responder may be unable to distinguish between these types of contaminants at an incident scene. Though air contaminants are commonly classified as either particulate or gas and vapor contaminants, visible releases of particulates may also include:

- **Dust** — Solid particle that is formed or generated from solid organic or inorganic materials by reducing its size through mechanical processes, such as crushing, grinding, drilling, abrading, or blasting. Example: Grain elevators with airborne grain dust.

- **Fume** — Suspension of particles that form when material from a volatilized (vapor state) solid condenses in cool air. In most cases, the solid, smokelike particles resulting from the condensation react with air to form an oxide. Examples: Paint, smoke.

- **Mist** — Finely divided liquid suspended in the atmosphere. Mists are generated by liquids condensing from a vapor back to a liquid or by breaking up a liquid into a dispersed state by splashing, foaming, or atomizing. Mists may also be generated during temperature differentials, such as temperature inversions. Mists are not usually pressurized. Example: Acids such as sulfuric acid.

- **Aerosol** — Form of pressurized mist characterized by highly respirable, minute liquid or solid particles. Usually identifiable by its high speed of travel. Example: Released anhydrous ammonia. Leaking thermonol is an example of a high-temperature aerosol.

- **Fiber** — Solid particle whose length is several times greater than its diameter is formed by a disruption of the natural state. Usually not visibly identifiable in the air. Example: Asbestos.

- **Vapor** — Gaseous form of a material that is normally in a solid or liquid state at room temperature and pressure. Vapors are formed by evaporation from a liquid or sublimation from a solid, and are visible as atmospheric disturbances (wavy lines) over a surface. Vapors are volatile. Examples: Gasoline, solvents.

- **Fog** — Visible aerosol of a liquid formed by condensation. Liquefied gases that auto-refrigerate at low pressure will form fogs. Fog particulates have a smaller droplet size than mists. Usually identifiable and discernable from an aerosol by its relatively low speed of travel that is dependent on wind speed. Examples: Chlorine, anhydrous ammonia.
Incidents involving gases are potentially the most dangerous for emergency responders. Many hazmat-related injuries are due to the inhalation of vapors or gases. Gaseous materials could have many variables and hazards, such as:

- May have an odor (such as chlorine)
- May be colorless, odorless, and/or tasteless (such as carbon monoxide)
- May be separately, or any combination of: toxic (such as phosgene), corrosive (such as ammonia), or flammable (such as methane, natural gas)
- May have high pressure in excess of 15,000 psi (103 421 kPa) (such as liquid helium)
- May be extremely cold upon release and/or may have a large expansion ratio if liquefied

Gases have an undefined shape and volume and keep expanding if uncontained. As a result, it is difficult to detect where they are, where they are not, and where they may be going (Figure 4.4). A gas leak in a building has many potential directions to spread. Depending on ventilation and other factors, the gas may spread:

- Throughout the building.
- To other buildings.
- Through access shafts.
- Into the soil.
- Into the street, where it will drift wherever the wind may take it.

Gases are difficult (if not impossible) to contain for mitigation purposes (Figure 4.5). Compressed gases and liquefied gases expand rapidly when released, potentially threatening large areas. If a gas is invisible and/or has little or no odor, it may be impossible to detect without specialized detection equipment, such as a combustible gas detector or another instrument (Figure 4.6). NOTE: Research has shown that 1- and 2-ton quantities of chlorine and anhydrous ammonia released in an open area both initially spread in a 360° radius before being dispersed downwind in some situations.
Materials kept under pressures and/or temperatures higher or lower than ambient conditions may change state upon release. The ratio that a gas will expand (expansion ratio) from its liquid state is a significant factor in mitigating a hazmat incident involving materials under specific conditions (especially cryogenic liquids and liquefied gases).

**NOTE:** For additional information on the behavior of gases, refer to Chapter 5.

If a hazardous material is a gas, it will be present in the air and will potentially present a breathing/inhalation hazard. Some gases may also present a contact hazard (Figure 4.7). In general, if an incident involves a gas, it has the potential to be much harder to mitigate and affect larger areas than incidents involving other states of matter. Incidents involving gas require complex and difficult actions to protect responders and the public.
Liquids
Liquids are usually visible, even if their vapors are not, so it may be easier to detect their presence and determine the hazard area (Figure 4.8). Liquids typically do not travel as far as gases unless they spill into a path or channel, such as a storm drain, stream, river, or other waterway, that transports liquids quickly and efficiently (Figure 4.9). Responders may be able to predict the paths that spilled liquids will most likely follow.

Liquids will flow or pool according to surface contours and topography, permitting opportunities for containment or confinement (Figure 4.10). Liquids present a splash or contact hazard (Figure 4.11).

Liquids may pose unique challenges to responders because they may take on the additional characteristics of a gas by emitting vapors (Figure 4.12). The conversion of liquid to vapor increases both the hazardous material’s mobility and the challenges responders face when dealing with the material.

Vapors from liquids may travel much like gases, although typically not as far from their source, and they may be much more difficult to detect than the liquid itself (Figure 4.13). Be cautious and alert to vapors from liquids as they may be:
- Contact hazards
- Inhalation hazards
- Flammable
- Corrosive
- Toxic

CAUTION
Vapors from liquids behave like gases, and may be flammable, corrosive, or toxic.

Figure 4.8 Liquids are usually visible even if their vapors are not. This may assist in determining the hazard area. Courtesy of Rich Mahaney.

Figure 4.9 Liquids tend not to travel as far as gases unless topography assists them; for example, they reach a storm drain or stream.

Figure 4.10 Because liquids follow topography, they can be contained. Courtesy of Phil Linder.
Solids are the least mobile of the three states of matter. They typically will remain in place unless acted upon by exterior forces, such as wind, water, and gravity (Figure 4.14, p. 144). The particle size of solids, such as dusts, fumes, or powders, may influence their behavior. Larger par-
Particles will probably settle out of the air fairly quickly. Smaller particles may remain suspended longer and travel further than larger particles (Figure 4.15). Micron is the unit of measure typically used to express particle size.

Solids may have the following dangerous properties:

- Inhalation or contact hazards
- Small, combustible particles that, if ignited, may explode
- Entrapment hazard in the form of loose solids confined to large containers (Figure 4.16)
- Flammable, reactive, radioactive, corrosive, toxic

You can usually detect a solid visually, unless it has microscopic particles. This visibility makes detecting the presence of solids easier than detecting gases or vapors from liquids. Solids such as dry ice, elemental iodine and naphthalene may sublime (transition directly from a solid to a gas). Sublimating materials present the same hazards and concerns as liquids that emit vapors.

With some exceptions, incidents involving solid materials are confined to limited areas, with less likelihood of undetected travel. Solid...
incidents may require less complicated mitigation and protective actions than gas and liquid incidents. This response depends on the chemical and physical properties of the material involved.

**Physical Properties**

*Physical properties* are the characteristics of a material that do not involve the chemistry or chemical nature of the material. Physical properties describe how a material behaves in relation to physical influences, such as temperature and pressure, or how a material behaves when mixed with, or compared to, another material. Materials can be characterized by the following physical properties:

- Vapor pressure
- Boiling point
- Melting point/freezing point/sublimation
- Vapor density
- Solubility/miscibility
- Specific gravity
- Persistence
- Appearance and odor

**Vapor Pressure**

*Vapor pressure* is the pressure exerted by a saturated vapor above its own liquid in a closed container. More simply, it is the pressure produced or exerted by the vapors released by a liquid. Vapor pressure can be viewed as the measure of the tendency of a substance to evaporate.

Vapor pressures reported in reference materials may use any of the following units:

- Pounds per square inch (psi)
- Kilopascals (kPa)
- Bars
- Millimeters of mercury (mmHg) (used in older-style material safety data sheets [MSDS])
- Atmospheres (atm)
- Hectopascals (hPa) (used on new GHS safety data sheets [SDS])

Be aware of the following facts regarding vapor pressure:

- Materials with a vapor pressure over 760 mmHg will be gases under normal conditions.
- The higher the temperature of a substance, the higher its vapor pressure will be (Figure 4.17). The vapor pressure of a material at 100°F (38°C) will always be higher than the vapor pressure of the same material at 68°F (20°C). Higher temperatures provide more

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**Physical Properties** — Properties that do not involve a change in the chemical identity of the substance, but affect the physical behavior of the material inside and outside the container, which involves the change of the state of the material. Examples include boiling point, specific gravity, vapor density, and water solubility.

**Vapor Pressure** — The pressure at which a vapor is in equilibrium with its liquid phase for a given temperature; liquids that have a greater tendency to evaporate have higher vapor pressures for a given temperature.

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Figure 4.17 A liquid’s vapor pressure increases as the temperature rises.
energy to a liquid, which allows more liquid to escape into a gaseous form. The gas rises above the liquid and exerts a downward pressure.

- Atmospheric pressure is the baseline measurement for pressure. Other measurements are listed in the Information Box in this section.
- The lower the boiling point (the temperature at which a liquid turns to a gas) of a material, the higher its vapor pressure will be. If a material has a low boiling point, it requires less heat to change from liquid into a gas.

**NOTE:** Water requires a lot of heat to boil (212°F [100°C]), but some substances boil at room temperature (68°F [20°C]).

---

### Units of Pressure Measurement

- 1 atmosphere
  - 760 mmHg = 760 torr (1 mmHg = 1 torr)
  - 29.9 inHg (inches of mercury)
  - 407 inches of water
  - 14.7 psi
  - 1.01 bar
  - 101.3 kPa
  - 1013.25 hPa (hPa = millibar)
- 1 bar = 14.5 psi
- 1 bar = 100,000 pascals
- 1 foot water = 0.43 psi

---

### What This Means To You

#### Vapor Pressure as an Evaporation Indicator

If you know the vapor pressure of a material, you can use it as a general gauge to tell how fast a product will evaporate under normal circumstances. A product such as acetone, with a relatively high vapor pressure, evaporates much more quickly at room temperature and normal atmospheric pressure than water, with a relatively low vapor pressure. In the same conditions, motor oil does not evaporate easily.

Under most normal conditions, a spill of a liquid with a high vapor pressure (such as isopropylamine) will produce a greater concentration of vapors than a substance with a low vapor pressure (such as sarin). These fumes or vapors could then be carried by the wind or travel distances on air currents. Due to the increased mobility of vapors over liquids, the hazardous vapors could cause problems far from the spill itself (such as toxic or flammable vapors being blown into a residential neighborhood).

Vapor pressure may indicate the state of matter of a product. For example, chlorine, with its extremely high vapor pressure, is likely to be released as a gas since it instantly evaporates at normal atmospheric pressure and temperatures (Figure 4.18).

Vapor pressure may also indicate the degree to which a material will present an inhalation hazard. Materials with lower vapor pressure are less likely to produce fumes or vapors. Substances with higher vapor pressures are much more likely to produce fumes or vapors.
Boiling Point

Boiling point is the temperature at which a liquid changes to a gas at a given pressure. Boiling point is usually expressed in degrees Fahrenheit (Celsius) at sea level air pressure (Figure 4.19). For mixtures, the initial boiling point or boiling-point range may be given. Flammable materials with low boiling points generally present special fire hazards.

A boiling liquid expanding vapor explosion (BLEVE) (also called violent rupture) can occur when a liquid within a container is heated, causing the material inside to boil or vaporize (such as in the case of a liquefied petroleum gas tank exposed to a fire). If the resulting increase in internal vapor pressure exceeds the vessel’s ability to relieve (or retain) the excess pressure, the container can fail catastrophically. As the vapor is released, it expands rapidly and ignites, sending flames and pieces of tank flying. BLEVEs most commonly occur when flames contact a tank shell above the liquid level or when insufficient water is applied to keep a tank shell cool.

Melting Point/Freezing Point/Sublimation

Melting point is the temperature at which a solid substance changes to a liquid state at normal atmospheric pressure. An ice cube melts at just above 32°F (0°C) — its melting point.

Freezing point is the temperature at which a liquid becomes a solid at normal atmospheric pressure. Water freezes at 32°F (0°C) — its freezing point. Some substances will actually sublime or change directly from a solid into a gas without going into a liquid state in between (Figure 4.20). Dry ice (solid-state carbon dioxide) and mothballs sublimate rather than melt.

Temperatures change throughout the day due to weather patterns and exposure to the sun. A material that begins the day as a solid may change to a liquid if heated sufficiently. Since materials are typically easier to control as a solid than a liquid, this may affect mitigation strategies.

Boiling Point Example

212° (100° C) at Sea Level

Figure 4.19 Boiling point is the temperature at which a liquid will boil at sea level. Flammable liquids with low boiling points are especially hazardous because they turn into a gas at normal temperatures. Liquids with high boiling points have to be heated before they start to boil.

Figure 4.20 Dry ice sublimates from a solid into a gas without transitioning into a liquid.
Vapor Density

Vapor density is the weight of a given volume of pure vapor or gas compared to the weight of an equal volume of dry air at the same temperature and pressure. A vapor density less than one indicates a vapor lighter than air; while a vapor density greater than one indicates a vapor heavier than air. Lighter than air gases and vapors will rise, while heavier than air gases and vapors will sink (Figure 4.21). Examples of materials with a vapor density less than one include helium, neon, acetylene, and hydrogen (see information box). Gases with a vapor density less than one will rise quickly and spread to a wide geographical area.

Figure 4.21 Materials with vapor densities less than one will rise in air while materials with vapor densities greater than one will sink.

Lighter-than-Air Gases

The list of gases that are lighter than air is short compared to the list of gases heavier than air. Thirteen common chemicals have a vapor density lighter than or equal to air:

- Acetylene (.9)
- Ammonia (.59)
- Carbon monoxide (.96)
- Diborane (.96)
- Ethylene (.96)
- Helium (.14)
- Hydrogen (.07)
- Hydrogen cyanide (.95)
- Hydrogen fluoride (.34)
- Illuminating gases (.6)
- Methane (.55)
- Neon (.34)
- Nitrogen (.96)
Most gases have a vapor density greater than one; they will sink in relation to ambient air and will displace oxygen at low elevations. Heavier vapors and gases are likely to concentrate in low places along or under floors; in sumps, sewers, and manholes; and in trenches and ditches where they may create fire or health hazards (Figure 4.22). Examples of common materials with a vapor density greater than one include:

- Propane
- Hydrogen sulfide
- Ethane
- Butane
- Chlorine
- Sulfur dioxide

Vapor density varies with the temperature of the vapor or gas. Hot vapors will rise, but unless totally dispersed, they will sink once they have cooled. Cold vapors are dense and will stay low but will rise when they warm.

Personnel cannot precisely predict the spread of vapors from the vapor density because topography, weather conditions, and the vapor mixture with air affect vapors. However, knowing the vapor density gives a general idea of what to expect from a specific gas or vapor.

**NOTE:** All vapors and gases will mix with air, but the lighter materials (unless confined) tend to rise and dissipate.

### Solubility/Miscibility

**Solubility** in water expresses the percentage of a material (by weight) that will dissolve in water at ambient temperature. A substance’s solubility affects whether it mixes in water. Solubility information can be useful in determining spill cleanup methods and extinguishing agents. When a non-water-soluble liquid such as a hydrocarbon (gasoline, diesel fuel, pentane) combines with water, the two liquids remain separate (Figure 4.23, p. 150). When a water-soluble liquid such as a polar solvent (alcohol, methanol, methyl ethyl ketone [MEK]) combines with water, the two liquids mix.

**NOTE:** Emergency responders may find that some materials, such as hydrocarbons (gasoline, oil), will initially float, but will sink over time. Degradation, chemical reactions, exposure, and time will all affect materials and change their characteristics.

Water solubility is also an important contributor for symptom development. Irritant agents that are water-soluble usually cause early upper respiratory tract irritation, resulting in coughing and throat irritation. Partially water-soluble chemicals will penetrate into the lower respiratory system and cause delayed (12 to 24 hours) symptoms that include breathing difficulties, pulmonary edema, and coughing up blood.
Degrees of Solubility

Materials with higher degrees of solubility are easier to control using water. The following terms describe degrees of solubility:

- Negligible (insoluble) — Less than 0.1 percent
- Slight (slightly soluble) — From 0.1 to 1 percent
- Moderate (moderately soluble) — From 1 to 10 percent
- Appreciable (partly soluble) — More than 10 to 25 percent
- Complete — Soluble at all proportions

**NOTE:** Some materials may be soluble at percentages higher than 100 percent. For example, NIOSH lists materials that are over 300 percent soluble.

Miscibility describes the ability of two or more gases or liquids to mix with or to dissolve into each other. Two liquids or gases are miscible if they mix or dissolve into each other in any proportion. Typically, two materials that do not readily dissolve into each other are considered **immiscible**. For example, water and fuel oil are immiscible. Immiscible materials can create a hazard because oil (which weighs less than water) will float on top of water and could ignite and burn **(Figure 4.24)**.
Specific Gravity

Specific gravity is the ratio of the density (mass per volume) of a material to the density of a standard material, usually an equal volume of water, at standard conditions of pressure and temperature. If a volume of a material weighs 8 pounds (3.6 kg), and an equal volume of water weighs 10 pounds (4.5 kg), the material is said to have a specific gravity of 0.8. Materials with specific gravities less than one will float in (or on) water. Materials with specific gravities greater than one will sink in water.

Solubility plays an important role in specific gravity. Highly soluble materials will mix or dissolve more completely in water (distributing themselves more evenly throughout), rather than sinking or floating (without dissolving) according to their specific gravities. Most (but not all) flammable liquids have specific gravities less than one and will float on water (Figure 4.25). An important consideration for fire-suppression activities is that flammable liquids will float on water.

Figure 4.24 Most hydrocarbons are also immiscible. Oil weighs less than water, so it will float on top, where it can ignite. Courtesy of U.S. Coast Guard.

Figure 4.25 Water alone is not very effective at putting out flammable liquid fires because flammable liquids have specific gravities less than water and will float to the surface where they will continue burning.
What This Means To You

Heptane

Heptane is a major component of gasoline and has the following physical and chemical properties:

- Vapor Pressure: 45 mmHg
- Flash Point: 25°F (-4°C)
- Boiling Point: 210°F (98°C)
- Vapor Density: 3.5
- Solubility in Water: Negligible
- Specific Gravity: 0.7

By understanding how to interpret this information, you can predict how the material is likely to behave. If a significant amount of heptane spills into a pond or waterway, you might follow this chain of thought:

- First, note that the heptane was spilled in water. Consider what the material will do relative to the water. Will it mix with the water? Will it sink or float? Since heptane’s solubility in water is negligible, you can gather that it will not dissolve or mix in water. Because heptane’s specific gravity is less than one, it will float on the surface of water.

- You know that heptane will not mix with water, will float on top of the water, and it will burn. You now will want to know whether it will emit vapors or fumes that could accidentally ignite. Its vapor pressure of 45 mmHg (higher than that of water) tells you that it will likely evaporate under most normal conditions. Its flashpoint of 25°F (-4°C) tells you that those vapors will burn if exposed to most ignition sources. Therefore, prioritize and keep ignition sources away from the vapors.

- What are the vapors doing and where might they be going? Are they rising in the air or staying close to the surface of the water? Heptane’s vapor density of 3.5 tells you that they will tend to stay low or close to the surface of the water (assuming there is no wind or other disturbances).

Persistence and Viscosity

The **persistence** of a chemical is its ability to remain in the environment. Chemicals that remain in the environment for a long time are more persistent than chemicals that quickly dissipate or break down (Figure 4.26). Persistent nerve agents will remain effective at their point of dispersion (release) for a much longer time than nonpersistent nerve agents.

**NOTE:** Persistence is not often referenced on an SDS.

**Viscosity** is the measure of the thickness or flowability of a liquid at a given temperature (Figure 4.27). Numerical values sometimes describe viscosity, with higher numbers indicating higher viscosity. Viscosity determines the ease with which a product will flow; it is greatly affected by temperature. Usually, the hotter a liquid, the thinner or more fluid it becomes. Likewise, the cooler a liquid, the thicker or less fluid it becomes. Liquids with high viscosities, such as heavy oils, have to be heated to increase their fluidity. Viscous materials tend to be more persistent and may have a lower vapor pressure. Examples of materials with differences in viscosity are acetone, water, oil, and honey. First
responders use viscous materials to reference the way the viscosity of these materials will affect decontamination or collection.

**Appearance and Odor**
A safety data sheet (SDS) typically contains a description of the material’s appearance (such as physical state or color) and odor. Referring to the SDS could allow first responders to quickly gain important information about the state of matter and potential behavior of the substance or material.

Appearance may help you detect a substance/material. You should evaluate a change in appearance, which may indicate a change in the behavior of the substance or material. For many industrial products, the color listed on the SDS may represent an “average,” and the product shipped may vary significantly in color and still be the same product. In other instances, a significant difference in color may also show contamination or high levels of impurities that may have their own hazards.

Responders detecting a chemical via odor could indicate that they are too close. Some chemicals have little or no odor, while others have a strong characteristic odor (Figure 4.28). Some characteristic odors can help identify a material. The smell of natural gas, based on an additive, mercaptan, is similar to that of rotten eggs or sewage. An unexpected odor may be a warning that a substance has escaped from its container.

**WARNING!**
If you can smell a chemical, you are exposed. Move out of the area and reassess the situation.

---

**Figure 4.26** Persistent chemicals stick around in the environment before dispersing.

**Figure 4.27** Molasses are very viscous at room temperature, unlike water. Viscosity changes with temperature.

**Figure 4.28** Odorants may be added to some hazardous materials to make them easier to detect, but many products have no odor. Courtesy of Rich Mahaney.

**Mercaptan** — A sulfur-containing organic compound often added to natural gas as an odorant. Natural gas is odorless; natural gas treated with mercaptan has a strong odor. Also known as a Thiol.
The ability to smell or sense an odor is highly dependent on the individual. *Odor threshold* is the concentration (in air) at which the “average person” can smell a particular compound. Some people can smell a given compound at an extremely low level. Other people may not be able to smell a particular compound even at very high concentrations in the air.

Never use odors to determine safe or unsafe areas; some highly toxic products may cause significant damage at a concentration below the odor threshold. Responders spending too much time exposed to some compounds may become desensitized to the smell of a chemical and may no longer be able to determine its presence.

**NOTE:** Visual indicators and chemical odors were described in greater detail in Chapter 2, *Senses* section.

### Chemical Properties

**Chemical properties** describe the chemical nature of a material and the behaviors and interactions that occur at a molecular level. While not always grouped with other chemical properties, toxicity and biological hazards will also be addressed in this section and in greater detail than in Chapter 1. This section also explains the following important chemical properties in order of commonality at incidents:

- Flammability
- Reactivity
- Corrosivity
- Radioactivity

### Flammability

Most hazardous materials incidents involve flammable materials. Flammable materials can damage life and property when they ignite, burn, or explode. Use a hazard’s flammability to help determine incident strategies and tactics. A flammable hazard depends on properties, including its:

- Flash point
- Autoignition temperature (sometimes called the *autoignition point*)
- Flammable (explosive or combustible) range

**Flash Point**

*Flash point* is the minimum temperature at which a liquid or volatile solid gives off sufficient vapors at its lower explosive limit (LEL) to form an ignitable mixture with air near its surface (*Figure 4.29*). At its flash point, a material’s vapors will flash in the presence of an ignition source but will not continue to burn. Do not confuse flash point with fire point. *Fire point* is the temperature at which a liquid or volatile substance gives off enough vapors to support continuous burning. A material’s fire point is usually only a few degrees (10-30 degrees Celsius) higher than its flash point.

Only the vapors burn. The liquid or volatile solid that produces the vapors does not burn. As the liquid’s temperature increases, it emits more vapors. Vapors are emitted below the flash point but not in sufficient quantities to ignite. A substance will not burn if it is not at its flash point temperature. Flammable gases have extremely low flash points so they are flammable all the time.
Is it Flammable, Inflammable, or Combustible?

In everyday language, the terms *flammable* and *combustible* can be used interchangeably to denote a substance that will burn. These terms have more technical meanings when referring to hazardous materials, particularly liquids. The flash point is commonly used to determine the flammability of a liquid. Liquids that have low flash points and burn easily are designated as *flammable liquids*, whereas liquids with higher flash points that do not burn as easily are called *combustible liquids*. However, different U.S. agencies use different flash points as the threshold to designate flammable and combustible substances.

The term *inflammable* means the same thing as *flammable* in many parts of the world. In contrast, a *nonflammable* material does not ignite easily. In Mexico, for example, a tank truck carrying flammable liquids may read either *flammable* or *inflammable* (Figure 4.30, p. 156). Transport Canada (TC) allows only the term *flammable*, but inflammable is the French word for flammable.

**Autoignition Temperature**

The **autoignition temperature** of a substance is the minimum temperature to which the fuel in air must be heated to initiate self-sustained combustion without initiation from an independent ignition source. This temperature, also known as the **ignition temperature**, is the point at which a fuel spontaneously ignites. All flammable materials have autoignition temperatures,
and these are considerably higher than the flash and fire points. For example, the autoignition temperature of gasoline is about 536°F (280°C), but the flash point of gasoline is -45°F (-43°C). This difference means that at -45°F (-43°C), gasoline will temporarily ignite if a match is waved through its vapors, whereas at 536°F (280°C) it ignites all by itself. The terms autoignition temperature and ignition temperature are often used synonymously; they are always the same temperature. However, the NFPA defines these terms separately.

**Flammable, Explosive, or Combustible Range**

The flammable, explosive, or combustible range is the percentage of the gas or vapor concentration in air that will burn or explode if ignited. The LEL or lower flammable (explosive) limit (LFL) of a vapor or gas is the lowest concentration (or lowest percentage of the substance in air) that will produce a flash of fire when an ignition source is present. At concentrations lower than the LEL, the mixture is too lean to burn. The upper explosive limit (UEL) or upper flammable limit (UFL) of a vapor or gas is the highest concentration (or highest percentage of the substance in air) that will produce a flash of fire when an ignition source is present. At higher concentrations, the mixture is too rich to burn (Fig 4.31). Within the upper and lower limits, the gas or vapor concentration will burn rapidly if ignited. Atmospheres within the flammable range are particularly dangerous. Table 4.1 provides the flammable ranges for some selected materials.

**What This Means To You**

**Lower and Upper Explosive Limits**

Products with a low LEL and products with a wide range between the LEL and UEL are especially dangerous. Concentrations above the UEL do not guarantee safety. If the concentration drops for any reason, you could still be in an explosive atmosphere. The addition of fresh air may dilute the concentration, or the concentration may be lower than the UEL in places where you did not measure.
Chapter 1 introduced corrosives as materials that destroy living tissue and damage or destroy metal. Corrosives are commonly divided into two broad categories: acids and bases (bases are sometimes called *alkalis* or *caustics*). However, some corrosives (such as hydrogen peroxide) are neither acids nor bases. The corrosivity of acids and bases is often measured or expressed in terms of *pH* (Figure 4.32, p. 158). Acids and bases have the following characteristics:

- **Acid** — Any chemical that ionizes (dissociates) to yield hydrogen ions (hydronium) in water. Acids have pH values of 0 to 6.9. An acid may cause severe chemical burns to flesh and permanent eye damage. Contact with an acid typically causes immediate pain. Hydrochloric acid, nitric acid, and sulfuric acid are examples of common acids.

- **Base** (alkalis) — A water-soluble compound that chemically dissociates in water to form a negatively charged hydroxide ion. Bases react with an acid to form a salt by releasing an unshared pair of electrons to the acid or by receiving a proton (hydrogen ion) from the acid. Bases have pH values of 7.1 to 14. A base breaks down fatty skin tissues and can penetrate deeply into the body. Bases tend to adhere to the tissues in the eye, which makes them difficult to remove. Bases often cause more eye damage than acids due to the longer duration of exposure. Contact with a base does not normally cause immediate pain. A common sign of exposure to a base is a greasy or slick feeling of the skin, which is caused by saponification, the breakdown of fatty tissues. Examples of bases include caustic soda, potassium hydroxide, and other alkaline materials commonly used in drain cleaners.

**Corrosivity**

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**Figure 4.31** Flammable vapors and gases can burn or explode when they are mixed with the right concentration of air. If there is too little air, the mixture is too lean to ignite; with too much flammable vapor or gas, the mixture is too rich to ignite.

<table>
<thead>
<tr>
<th>Material</th>
<th>Lower Flammable Limit (LFL)</th>
<th>Upper Flammable Limit (UFL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetylene</td>
<td>2.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Carbon</td>
<td>12.5</td>
<td>74.0</td>
</tr>
<tr>
<td>Monoxide</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>Ethyl Alcohol</td>
<td>3.3</td>
<td>19.0</td>
</tr>
<tr>
<td>Fuel Oil No. 1</td>
<td>0.7</td>
<td>5.0</td>
</tr>
<tr>
<td>Gasoline</td>
<td>1.4</td>
<td>7.6</td>
</tr>
<tr>
<td>Methane</td>
<td>5.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Propane</td>
<td>2.1</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Source: NIOSH Pocket Guide to Chemical Hazards

**pH** — Measure of the acidity or alkalinity of a solution.

**Acid** — Compound containing hydrogen that reacts with water to produce hydrogen ions; a proton donor; a liquid compound with a pH less than 7. Acidic chemicals are corrosive.

**Ion** — Atom that has lost or gained an electron, thus giving it a positive or negative charge.

**Base** — Any alkaline or caustic substance; corrosive water-soluble compound or substance containing group-forming hydroxide ions in water solution that reacts with an acid to form a salt.

**Dissociation (Chemical)** — Process of splitting a molecule or ionic compounds into smaller particles, especially if the process is reversible. *Opposite of Recombination.*

**Saponification** — Reaction between an alkaline and a fatty acid that produces soap.
Is it Corrosive, Caustic, an Acid, a Base, or an Alkali?

Some people make this differentiation: acids are corrosive, while bases are caustic. In the world of emergency response, however, both acids and bases are called corrosives. The U.S. Department of Transportation (DOT) and Transport Canada (TC), for example, do not differentiate between the two. These agencies consider ANY materials that destroy skin tissue or metal as corrosives.

The terms base and alkali are often used interchangeably, but some chemical dictionaries define alkalis as strong bases. Basic solutions are usually referred to as alkaline rather than basic, but, again, the two terms are often used synonymously. Just be aware that if you hear the terms caustic, alkali, or alkaline, they are referring to bases or basic solutions.

NOTE: For the purposes of this manual, the phrase basic solutions will refer to both basic and alkaline solutions.

Reactivity

The chemical reactivity of a substance describes its relative ability to undergo a chemical reaction with itself or other materials. As a result, pressure buildup, temperature increase, and/or formation of noxious, toxic, or corrosive by-products may occur. Reactive materials commonly react vigorously or violently with air, water, heat, light, each other, or other materials.
Many first responders are familiar with the fire tetrahedron or the four elements necessary to produce combustion: oxygen, fuel, heat, and a chemical chain reaction. Fire is just one type of chemical reaction. A reactivity triangle can be used to explain the basic components of many (though not all) chemical reactions: an oxidizing agent (oxygen), a reducing agent (fuel), and an activation energy source (often, but not always, heat) (Figure 4.33).

All reactions require some energy to get them started (Figure 4.34) (commonly referred to as activation energy). How much energy is needed depends on the particular reaction. In some cases, heat from an external source provides the energy-added heat from an external source (such as when starting a fire with a match). In some instances, radio waves, radiation, or another waveform of energy may provide the activation energy to the molecules (such as when food is heated in a microwave oven). In other reactions, the energy could come from a shock or pressure change (such as might occur when nitroglycerin is jostled).

Reactivity Triangle

![Reactivity Triangle Diagram]

Figure 4.33 Many reactions need an oxidizing agent, a reducing agent, and some kind of activation energy to get them started.

Activation Energy

- Oxidizing Agent: Oxygen, Organic Peroxides, Alkyl Nitrates
- Reducing Agent (Fuel): Activating Dynamite
- Activation Energy: Heat, Shock, Radiation, Light

Figure 4.34 Activation energy is the energy needed to start the reaction, much like a blasting cap activating dynamite.

Reactions that have low-activation energies need little help to begin reacting. Materials that are generally classified as water-reactive typically react with water easily at room temperature because the ambient temperature is sufficient to start the reaction. First responders may see terms such as light-sensitive, heat-sensitive, or shock-sensitive on SDSs and/or manufacturers’ labels, indicating that those products have an increased susceptibility to those sources of activation energy. See Table 4.2, p. 160, for a summary of the different ways in which chemicals can be reactive. This table supplies the definition and chemical examples of nine reactive hazard classes.
Table 4.2
Nine Reactive Hazard Classes

<table>
<thead>
<tr>
<th>Reactive Hazard Class</th>
<th>Definition</th>
<th>Chemical Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Highly Flammable</strong></td>
<td>Substances having flash points less than 100°F (38°C) and mixtures that include substances with flash points less than 100°F (38°C).</td>
<td>Gasoline, Acetone, Pentane, Ethyl Ether, Toluene, Methyl Ethyl Ketone (MEK), Turpentine</td>
</tr>
<tr>
<td><strong>Explosive</strong></td>
<td>A material synthesized or mixed deliberately to allow the very rapid release of chemical energy; also, a chemical substance that is intrinsically unstable and liable to detonate under conditions that might reasonably be encountered.</td>
<td>Dynamite, Nitroglycerin, Perchloric Acid, Picric Acid, Fulminates, Azide</td>
</tr>
<tr>
<td><strong>Polymerizable</strong></td>
<td>Capable of undergoing self-reactions that release energy; some polymerization reactions generate a great deal of heat. (The products of polymerization reactions are generally less reactive than the starting materials.)</td>
<td>Acrylic Acid, Butadiene, Ethylene, Styrene, Vinyl Chloride, Epoxies</td>
</tr>
<tr>
<td><strong>Strong Oxidizing Agent</strong></td>
<td>Oxidizing agents gain electrons from other substances and are themselves thereby chemically reduced, but strong oxidizing agents accept electrons particularly well from a large range of other substances. The ensuing oxidation-reduction reactions may be vigorous or violent and may release new substances that may take part in further additional reactions. Keep strong oxidizing agents well separated from strong reducing agents. In some cases, the presence of a strong oxidizing agent can greatly enhance the progress of a fire.</td>
<td>Hydrogen Peroxide, Fluorine, Bromine, Calcium Chlorate, Chromic Acid, Ammonium Perchlorate</td>
</tr>
<tr>
<td><strong>Strong Reducing Agent</strong></td>
<td>Reducing agents give up electrons to other substances and are thereby oxidized, but strong reducing agents donate electrons particularly well to a large range of other substances. The ensuing oxidation-reduction reactions may be vigorous or violent and may generate new substances that take part in further additional reactions.</td>
<td>Alkali metals (Sodium, Magnesium, Lithium, Potassium), Beryllium, Calcium, Barium, Phosphorus, Radium, Lithium Aluminum Hydride</td>
</tr>
<tr>
<td><strong>Water-Reactive</strong></td>
<td>Substances that may react rapidly or violently with liquid water and steam, producing heat (or fire) and often toxic reaction products.</td>
<td>Alkali metals (Sodium, Magnesium, Lithium, Potassium), Sodium Peroxide, Anhydrides, Carbides</td>
</tr>
<tr>
<td><strong>Air-Reactive</strong></td>
<td>Likely to react rapidly or violently with dry air or moist air; may generate toxic and corrosive fumes upon exposure to air or catch fire.</td>
<td>Finely divided metal dusts (Nickel, Zinc, Titanium), Alkali metals (Sodium, Magnesium, Lithium, Potassium), Hydrides (Diborane, Barium Hydrides, Diisobutyl Aluminum Hydride)</td>
</tr>
<tr>
<td><strong>Peroxidizable Compound</strong></td>
<td>Apt to undergo spontaneous reaction with oxygen at room temperature, to form peroxides and other products. Most such auto-oxidations are accelerated by light or trace impurities. Many peroxides are explosive, which makes peroxidizable compounds a particular hazard. Ethers and aldehydes are particularly subject to peroxide formation (the peroxides generally form slowly after evaporation of the solvent in which a peroxidizable material had been stored).</td>
<td>Isopropyl Ether, Furan, Acrylic Acid, Styrene, Vinyl Chloride, Methyl Isobutyl Ketone, Ethers</td>
</tr>
<tr>
<td><strong>Radioactive Material</strong></td>
<td>Spontaneously and continuously emitting ions or ionizing radiation. Radioactivity is not a chemical property, but an additional hazard that exists in addition to the chemical properties of a material.</td>
<td>Radon, Uranium</td>
</tr>
</tbody>
</table>

Source: U.S. Environmental Protection Agency's CEPPPO (Chemical Emergency Preparedness and Prevention Office) Computer-Aided Management of Emergency Operations (CAMEO) software was used to identify this information.
What This Means To You

Predicting Chemical Interactions

Stability and reactivity are important factors in chemical interactions. Knowing the reactions between known quantities of different chemicals and knowing how stable a chemical is on its own will aid in securing a scene at a hazardous materials incident. SDSs and the NIOSH Pocket Guide will offer guidance on securing defensible spaces. Beyond establishing scene perimeters, securing the hazardous materials is outside the scope of the Operations Level Responder.

The oxidizing agent in the reactivity triangle provides the oxygen necessary for the chemical reaction. Strong oxidizers are materials that encourage a strong reaction (by readily accepting electrons) from reducing agents (fuels). The greater the concentrations of oxygen present in the atmosphere, the hotter, faster, and brighter a fire will burn. The same principle applies to oxidation reactions—in general, the stronger the oxidizer, the stronger the reaction.

Many organic materials ignite spontaneously when they come into contact with a strong oxidizer. An asphalt roadway could explode if liquid oxygen (a cryogenic liquid) spills on it and is accompanied by sufficient activation energy (from shock or friction such as someone stepping on it) (Figure 4.35).

The reducing agent in the fire tetrahedron acts as the fuel source for the reaction. It combines with the oxygen (or losing electrons to the oxidizer) in such a way that energy is being released. Oxidation-reduction (redox) reactions can be extremely violent and dangerous because they release a tremendous amount of energy. Some reducing agents (fuels) are more volatile than others.

NOTE: Wood is not as prone to undergo rapid oxidation (it will not burn as easily) as a highly flammable liquid such as MEK.

Polymerization is a chemical reaction in which simple molecules combine to form long chain molecules. Catalysts will increase the rate of polymerization and decrease the activation energy necessary for further polymerization. Examples of catalysts include light, heat, water, acids, or other chemicals. Uncontrolled polymerization often results in a tremendous release of energy. Materials that may undergo violent polymerization if subjected to heat or contamination are designated with a P in the blue and yellow sections of the ERG (Figure 4.36, p. 162).

NOTE: Potential for polymerization may not be included on any type of reference material other than the ERG, and the ERG may not be fully inclusive of all polymerizing materials.

Inhibitors are materials that are added to products that easily polymerize in order to control or prevent an undesired reaction. Inhibitors increase the needed activation energy. They may be exhausted over a period of time or when exposed to circumstances or unexpected contamination that causes them to be consumed more rapidly, such as exposure to heat or other reaction triggers. Shipments of polymerizing materials may become unstable if

Strong Oxidizer — Substance that readily gives off large quantities of oxygen, thereby stimulating combustion; produces a strong reaction by readily accepting electrons from a reducing agent (fuel).

Reducing Agent — Fuel that is being oxidized or burned during combustion. Also known as Reducer.

Inhibitor — Material that is added to products that easily polymerize in order to control or prevent an undesired reaction. Also known as Stabilizer.

Figure 4.35 Liquid oxygen is a powerful oxidizer. If spilled on asphalt, very little activation energy is needed to cause an explosion.
delayed during transport or involved in accidents. For example, time-sensitive inhibitors are added to liquid styrene before it is shipped in order to prevent the styrene from polymerizing during transport (Figure 4.37). If containers holding the styrene rupture or emergency responders add water, the inhibitor becomes exhausted (often 20-30 days), and the polymerization reaction begins. The sudden loss of containment due to polymerization is a chemical process that may not require an external heat source.

Under emergency conditions, reactive materials can be extremely destructive and dangerous. Keep people and equipment upwind, uphill, and back a safe distance or in protected locations until pertinent facts are established and definite plans can be formulated. With advances in modern technology, more and more reactive and unstable materials are being used for various processes, and you must be prepared to deal with them.
Radioactivity
In addition to recognizing radioactive material packaging, as explained in Chapter 2, first responders need to understand basic protection strategies if radioactive materials or radiation is present at an incident. Radiation comes in different forms, some more energetic than others (Figure 4.38). The least energetic form of radiation is nonionizing radiation such as visible light and radio waves. The most energetic (and hazardous) form of radiation is ionizing radiation.

The following sections will address:

- Types of ionizing radiation
- Radioactive material exposure and contamination

Types of Ionizing Radiation
Ionizing radiation can be divided into four types: alpha, beta, gamma, and neutron. Each type will be explained in the following (Figure 4.39, p.164):

- **Alpha** — Energetic, positively charged alpha particles (helium nuclei) emitted from the nucleus during radioactive decay that rapidly lose energy when passing through matter (Figure 4.40, p. 164). They are commonly emitted in the radioactive decay of some manmade elements and the heaviest radioactive elements such as uranium and radium. Alpha particles do not travel far in open air; you may have to get very close to the source for the equipment to detect particles. Details:
  - Alpha particles lose energy rapidly when travelling through matter and do not penetrate deeply. They can cause damage over a short path through human tissue. They are usually completely blocked by the outer, dead
layer of the human skin, so alpha-emitting radioisotopes are not a hazard outside the body. However, they can be very harmful if the material emitting the alpha particles is ingested or inhaled.

— Alpha particles can be stopped completely by a sheet of paper.

• Beta — Fast-moving, positively charged protons or negatively charged electrons emitted from the atom’s nucleus during radioactive decay. Humans are exposed to beta particles from manufactured and natural sources such as tritium, carbon-14, and strontium-90.

Electron — Subatomic particle with a physical mass and a negative electric charge.
Details:

— Beta particles penetrate further than alpha particles but cause less damage over equally traveled distances. Beta particles are capable of penetrating the skin and causing radiation damage; however, as with alpha emitters, beta emitters are generally more hazardous when inhaled or ingested.

— Beta particles travel appreciable distances in air but can be reduced or stopped by a layer of clothing, a thin sheet of metal, or thick Plexiglass. Detection distances for beta particles vary based on the activity of the source. Compared to alpha radiation, beta radiation will travel farther. Shielding beta emitters with dense metals can result in the release of X-rays (Bremsstrahlung radiation).

• **Gamma** — High-energy **photons** (weightless packets of energy like visible light and X-rays). Gamma rays often accompany the emission of alpha or beta particles from a nucleus. They have neither a charge nor a mass but are penetrating. One source of gamma radiation in the environment is naturally occurring potassium-40. Common industrial gamma emitting sources include cobalt-60, iridium-192, and cesium-137. Details:

  — Gamma radiation can easily pass completely through the human body or be absorbed by tissue. It constitutes a radiation hazard for the entire body.

  — Gamma radiation levels vary depending on the isotope and activity (Figure 4.41). Materials such as concrete, earth, and lead may be useful as a shield against radiation. Standard fire fighting protective clothing provides no protection against gamma radiation.

• **Neutron** — Particles that have a physical mass but have no electrical charge. Neutrons are highly penetrating. Fission reactions produce neutrons along with gamma radiation. Neutron radiation can be measured in the field using specialized equipment. Details:

  — Soil moisture density gauges, often used at construction sites, are a common source of neutron radiation. Neutrons may also be encountered in research laboratories or operating nuclear power plants.

  — Shielding from neutron radiation requires materials with high amounts of hydrogen, such as oil, water, and concrete.

  X-rays and gamma rays are high energy electromagnetic radiation commonly referred to as **photons**. The hazards of these types of radiation are directly correlated to their activity. For the purposes of this manual, they are identical and should be treated the same. Machines such as those found in medical facilities and airports are almost exclusively the sole source of terrestrial X-ray radiation. Since machines can only produce X-rays when powered on, the chances of encountering X-rays at a hazardous materials incident are remote.

**Radioactive Material Exposure and Contamination**

**Radioactive materials (RAM)** emit ionizing radiation. Incidents involving radioactive materials are uncommon because they are strictly governed in use, packaging, and transportation. However, there is some concern that radioactive materials could be used in a terrorist attack (Figure 4.42, p. 166).
Radiation exposure occurs when a person is near a radiation source and is exposed to the energy from that source. Exposure and damage are not necessarily related. A first responder will need to know the types of radiation that will cause damage and what proximity or level of exposure will cause what kinds of harm (Figure 4.43).

A person may receive a dose of radiation based upon the length of exposure, energy, and type of source (alpha, beta, gamma, or neutron). Exposure to radioactive material does not make a person or object radioactive. Damage is often described in terms of dosage, indicating the amount of energy absorbed by matter.

Figure 4.42 Incidents involving radiation are rare, but there are concerns that radioactive materials could be used in a terrorist attack.

Figure 4.43 First responders must understand how to protect themselves from exposure when radioactive materials are involved in an incident. Courtesy of Tom Clawson.
Radioactive contamination occurs when radioactive material is deposited on surfaces, skin, clothing, or any place where it is not desired. Radiation does not spread; radioactive material and contamination spread.

Exposure to radiation alone does not contaminate a person. Contamination only occurs when the radioactive material remains on a person or the person’s clothing after coming into contact with a contaminant. A person can become contaminated externally, internally, or both. Radioactive material can enter the body via one or more routes of entry. An unprotected person contaminated with radioactive material receives radiation exposure until the source of radiation (radioactive material) is removed. Radiation detectors capable of detecting alpha and beta contamination can detect radioactive contamination. Note the following examples:

• A person is externally contaminated (and receives external exposure) when radioactive material is on the skin or clothing.
• A person is internally contaminated (and receives internal exposure) when radioactive material is breathed, swallowed, or absorbed through wounds.
• The environment is contaminated when radioactive material is spread about or is unconfined. Environmental contamination is another potential source of external exposure.

NOTE: Some contamination, such as alpha contamination, often requires the detector to be almost touching the source.

Radiation Health Hazards

The effects of ionizing radiation occur at the cellular level. Ionizing radiation can negatively affect the normal operation of the cells that compose human organs.

Radiation may cause damage to any material by ionizing the atoms in that material. When atoms are ionized, the chemical properties of those atoms are altered. This change in chemical properties can result in a change in the chemical behavior of the atoms and/or molecules in the cell. If a person receives a sufficiently high dose of radiation and many cells are damaged, this may cause observable health effects, including genetic mutations and cancer.

The biological effects of ionizing radiation depend on how much and how fast a radiation dose is received. The two categories of radiation doses are acute and chronic.

Acute doses. Exposure to radiation received in a short period of time is an acute dose. Acute exposures are usually associated with large doses. Some acute doses of radiation are permissible and have no long-term health effects. However, high levels of radiation received over a short time can produce serious health effects, including reduced blood count, hair loss, nausea, vomiting, diarrhea, and fatigue. Extremely high levels of acute radiation exposure (such as those received by victims of a nuclear bomb) can result in death within a few hours, days, or weeks.

Chronic doses. Small amounts of radiation received over a long period of time. The body is better equipped to handle a chronic dose of radiation than an acute radiation dose. After a chronic dose, the body has enough time to replace dead or nonfunctioning cells with healthy ones. Chronic doses do not result
in the same detectable health effects seen with acute doses. However, chronic exposure to radiation causes cancer. Examples of chronic radiation doses include the everyday doses received from natural background radiation, and those received by workers in nuclear and medical facilities.

First responders at most hazmat incidents are unlikely to encounter exposures that cause any health effects, especially if proper precautions are taken. Even at terrorist incidents, it is unlikely that first responders will encounter dangerous or lethal doses of radiation (Figure 4.44).

Figure 4.44 It is unlikely that responders will encounter lethal doses of radiation, especially if monitoring and detection is used appropriately. Courtesy of the U.S. Department of Energy.

**Units Used for Measuring Radioactivity**

- Radioactivity — Quantifiable measurement of activity in a sample of material over time. Measured in curie (Ci) and becquerel (Bq).
- Exposure — Amount of radiation in the ambient air of a specific place. Measured in roentgen (R) and coulomb/kilogram (C/kg).
- Absorbed dose — Amount of radiation energy deposited in a material. Measured in radiation absorbed dose (rad) and gray (Gy).
- Dose equivalent — Absorbed dose plus medical effects. Measured in roentgen equivalent man (rem) and sievert (Sv). Biological dose equivalents are measured in rem or sieverts (Sv).

**Protection from Radiation**

Because radiation is invisible, it may be difficult to determine if it is involved in an incident.

Class 7 radioactive materials packages should have the appropriate placard or label in transport (Figure 4.45). If responders note their presence at an incident, they should initiate radiation detection and monitoring. Responders should conduct radiation monitoring if an incident is a suspected terrorist attack or explosion. **NOTE:** Chapter 11 provides more information about detecting and monitoring radiation.

While most incidents involving radioactive materials present minimal risks to emergency responders, it is still necessary to take appropriate precautions to prevent unnecessary exposures. One basic protection strategy uses time, distance, and shielding (Figure 4.46):

- **Time** — Decrease the amount of time spent in areas where there is radiation. At a minimum, the time required includes:
  - Entering the zone
  - Staying within the zone
  - Exiting the zone
• **Distance** — Know your dose rate to know the safe distances from the radioactive material. Increase the distance from a radiation source. Doubling the distance from a point source divides the dose by a factor of four. This calculation is sometimes referred to as the **inverse square law**. When the radius doubles, the radiation spreads over four times as much area, so the dose is only one-fourth as much (Figure 4.47, p. 170). If sheltered in a contaminated area, keep a distance from exterior walls and roofs. This calculation is only a rule of thumb, and the information must be supplemented with information from your meter.
Shielding — Create a barrier between responders and the radiation source with a building, earthen mound, or vehicle. Buildings, especially those made of brick or concrete, provide considerable shielding from radiation. For example, exposure from fallout is reduced by about 50 percent inside a one-story building and by about 90 percent at a level belowground.

**NOTE:** Using time, distance, and shielding to limit exposure to radiation is sometimes referred to as the ALARA (As Low As Reasonably Achievable) method or principle.

---

**Toxicity**

The degree to which a substance causes harm within the body is called its **toxicity.** A chemical injury at the site of contact (typically the skin and mucous membranes of the eyes, nose, mouth, or respiratory tract) is termed a local *toxic effect*. Irritant gases such as chlorine and ammonia can, for example, produce a localized toxic effect in the respiratory tract. In addition, toxic materials may be absorbed into the bloodstream and distributed to other parts of the body, producing **systemic effects.** Many pesticides absorb through the skin, distribute to other sites in the body, and produce adverse effects such as seizures or cardiac, pulmonary, or other problems.

Exposure to toxic materials can result not only in the development of a single systemic effect but also in the development of multiple systemic effects or a combination of systemic and local effects. Some of these effects may be delayed in a range anywhere between seconds and decades. **Table 4.3** gives types of chemical toxins, their target organs, and chemical examples.
### Table 4.3
Types of Toxicants and Their Target Organs

<table>
<thead>
<tr>
<th>Toxin</th>
<th>Targets</th>
<th>Chemical Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nephrotoxicant</td>
<td>Kidney</td>
<td>Halogenated Hydrocarbons, Mercury, Carbon Tetrachloride</td>
</tr>
<tr>
<td>Hemotoxicant</td>
<td>Blood</td>
<td>Carbon Monoxide, Cyanides, Benzene, Nitrates, Arsine, Naphthalene, Cocaine</td>
</tr>
<tr>
<td>Neurotoxicant</td>
<td>Nervous System</td>
<td>Organophosphates, Mercury, Carbon Disulphide, Carbon Monoxide, Sarin</td>
</tr>
<tr>
<td>Hepatotoxicant</td>
<td>Liver</td>
<td>Alcohol, Carbon Tetrachloride, Trichloroethylene, Vinyl Chloride, Chlorinated HC</td>
</tr>
<tr>
<td>Immunotoxicant</td>
<td>Immune System</td>
<td>Benzene, Polybrominated Biphenyls (PBBs), Polychlorinated Biphenyls (PCBs), Dioxins, Dieldrin</td>
</tr>
<tr>
<td>Endocrine Toxicant</td>
<td>Endocrine System (including the pituitary, hypothalamus, thyroid adrenals, pancreas, thymus, ovaries, and testes)</td>
<td>Benzene, Cadmium, Chlordane, Chloroform, Ethanol, Kerosene, Iodine, Parathion</td>
</tr>
<tr>
<td>Musculoskeletal Toxicant</td>
<td>Muscles/Bones</td>
<td>Fluorides, Sulfuric Acid, Phosphine</td>
</tr>
<tr>
<td>Respiratory Toxicant</td>
<td>Lungs</td>
<td>Hydrogen Sulfide, Xylene, Ammonia, Boric Acid, Chlorine</td>
</tr>
<tr>
<td>Cutaneous Hazards</td>
<td>Skin</td>
<td>Gasoline, Xylene, Ketones, Chlorinated Compounds</td>
</tr>
<tr>
<td>Eye Hazards</td>
<td>Eyes</td>
<td>Organic Solvents, Corrosives, Acids</td>
</tr>
<tr>
<td>Mutagens</td>
<td>DNA</td>
<td>Aluminum Chloride, Beryllium, Dioxins</td>
</tr>
<tr>
<td>Teratogens</td>
<td>Embryo/Fetus</td>
<td>Lead, Lead Compounds, Benzene</td>
</tr>
<tr>
<td>Carcinogens</td>
<td>All</td>
<td>Tobacco Smoke, Benzene, Arsenic, Radon, Vinyl Chloride</td>
</tr>
</tbody>
</table>

Following exposure to a toxic substance, the likelihood of an adverse health effect occurring and the severity of the effect depend on the following:

- Toxicity of the chemical or biological substance
- Exposure pathway or route
- Nature and extent of the exposure
- Person’s susceptibility to illness or injury, affected by such factors as their age or other health concerns (including chronic diseases)

**CAUTION**

All personnel working at hazardous materials incidents must use appropriate personal protective equipment, including appropriate respiratory protection equipment.
Eating and Drinking Can be Dangerous . . .

. . . especially on the scene of a hazardous material incident. If hazardous materials at an incident site contaminate food or water, the chemicals can be ingested into the body where they can cause harm. Therefore, never eat or drink in areas where hazardous materials may be present. Make sure that water comes from a clean source and is dispensed in disposable cups. Always place rehabilitation areas far away from any sources of contamination. Finally, wash your hands and be certain that you are completely decontaminated before eating or drinking.

The following are some specific toxic chemical hazard categories:

- **Asphyxiants** — Asphyxiants prevent access to sufficient volumes of oxygen. They can be divided into two classes: simple and chemical. Simple asphyxiants are gases that displace oxygen (Figure 4.48). These gases may dilute or displace the oxygen concentration below the level required to sustain life. Chemical asphyxiants are materials that prohibit the body’s cells from using oxygen. Some chemical asphyxiants may be used in terrorist attacks.

- **Irritants** — Irritants cause temporary, sometimes severe, inflammation to the eyes, skin, or respiratory system (Figure 4.49). Irritants often attack the body’s mucous membranes, such as the surfaces of the eyes or the linings of the nose, mouth, throat, and lungs.

- **Convulsants** — Convulsants cause convulsions (involuntary muscle contractions). Convulsants can kill if the victim asphyxiates or succumbs to exhaustion while convulsing. Examples of convulsants include strychnine, organophosphates, carbamates, and infrequently used drugs such as picROTOXIN (Figure 4.50).
• **Carcinogens** — Carcinogens are known, or suspected, to cause cancer. While exact exposure data is unknown for most carcinogens, exposures to only small amounts of some substances may have long-term consequences. Disease and complications can occur as many as 10 to 40 years after exposure. Statistics reveal 1 in 3 firefighters will be diagnosed with cancer during their career (Figure 4.51). Another 45% of firefighters will have cancer diagnosed within seven years of retirement. Meta studies in the U.S. and Australia show firefighters have an elevated risk of suffering from leukemia and testicular cancer (114%-202% respectively) to name just two. Known or suspected carcinogens include:
  — Arsenic
  — Asbestos
  — Benzene
  — Many plastics
  — Nickel
  — Polyvinyl chloride
  — Some chlorinated hydrocarbons
  — Some pesticides

• **Allergens** and sensitizers — Allergens cause allergic reactions in people or animals. Sensitizers are chemicals that cause a substantial proportion of exposed people or animals to develop an allergic reaction after one or more exposures to the chemical. Some individuals exposed to a material...
may not be abnormally affected at first but may experience significant and dangerous effects when exposed to the material again. Common examples of sensitizers and allergens include latex, bleach, and urushiol (the chemical found in the sap of poison ivy, poison oak, and poison sumac) (Figure 4.52).

*Toxic Products of Combustion*

While the heat energy from a fire is a danger to anyone directly exposed to it, exposure to toxic smoke can cause both acute and chronic health effects. Smoke is an aerosol comprised of gases, vapor, and solid particulates. Fire gases, such as carbon monoxide, are generally colorless, while vapor and particulates give smoke its varied colors. Most components of smoke are toxic and many are carcinogenic. Almost all present a significant threat to human life. The materials that compose smoke vary from fuel to fuel. Generally, consider all smoke toxic and carcinogenic. In addition to the gases listed below, fires and smoke may expose responders to a wide range of potentially carcinogenic substances such as asbestos, soot, and creosote. Table 4.4 lists some of the more common products of combustion and their toxic effects. Three of the more common products of combustion are:

- **Carbon monoxide (CO)** is a chemical asphyxiant that is a byproduct of the incomplete combustion of organic (carbon-containing) materials. This gas is probably the most common product of combustion encountered in structure fires. Exposure to it is frequently identified as the cause of death for civilian fire fatalities and for firefighters who have run out of air in their SCBAs.

- **Hydrogen cyanide (HCN)**, produced in the combustion of materials containing nitrogen, is also commonly encountered in smoke, although at lower concentrations than CO. HCN also acts as a chemical asphyxiant. HCN is a significant byproduct of the combustion of polyurethane foam, which is commonly used in furniture and bedding.

- **Carbon dioxide (CO₂)** is a product of complete combustion of organic materials. It acts as a simple asphyxiant by displacing oxygen. Carbon dioxide also increases respiratory rate.

*Biological Hazards*

Biological (or etiological) hazards are microorganisms, such as viruses or bacteria (or their toxins), that may cause severe, disabling disease or illness. Many of these hazards can be transferred from the blood or other bodily fluids of an infected individual. Additionally, some biological hazards cause illness through their toxicity. Always wear appropriate PPE to prevent potential transmission.

Types of biological hazards include:

- **Viruses** — Viruses are the simplest types of microorganisms that can only replicate themselves in the living cells of their hosts (Figure 4.53, p. 176). Viruses do not respond to antibiotics.

- **Bacteria** — Bacteria are microscopic, single-celled organisms (Figure 4.54, p. 176). Bacteria may cause disease in people either by invading the tissues or by producing toxins (poisons).
### Table 4.4
Common Products of Combustion and Their Toxic Effects

<table>
<thead>
<tr>
<th>Product</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetaldehyde</td>
<td>Colorless liquid with a pungent choking odor, which is irritating to the mucous membranes and especially the eyes. Breathing vapors will cause nausea, vomiting, headache and unconsciousness.</td>
</tr>
<tr>
<td>Acrolein</td>
<td>Colorless to yellow volatile liquid with a disagreeable choking odor, this material is irritating to the eyes and mucous membranes. This substance is extremely toxic; inhalation of concentrations as little as 10 ppm may be fatal within a few minutes.</td>
</tr>
<tr>
<td>Asbestos</td>
<td>A magnesium silicate mineral that occurs as slender, strong flexible fibers. Breathing of asbestos dust causes asbestosis and lung cancer.</td>
</tr>
<tr>
<td>Benzene</td>
<td>Colorless liquid with a petroleum-like odor. Acute exposure to benzene can result in dizziness, excitation, headache, difficulty breathing, nausea and vomiting. Benzene is also a carcinogen.</td>
</tr>
<tr>
<td>Benzaldehyde</td>
<td>Colorless to clear yellow liquid with a bitter almond odor. Inhalation of concentrated vapor is irritating to the eyes, nose, and throat.</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>Colorless, odorless gas. Inhalation of carbon monoxide causes headache, dizziness, weakness, confusion, nausea, unconsciousness, and death. Exposure to as little as 0.2% carbon monoxide can result in unconsciousness within 30 minutes. Inhalation of high concentration can result in immediate collapse and unconsciousness.</td>
</tr>
<tr>
<td>Formaldehyde</td>
<td>Colorless gas with a pungent irritating odor that is highly irritating to the nose. 50-100 ppm can cause severe irritation to the respiratory tract and serious injury. Exposure to high concentrations can cause injury to the skin. Formaldehyde is a suspected carcinogen.</td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td>Light yellow liquid that causes severe irritation of the eyes and irritation of the skin.</td>
</tr>
<tr>
<td>Hydrogen Chloride</td>
<td>Colorless gas with a sharp, pungent odor. Mixes with water to form hydrochloric acid. Hydrogen chloride is corrosive to human tissue. Exposure to hydrogen chloride can result in irritation of skin and respiratory distress.</td>
</tr>
<tr>
<td>Isovaleraldehyde</td>
<td>Colorless liquid with a weak, suffocating odor. Inhalation causes respiratory distress, nausea, vomiting and headache.</td>
</tr>
<tr>
<td>Nitrogen Dioxide</td>
<td>Reddish brown gas or yellowish-brown liquid, which is highly toxic and corrosive.</td>
</tr>
<tr>
<td>Particulates</td>
<td>Small particles that can be inhaled and be deposited in the mouth, trachea, or the lungs. Exposure to particulates can cause eye irritation, respiratory distress (in addition to health hazards specifically related to the particular substances involved).</td>
</tr>
<tr>
<td>Polycyclic Aromatic Hydrocarbons (PAH)</td>
<td>PAH are a group of over 100 different chemicals that generally occur as complex mixtures as part of the combustion process. These materials are generally colorless, white, or pale yellow-green solids with pleasant odor. Some of these materials are human carcinogens.</td>
</tr>
<tr>
<td>Sulfur Dioxide</td>
<td>Colorless gas with a choking or suffocating odor. Sulfur dioxide is toxic and corrosive and can irritate the eyes and mucous membranes.</td>
</tr>
</tbody>
</table>

Source: Computer Aided Management of Emergency Operations (CAMEO) and Toxicological Profile for Polycyclic Aromatic Hydrocarbons.
- **Rickettsias** — Rickettsias are specialized bacteria that live and multiply in the gastrointestinal tract of arthropod carriers (such as ticks and fleas) *(Figure 4.55)*. They are smaller than most bacteria, but larger than viruses. Like bacteria, they are single-celled organisms with their own metabolisms, and they are susceptible to broad-spectrum antibiotics. However, like viruses, they only reproduce in living cells. Most rickettsias spread only through the bite of infected arthropods (such as ticks) and not through human contact. Two types of rickettsia have been weaponized as bioterrorism agents.

- **Biological toxins** — Biological toxins are produced by living organisms; however, the biological organism itself is usually not harmful to people *(Figure 4.56)*.

*Infectious* diseases are caused by the reproduction and spread of microorganisms (*pathogens*) in the body. They may be *contagious*.

*Figure 4.53* Viruses like the deadly Ebola virus pictured here are unaffected by antibiotics. *Courtesy of the CDC Public Health Image Library.*

*Figure 4.54* Anthrax is a type of bacteria. Bacterial infections can be treated with antibiotics. *Courtesy of the CDC Public Health Image Library.*

*Figure 4.55* Ticks, fleas, and other arthropods may carry rickettsias. *Courtesy of the U.S. Department of Agriculture.*

*Figure 4.56* Ricin, a biological toxin, is made from castor beans.
Exposure to biological hazards may occur in biological and medical laboratories, agricultural facilities, or when dealing with people or animals who are carriers of such diseases. Some of these diseases are carried in body fluids and are transmitted by contact with the fluids. For instance, in 2014, health care providers in Dallas, TX, were infected with a naturally occurring strain of Ebola after contact with one patient exposed in the outbreak in Africa. Examples of diseases associated with biological hazards or threats are:

- Malaria
- Tuberculosis
- Hepatitis B
- Measles
- Ebola
- Influenza
- Typhoid

First responders may also be exposed to biological agents used as weapons in terrorist attacks and criminal activities. These biological attacks could produce death and disease in people, animals, and plants. The 2001 anthrax attacks in the United States were an example of a biological attack. Biological attacks use weaponized forms of disease-causing organisms and/or their toxins. Examples of potential biological weapons include:

- Smallpox (virus) (Figure 4.57)
- Anthrax (bacteria)
- Botulism (toxin from the bacteria Clostridium botulinum)

**Hazard Classes**

Transportation hazard classes, introduced in Chapter 2, are easier to understand once you have a better understanding of the basic physical and chemical properties explained in the previous sections. In general, a product’s hazard class is assigned based on its most dangerous chemical and/or physical properties. Flammable gases combine the physical hazard of a gaseous state, which expands rapidly, spreads easily, and is difficult to confine, with flammability.

This section describes:

- Class 1—Explosives
- Class 2—Gases
- Class 3—Flammable liquids (and combustible liquids in the U.S.)
- Class 4—Flammable solids, spontaneously combustible, and dangerous when wet
- Class 5—Oxidizers and organic peroxides

![Smallpox virus could be used as a biological weapon. Courtesy of the CDC Public Health Image Library.](image)
Class 1: Explosives

Explosives are reactive. An explosive is any substance or article with a great deal of potential energy that may rapidly expand and release upon activation (undergo an explosion) (Figure 4.58). Explosives may release energy in the form of light, gas, and/or heat. Some explosives may not be specifically designed to explode. Chapter 8 describes the explosives as a hazard that responders face.

Explosive placards list both a division number and a compatibility group letter on them. First responders should pay particular attention to the division number, which assigns the level of explosion hazard to the product. Compatibility group letters categorize different types of explosive substances and articles for purposes of stowage and segregation (Figure 4.59).

Explosives will typically be packaged as solids in individual packages or boxes. However, some explosives are liquids such as certain binary explosives. Some transportation vehicles and certain storage areas are specifically designed for explosives (Figures 4.60).
The primary hazards of explosives are thermal and mechanical. These hazards may manifest in the following conditions:

- **Blast-pressure wave (shock wave)** — Rapidly released gases can create a shock wave that travels outward from the center. As the wave increases in distance, the strength decreases. This blast-pressure wave is the primary reason for injuries and damage. The blast-pressure wave has a positive and negative phase, both of which can cause damage (Figures 4.61a, b, and c).

**Figure 4.60** Certain containers and storage areas are specifically designed for explosives. Courtesy of David Alexander with the Texas Commission on Fire Protection.

**Figure 4.61a** An explosion's blast pressure will compress the surrounding atmosphere into a rapidly expanding shock front. Depending on its force, this positive pressure wave can be extremely destructive.
Figure 4.61b Typically less destructive than the positive pressure phase, additional damage can be done during the negative pressure phase, particularly to buildings and structures damaged in the initial blast.

Figure 4.61c Effects of an explosion include the blast pressure effect, incendiary/thermal effects, the shock front, and the fragmentation effect.
• **Shrapnel and fragmentation** — Small pieces of debris thrown from a container or structure that ruptures during an explosion from containment or restricted blast pressure. Shrapnel and fragmentation may be thrown over a wide area and great distances, causing personal injury and other types of damage to surrounding structures or objects. Shrapnel and fragmentation can result in bruises, punctures, or even avulsions (part of the body being torn away) when they strike a person.

• **Seismic effect** — Vibration is similar to an earthquake. Explosions can cause a seismic effect. When a blast occurs at or near ground level, the air blast creates a ground shock or crater. As the shock waves move across or underground, they form a seismic disturbance. The distance the shock wave travels depends on the type and size of the explosion and type of soil.

• **Incendiary thermal effect** — Occurs during an explosion when thermal heat energy forms a fireball. Fireballs result from the interactions among burning combustible gases or flammable vapors and ambient air at high temperatures. The thermal heat fireball is present for a limited time after the explosive event.

Additional hazards unrelated to the explosion include:

• Chemical hazards will probably result from the production of toxic gases and vapors.

• Explosives may self-contaminate as they age, which increases their sensitivity and instability.

• Explosives may have high sensitivity to shock and friction.

Table 4.5 provides the U.S. DOT’s explosive divisions’ definitions, with examples.

<table>
<thead>
<tr>
<th>Division Number</th>
<th>Definition</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Division 1.1</td>
<td>Explosives that have a mass explosion hazard. A mass explosion is one that affects almost the entire load instantaneously.</td>
<td>Dynamite, mines, wetted mercury fulminate</td>
</tr>
<tr>
<td>Division 1.2</td>
<td>Explosives that have a projection hazard but not a mass explosion hazard.</td>
<td>Detonation cord, rockets (with bursting charge), flares, fireworks</td>
</tr>
<tr>
<td>Division 1.3</td>
<td>Explosives that have a fire hazard and either a minor blast hazard or a minor projection hazard or both. Not a mass explosion hazard.</td>
<td>Liquid-fueled rocket motors, smokeless powder, practice grenades, aerial flares</td>
</tr>
<tr>
<td>Division 1.4</td>
<td>Explosives that present a minor explosion hazard. The explosive effects are largely confined to the package and no projection of fragments of appreciable size or range is expected. An external fire must not cause virtually instantaneous explosion of almost the entire contents of the package.</td>
<td>Signal cartridges, cap type primers, igniter fuses, fireworks</td>
</tr>
<tr>
<td>Division 1.5</td>
<td>Substances that have a mass explosion hazard but are so insensitive that there is little probability of initiation or of transition from burning to detonation under normal transportation conditions.</td>
<td>Prilled ammonium nitrate fertilizer or fuel oil (ANFO) mixtures and blasting agents</td>
</tr>
<tr>
<td>Division 1.6</td>
<td>Extremely insensitive articles that do not have a mass explosive hazard. This division is comprised of articles that contain only extremely insensitive detonating substances and that demonstrate a negligible probability of accidental initiation or propagation.</td>
<td>Low vulnerability military weapons</td>
</tr>
</tbody>
</table>

Source: 49 CFR 173.50
Class 2: Gases

Gases are materials that are in a gaseous state at normal temperatures and pressures (Figure 4.62). Gases are transported or stored in pressure containers or cryogenic containers (Figures 4.63 a and b). Gas division numbers are assigned according to the type of potential hazard gases pose, such as flammability. The potential hazards of gas include energy, toxicity (including asphyxiation), and corrosivity (Figure 4.64). Other potential hazards include:

- **Heat hazards** — Fires, particularly associated with Division 2.1 and oxygen; gases can travel great distances to an ignition source
- **Asphyxiation hazards** — Leaking or released gases displacing oxygen in a confined space
- **Cold hazards** — Exposure to Division 2.2 cryogens
- **Mechanical hazards** — A BLEVE (boiling liquid expanding vapor explosion) for containers exposed to heat or flame; a ruptured cylinder rocketing after exposure to heat or flame
- **Chemical hazards** — Toxic and/or corrosive gases and vapors, particularly associated with Division 2.3

Figure 4.62 Class 2 materials are gases at normal temperatures and pressures.

Figure 4.63a and b Gases are transported in (a) pressure containers and (b) cryogenic containers.
Table 4.6, p. 184, provides the U.S. DOT’s Class 2 divisions’ placards, definitions, and examples.

Class 3: Flammable Liquids (and Combustible Liquids [U.S.])
Flammable and combustible liquids ignite and burn with relative ease (Figure 4.65, p. 185). Most hazmat incidents, such as gasoline and diesel fuel spills, involve this hazard class. In addition to burning, all flammable and combustible liquids exhibit varying degrees of toxicity. Some flammable liquids are also corrosive.

While these materials are transported in liquid containers, they may give off hazardous vapors, much like gases, that may travel from their source (Figure 4.66, p. 185). These vapors will burn if ignited.

The primary hazards of flammable and combustible liquids are energy, corrosivity, and toxicity. They often manifest in the following conditions:

- **Thermal hazards (heat)** — Fires and vapor explosions (Figure 4.67, p. 185)
- **Asphyxiation** — Heavier-than-air vapors displacing oxygen in low-lying and/or confined spaces
- **Chemical hazards** — Toxic and/or corrosive gases and vapors; these may be produced by fires
- **Mechanical hazards** — A BLEVE, for containers exposed to heat or flame; caused by a vapor explosion
- **Vapors** — Can mix with air and travel great distances to an ignition source
- **Environmental hazards (pollution)** — Caused by runoff from fire control

**Figure 4.64** Gases can cause harm via energy release, toxicity, and corrosivity.

**Vapor Explosion** — Occurrence when a hot liquid fuel transfers heat energy to a colder, more volatile liquid fuel. As the colder fuel vaporizes, pressure builds in a container and can create shockwaves of kinetic energy.
## Table 4.6
Class 2 Divisions, Placards, Definitions, and Examples

<table>
<thead>
<tr>
<th>Division Number and Placard</th>
<th>Definition</th>
</tr>
</thead>
</table>
| **Division 2.1** | **Flammable Gas** — Consists of any material that is a gas at 68°F (20°C) or less at normal atmospheric pressure or a material that has a boiling point of 68°F (20°C) or less at normal atmospheric pressure and that  
(1) Is ignitable at normal atmospheric pressure when in a mixture of 13 percent or less by volume with air, or  
(2) Has a flammable range at normal atmospheric pressure with air of at least 12 percent, regardless of the lower limit.  
*Examples:* compressed hydrogen, isobutene, methane, and propane |
| **Division 2.2** | **Nonflammable, Nonpoisonous Gas** — Nonflammable, nonpoisonous compressed gas, including compressed gas, liquefied gas, pressurized cryogenic gas, and compressed gas in solution, asphyxiant gas and oxidizing gas; means any material (or mixture) which exerts in the packaging an absolute pressure of 40.6 psi (280 kPa) or greater at 68°F (20°C) and does not meet the definition of Divisions 2.1 or 2.3.  
*Examples:* carbon dioxide, helium, compressed neon, refrigerated liquid nitrogen, cryogenic argon |
| **Division 2.3** | **Gas Poisonous by Inhalation** — Material that is a gas at 68°F (20°C) or less and a pressure of 14.7 psi (101.3 kPa) (a material that has a boiling point of 68°F (20°C) or less at 14.7 psi [101.3 kPa]), and that is known to be so toxic to humans as to pose a hazard to health during transportation; or (in the absence of adequate data on human toxicity) is presumed to be toxic to humans because of specific test criteria on laboratory animals.  
Division 2.3 has ERG-designated hazard zones associated with it, determined by the concentration of gas in the air:  
• Hazard Zone A — LC50 less than or equal to 200 ppm  
• Hazard Zone B — LC50 greater than 200 ppm and less than or equal to 1,000 ppm  
• Hazard Zone C — LC50 greater than 1,000 ppm and less than or equal to 3,000 ppm  
• Hazard Zone D — LC50 greater than 3,000 ppm and less than or equal to 5,000 ppm  
*Examples:* cyanide, diphosgene, germaine, phosphine, selenium hexafluoride, and hydrocyanic acid |
| **Oxygen Placard** | **Oxygen** is not a separate division under Class 2, but first responders may see this oxygen placard on containers with 1,001 lbs (454 kg) or more gross weight of either compressed gas or refrigerated liquid. |

Source: 49 CFR 173.115
Figure 4.65 Class 3 materials ignite and burn easily.

Figure 4.66 Although liquids, in most conditions, Class 3 materials will give off flammable vapors that behave much like gases.

Figure 4.67 While flammable liquids may be corrosive and/or toxic, their primary hazard is flammability. Courtesy Williams Fire & Hazard Control Inc., Brent Gaspard.
Table 4.7 provides the U.S. DOT’s Class 3 divisions’ placards, definitions, and examples.

<table>
<thead>
<tr>
<th>Placard</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flammable</strong>&lt;br&gt;<img src="image" alt="Flammable Placard" /></td>
<td>A flammable liquid is generally a liquid having a flash point of not more than 140°F (60°C), or any material in a liquid state with a flash point at or above 100°F (37.8°C) that is intentionally heated and offered for transportation or transported at or above its flash point in a bulk packaging.&lt;br&gt;&lt;em&gt;Examples:&lt;/em&gt; gasoline, methyl ethyl ketone</td>
</tr>
<tr>
<td><strong>Gasoline Placard</strong>&lt;br&gt;<img src="image" alt="Gasoline Placard" /></td>
<td>May be used in the place of a flammable placard on a cargo tank or a portable tank being used to transport gasoline by highway</td>
</tr>
<tr>
<td><strong>Combustible</strong>&lt;br&gt;<img src="image" alt="Combustible Placard" /></td>
<td>A combustible liquid is any liquid that does not meet the definition of any other hazard class and has a flash point above 140°F (60°C) and below 200 °F (93 °C). A flammable liquid with a flash point at or above 100°F (37.8°C) that does not meet the definition of any other hazard class may be reclassified as a combustible liquid. This provision does not apply to transportation by vessel or aircraft, except where other means of transportation is impracticable. An elevated temperature material that meets the definition of a Class 3 material because it is intentionally heated and offered for transportation or transported at or above its flash point may not be reclassified as a combustible liquid.&lt;br&gt;&lt;em&gt;Examples:&lt;/em&gt; diesel, fuel oils, pine oil</td>
</tr>
<tr>
<td><strong>Fuel Oil Placard</strong>&lt;br&gt;<img src="image" alt="Fuel Oil Placard" /></td>
<td>May be used in place of a combustible placard on a cargo tank or portable tank being used to transport fuel oil by highway.&lt;br&gt;&lt;em&gt;Examples:&lt;/em&gt; Bunker fuel, heating fuel</td>
</tr>
</tbody>
</table>

Source: 49 CFR 173.120

**Class 4: Flammable Solids, Spontaneously Combustible, and Dangerous When Wet**

Class 4 materials are divided into three different divisions (Figure 4.68):

- 4.1 Flammable Solids
- 4.2 Spontaneously Combustible Materials
- 4.3 Dangerous When Wet
It may be difficult for responders to extinguish fires involving Class 4 materials. Class 4 materials are often solids (metals) that react violently in unexpected ways. For example:

- Some flammable solids will react to friction.
- Spontaneously combustible materials may ignite after contact with air.
- Dangerous when wet materials, if involved in a fire, may burn more intensely if firefighters attempt to extinguish the fire with water (Figure 4.69).
- Fires involving Class 4 materials may be difficult to extinguish.
- Incidents involving these materials can be difficult to manage. Even more experienced responders may not fully understand the hazards, and the typical response may make the situation worse.

**Figure 4.68** Class 4 materials are divided into three categories based on type of reactivity.

**Figure 4.69** Some Class 4 materials react violently when contacted by water.

The primary hazards of Class 4 materials are: chemical energy, mechanical energy, corrosivity, and toxicity. Some examples include:

- Thermal hazards (heat)
- Fires that may start or reignite spontaneously or upon contact with air or water
- Fires and vapor explosions
- Molten substances
- Chemical hazards from irritating, corrosive, and/or highly toxic gases and vapors produced by fire or decomposition
- Severe chemical burns
- Mechanical effects from a BLEVE (if containers exposed to heat, or flame or Division 4.3 contaminated with water) or other unexpected, violent chemical reactions and explosions
• Chemical hazards from:
  — Production of hydrogen gas from contact with metal
  — Production of corrosive solutions on contact with water, for Division 4.3
  — Production of flammable gas on contact with water, for Division 4.3 (such as calcium carbide)
• Environmental hazards (pollution) caused by runoff from fire control

Table 4.8 provides the U.S. DOT’s Class 4 divisions’ placards, definitions, and examples.

<table>
<thead>
<tr>
<th>Division Number and Placard</th>
<th>Definition</th>
</tr>
</thead>
</table>
| Division 4.1 | Flammable Solid Material — Includes (1) wetted explosives, (2) self-reactive materials that can undergo a strongly exothermic decomposition, and (3) readily combustible solids that may cause a fire through friction, certain metal powders that can be ignited and react over the whole length of a sample in 10 minutes or less, or readily combustible solids that burn faster than 2.2 mm/second:  
  • Wetted explosives: Explosives with their explosive properties suppressed by wetting with sufficient alcohol, plasticizers, or water  
  • Self-reactive materials: Materials liable to undergo a strong exothermic decomposition at normal or elevated temperatures due to excessively high transport temperatures or to contamination  
  • Readily combustible solids: Solids that may ignite through friction or any metal powders that can be ignited  
  Examples: phosphorus heptasulfide, paraformaldehyde, magnesium alloys |
| Division 4.2 | Spontaneously Combustible Material — Includes (1) a pyrophoric material (liquid or solid) that, without an external ignition source, can ignite within 5 minutes after coming in contact with air and (2) a self-heating material that, when in contact with air and without an energy supply, is liable to self-heat  
  Examples: sodium sulfide, potassium sulfide, phosphorus (white or yellow, dry), aluminum and magnesium alkyls, charcoal briquettes when shipped in bulk |
| Division 4.3 | Dangerous-When-Wet Material — Material that, by contact with water, is liable to become spontaneously flammable or to release flammable or toxic gas at a rate greater than 1 liter per kilogram of the material per hour  
  Examples: magnesium powder, lithium, ethylidichlorosilane, calcium carbide, potassium |

Source: 49 CFR 173.124
Class 5: Oxidizers and Organic Peroxides
Class 5 is divided into two divisions (Figure 4.70):

- 5.1 Oxidizers — Typically solids or aqueous solutions
- 5.2 Organic Peroxides — Liquids or solids.

Oxidizers vigorously support combustion, may be explosive, and when combined with fuel, may burn continuously (Figure 4.71). Some oxidizers, in conjunction with a fuel, have the ability to burn continuously without air being present. Oxidizers may also be explosive. Oxygen is an example of an oxidizer.

Organic peroxides are oxidizers with a specific chemical composition that make them prone to reactivity. When these materials are involved in an incident, you will need a small amount of heat to start a fire or explosion. Organic peroxides are both a fuel and an oxidizer. Because of this, they are reactive. Store organic peroxides below the maximum safe storage temperature (MSST).

![Class 5 Placards](image)

**Figure 4.70** Class 5 materials are oxidizers and organic peroxides.

![Oxidizers support combustion.](image)

**Figure 4.71** Oxidizers support combustion.
If organic peroxides reach the **self-accelerating decomposition temperature (SADT)**, they undergo a chemical change and may violently release from their packaging. The time before reaction depends upon how much the SADT is exceeded, which can greatly accelerate the decomposition.

**WARNING!**
Immediately evacuate the area if the SADT is reached. If decomposition occurs, observe it from a safe distance and take only those measures necessary to preserve life and nearby property.

Organic peroxides are not the only materials to have SADTs. Many polymerization initiators or reactive chemicals have an SADT. The responder should recognize these materials by using an SDS or other reference source to obtain this data. Many times the SADT is written into the SDS as decompostion temperature.

**Relevance of SADT and MSST**

Benzoyl peroxide is used in several different formulations and chemical reactions in industry and college chemistry laboratories. It has an SADT at the melting point of 71°C (160°F). Its MSST is 30°C (86°F). The laboratory stores the material in an explosion-proof refrigerator.

At a university, a graduate assistant was using benzoyl peroxide in a research experiment. The material was stored in a normal small laboratory refrigerator set at 40°F (4.5°C). The assistant left a stainless steel scoopula in the container with the benzoyl peroxide. One evening, the fire alarm went off in the chemical lab.

The university and the local fire department responded rapidly. Responders entered the building wearing turnouts and breathing apparatus and made their way to the laboratory on the third floor. The third floor was full of smoke, but without any active fire. There was no loss of life, but damage to the laboratory was extensive. The refrigerator door had been violently thrown to the back wall of the laboratory, through several sets of oak benches. The far wall of the laboratory was black from the flash fire that had occurred some 40 feet (12 m) away.

An investigation showed that the refrigerator had lost power and the temperature in the refrigerator had reached room temperature at 70°F (21°C). Even though the temperature was below the MSST of 86°F (30°C), the metal scoopula acted as a catalyst. It dramatically lowered the SADT of the benzoyl peroxide. Responders should take steps to prevent contamination when responding to hazardous materials incidents involving peroxides.
The primary hazards of Class 5 materials are thermal, mechanical, chemical. Some examples include:

- Thermal hazards (heat) from fires that may explode or burn hot and fast or materials’/substances’ sensitivity to heat, friction, shock, and contamination.
- Explosive reactions to contact with hydrocarbons (fuels)
- Mechanical hazards
  - Violent reactions and explosions
  - Sensitivity to heat, friction, shock, and/or contamination with other materials
- Chemical hazards
  - From toxic gases, vapors, dust
  - From products of combustion
  - Resulting in burns
- Thermal hazards from ignition of combustibles (including paper, cloth, wood, etc.)
- Asphyxiation hazards from accumulation of toxic fumes and dusts in confined spaces

Table 4.9 provides the U.S. DOT’s Class 5 divisions’ placards, definitions, and examples.

<table>
<thead>
<tr>
<th>Division Number and Placard</th>
<th>Definition</th>
</tr>
</thead>
</table>
| Division 5.1 | Oxidizer — Material that may, generally by yielding oxygen, cause or enhance the combustion of other material  
*Examples:* chromium nitrate; copper chlorate; calcium permanganate, ammonium nitrate fertilizer |
| Division 5.2 | Organic Peroxide — Any organic compound containing oxygen (O) in the bivalent -O-O- structure and which may be considered a derivative of hydrogen peroxide, where one or more of the hydrogen atoms has been replaced by organic radicals  
*Examples:* liquid organic peroxide type B |

Source: 49 CFR 173.127 and 128
Class 6: Poisons, Poison Inhalation Hazards, and Infectious Substances

Class 6 materials and substances include poisons, poison inhalation hazards, and infectious substances (Figure 4.72). Poisonous materials are known to be toxic to humans. Avoid contact with these materials (Figure 4.73).

Inhalation hazards are toxic vapors that can be lethal if inhaled. These materials can be extremely dangerous at hazmat incidents because they can travel great distances and harm or kill anyone who breathes them (Figure 4.74).

Infectious substances and biohazards are materials that have the potential to cause disease in humans or animals. Infectious materials are typically shipped in small containers, so there is no placard for them, only a label. A biohazard label is used for large and small quantities of regulated medical waste.

The secondary hazards of Class 6 materials are:

- Toxic hazards
- Chemical hazards from toxic and/or corrosive products of combustion
- Thermal hazards (heat) from substances transported in molten form
- Thermal hazards (heat) from flammability and fires

**WARNING!**
Do not inhale or come into contact with Class 6 materials.

Table 4.10 provides the U.S. DOT’s Class 6 divisions’ placards, definitions, and examples. Table 4.11, p. 194, provides the U.S. DOT’s Class 6 unique labels, definitions, and examples.
### Table 4.10  
Class 6 Divisions, Placards, Definitions, and Examples

<table>
<thead>
<tr>
<th>Division Number and Placard</th>
<th>Definition</th>
</tr>
</thead>
</table>
| Division 6.1 <br> ![POISON](image) **6** | **Poisonous Material** — Material, other than a gas, that is known to be so toxic to humans as to afford a hazard to health during transportation or that is presumed to be toxic to humans based on toxicity tests on laboratory animals  
*Examples:* aniline, arsenic, liquid tetraethyl lead |
| ![PG III](image) **6** | **PG III** — For Division 6.1, packing group III* (PG III) materials, a POISON placard may be modified to display the text “PG III” below the mid line of the placard rather than the word “POISON.”  
*A packing group is a DOT packaging category based on the degree of danger presented by the hazardous material. Packing Group I indicates great danger; Packing Group II, medium danger; and Packing Group III, minor danger. The PG III placard, then, might be used for materials that are not as dangerous as those that would be placarded with the “POISON” placard.  
*Examples:* chloroform, alkaloid solids |
| ![INHALATION HAZARD](image) **6** | **Inhalation Hazard Placard** — Used for any quantity of Division 6.1, Zones A or B inhalation hazard only (see Division 2.3 for hazard zones)  
*Examples:* nerve agents, cyanide |

Source: 49 CFR 173.132 and 134
Radioactive materials cannot be detected with the senses (Figure 4.75). While Class 7 placards and labels can indicate that radioactive materials are present, without specialized monitoring and detection equipment, it is not possible to determine if a container is actually emitting radiation. It is impossible to tell if radiation is involved in an incident, such as a terrorist attack, where no placards or labels are evident.

Small packages of radioactive materials must be labeled on two opposite sides, with a distinctive warning label. Each of the three label categories — RADIOACTIVE WHITE-I, RADIOACTIVE YELLOW-II, or RADIOACTIVE YELLOW-III — bears the unique trefoil symbol for radiation.

Class 7 Radioactive I, II, and III labels must always contain the following additional information (Figure 4.76):

- **Isotope** name (Figure 4.77)
- Radiation activity

Radioactive II and III labels will also provide the Transport Index (TI), which indicates the carrier’s degree of control during transportation. The number in the transport index box indicates the maximum radiation level measured in (mrem/hr) at one meter from the surface of the package. Packages with the Radioactive I label have a Transport Index of 0.

**NOTE:** Items placarded as Radioactive II and III have a maximum allowed TI rating of 50 mrem/hr at 1 meter.

**Table 4.12** provides the U.S. DOT’s Class 7 divisions’ placards, definitions, and examples. **Table 4.13, p. 196**, provides the U.S. DOT’s Class 7 unique labels, definitions, and examples.
Figure 4.75 Class 7 materials are radioactive and cannot be detected with the senses.

Activity

The energy of radiation gives it the ability to penetrate matter. Higher energy radiation will be able to penetrate a higher volume and denser matter than lower energy radiation. The strength of a radioactive source is called its activity. The activity of a radioactive source can be defined as the rate at which a number of atoms will decay and emit radiation in one second.

The International System (SI) unit for activity is the Becquerel (Bq), which is the quantity of radioactive material in which one atom transforms per second. The Becquerel tends to be a small unit. The curie (Ci) is also used as the unit for activity of a particular source material. The curie is a quantity of radioactive material in which 1 Ci = 3.7 x 10¹⁰ atoms disintegrate per second.

Common Isotopes

<table>
<thead>
<tr>
<th>Isotope Name</th>
<th>Radioactive Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cs-137</td>
<td>7</td>
</tr>
<tr>
<td>Co-60</td>
<td>7</td>
</tr>
<tr>
<td>Ir-192</td>
<td>7</td>
</tr>
<tr>
<td>Am-241</td>
<td>7</td>
</tr>
<tr>
<td>Tl-201</td>
<td>7</td>
</tr>
<tr>
<td>Tc-99m</td>
<td>7</td>
</tr>
<tr>
<td>I-131</td>
<td>7</td>
</tr>
<tr>
<td>I-125</td>
<td>7</td>
</tr>
<tr>
<td>Pd-103</td>
<td>7</td>
</tr>
<tr>
<td>Ru-106</td>
<td>7</td>
</tr>
</tbody>
</table>

Figure 4.77 Common isotope names that might be seen on Class 7 labels.

Table 4.12

<table>
<thead>
<tr>
<th>Division Number and Label</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Division 7</td>
<td>Radioactive Placard — Is required on certain shipments of radioactive materials; vehicles with this placard are carrying “highway route controlled quantities” of radioactive materials and must follow prescribed, predetermined transportation routes. Examples: solid thorium nitrate, uranium hexafluoride</td>
</tr>
</tbody>
</table>

Source: 49 CFR 173.403
Corrosives are either a liquid or solid that cause full thickness destruction of human skin at the site of contact within a specific period of time, or a liquid that has a severe corrosion rate on steel or aluminum (Figure 4.78). Corrosives can also cause a fire or an explosion if they come in contact with other materials because their corrosive actions can generate enough heat to start
a fire. Some can react with metal to form (explosive) hydrogen gas. Different
types of corrosives (acids and bases) can react violently when mixed together
or when combined with water.

Corrosives can be toxic, flammable, reactive, and/or explosive and some are
oxidizers (Figure 4.79). Because of the wide variety of hazards presented by
corrosives, do not focus solely on the corrosive properties when considering
appropriate actions at incidents involving these materials.

The primary hazards of Class 8 materials are chemical, toxic, thermal and
mechanical. Some examples include:
• Chemical hazards such as chemical burns
• Toxic hazards due to exposure via all routes of entry into a body
• Thermal hazards (heat), including fire, caused by chemical reactions gen-
erating heat
• Mechanical hazards caused by BLEVEs and violent chemical reactions

Table 4.14 provides the U.S. DOT’s Class 8 divisions’ placards, definitions,
and examples.

Class 8 Corrosives

Figure 4.78 Corrosives cause damage to metal and skin.

Figure 4.79 Class 8 corrosives are liquids or solids.

Table 4.14

<table>
<thead>
<tr>
<th>Corrosive Placard</th>
</tr>
</thead>
<tbody>
<tr>
<td>A corrosive material means a liquid or solid that causes full thickness destruction of human skin at the site of contact within a specific period of time or a liquid that has a severe corrosion rate on steel or aluminum.</td>
</tr>
<tr>
<td>Examples: battery fluid, chromic acid solution, soda lime, sulfuric acid, hydrochloric acid (muriatic acid), sodium hydroxide, potassium hydroxide</td>
</tr>
</tbody>
</table>
Class 9 Miscellaneous Hazardous Materials

A miscellaneous dangerous good is a material that (Figure 4.80):

- Has an anesthetic, noxious, or other similar property that could cause distraction or discomfort to crew members during transportation
- Is a hazardous substance or a hazardous waste
- Is an elevated temperature material
- Is a marine pollutant

Miscellaneous dangerous goods will primarily have thermal and chemical hazards. For example, elevated temperature materials may present some thermal hazards, and polychlorinated biphenyls (PCBs) are carcinogenic. However, hazardous wastes may present any of the hazards associated with the materials in normal use.

Table 4.15 provides the U.S. DOT’s Class 9 divisions’ placard and examples.

![Class 9 Placard](image)

Figure 4.80 Class 9 materials mostly present thermal and chemical hazards.

<table>
<thead>
<tr>
<th>Class 9 Divisions, Placards, Definitions, and Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>A miscellaneous dangerous good is a material that (1) has an anesthetic, noxious, or other similar property that could cause extreme annoyance or discomfort to flight crew members and would prevent their correct performance of assigned duties; (2) is a hazardous substance or a hazardous waste; or (3) is an elevated temperature material; or (4) is a marine pollutant.</td>
</tr>
<tr>
<td>Miscellaneous dangerous goods will primarily have thermal and chemical hazards. For example, polychlorinated biphenyls (PCBs) are carcinogenic, while elevated temperature materials may present some thermal hazards. However, hazardous wastes may present any of the hazards associated with the materials in normal use.</td>
</tr>
</tbody>
</table>
| **Miscellaneous Placard**  
*Examples:* blue asbestos, polychlorinated biphenyls (PCBs), solid carbon dioxide (dry ice) |
| **Dangerous Placard** — A freight container, unit load device, transport vehicle, or railcar that contains nonbulk packaging with two or more DOT Chart 12, Table 2 categories of hazardous materials may be placarded **DANGEROUS.** However, when 2,205 lbs (1,000 kg) or more of one category of material is loaded at one loading facility, the placard specified in DOT Chart 12, Table 2 must be applied. |
Other Regulated Materials (ORM-Ds) and Materials of Trade (MOTs)

ORM-Ds are consumer commodities that present a limited hazard during transportation due to their form, quantity, and packaging. No placards are required for ORM-Ds, but they are otherwise subject to the requirements of the Hazardous Materials Regulations (HMR). Examples of ORM-Ds include consumer commodities and small arms cartridges.

A MOT is a hazardous material, other than a hazardous waste, that is carried on a motor vehicle for the purposes listed below. MOTs do not require placards, shipping papers, emergency response information, formal record keeping, or formal training. MOT purposes include:

- To protect the health and safety of motor vehicle operators or passengers. Examples: insect repellant, fire extinguishers, and self-contained breathing apparatus (SCBA)
- To support the operation or maintenance of motor vehicles, including its auxiliary equipment. Examples: spare batteries, gasoline, and engine starting fluid
- To directly support principal nontransportation businesses (by private motor carriers). Examples: lawn care, pest control, plumbing, welding, painting, and door-to-door sales

Many ORM-Ds (such as hairspray) may qualify as MOTs. However, self-reactive materials, poison inhalation hazard materials, and hazardous wastes never qualify as MOTs.

Additional Information

As soon as first responders identify an incident as a hazmat incident, they should take steps to gather additional information to identify the hazardous material(s)/substance(s) involved, take into account additional hazards or complications caused by surrounding conditions, and contact any additional resources that may provide additional technical information (Figure 4.81). The following sections address each of these concerns:

- Collecting hazard and response information
- Surrounding conditions
- Emergency response centers

Collecting Hazard and Response Information

After identifying a hazardous material/substance, use the following sources (described in Chapter 2) to gather information about its physical and chemical properties:

- *Emergency Response Guidebook (ERG)*
- Shippers and shipping papers (see Table 2.11 for typical locations)
- Safety Data Sheets (SDS) (available at fixed facilities where the products are stored or used)
- Pipeline operators
• Computer apps such as CAMEO and Wiser
• Placards and labels
• Manufacturers

**NOTE:** Local, state, and governmental authorities may also provide assistance and will be explained in Chapter 6, Notification section.

Responders can use the previous sources listed to determine a product’s hazards and the way it is likely to behave based on its chemical and physical properties. Additional information gathered from these sources may include:

• Potential health hazards
• Signs and symptoms of exposure
• Responsible party contact information
• Precautions for safe handling and control measures including PPE and spill cleanup procedures
• Emergency and first aid procedures

**Surrounding Conditions**

In addition to identifying hazmat containers and their contents, first responders need to survey surrounding conditions. While conducting this survey, first responders should identify relevant information, including (Figure 4.82):

• Potential site hazards, such as overhead power lines, highway traffic, and rail lines
• Potential ignition sources
• Potential victims and exposures
• Weather and time of day
• Topography
• Information about the building and building components, if indoors

![Figure 4.82](image) Always survey surrounding conditions for hazards such as overhead power lines, oncoming traffic, rail lines, weather, and topography. **Courtesy of Rich Mahaney.**
**Site Hazards**

Hazmat incidents can occur anywhere and, often, the location itself will present its own hazards (Figure 4.83). For example, if the incident occurs on a road or highway, responders will need to take protective actions against traffic and other highway hazards such as falls from overpasses, bridges, and other heights. If the incident occurs on or near rail lines, responders should protect themselves, victims, and property from passing trains and other rail hazards. Overhead power lines may have been knocked down during the incident or present a hazard to elevating equipment such as aerial apparatus or cranes. Other site-specific hazards could present potential contamination, environmental, or thermal hazards specific to the hazardous materials involved in the incident.

**Potential Ignition Sources**

If the incident involves a flammable or combustible material — and the majority of hazmat incidents do — responders must avoid igniting these materials. Even if the material involved at the incident has not been identified, remove as many ignition sources as possible. Flammable gases and vapors can travel to unexpected places and tend to settle in low-lying areas.

Many potential ignition sources may exist at the scene of a hazardous materials incident including (Figure 4.84):

- Open flames
- Static electricity
- Pilot lights
- Electrical sources including non-explosion-proof electrical equipment
- Internal combustion engines in vehicles and generators

![Figure 4.83 The locations of hazmat incidents often have their own hazards. Courtesy of South Wales Fire Brigades.](image)

![Figure 4.84 There are many potential ignition sources that can ignite flammable liquids, vapors, and gases. They can also provide activation energy to initiate other reactions.](image)
• Heated surfaces
• Cutting and welding operations
• Radiant heat
• Heat caused by friction or chemical reactions
• Cigarettes and other smoking materials
• Cameras/cellular phones
• Road flares

The following actions can ignite flammable/explosive atmospheres (Figure 4.85):

• Opening or closing a switch or electrical circuit such as a light-switch
• Turning on a flashlight
• Operating a radio
• Activating a cell phone

![Actions That Can Ignite Flammable/Explosive Atmospheres](image)

**Figure 4.85** Common actions can ignite flammable/explosive atmospheres.

**Potential Victims and Exposures**
Responders must quickly identify potential victims and exposures. Potential exposures include people, property, and the environment. The potential exposures will determine the need for rescue and protective actions. The nature and extent of injuries may give clues to the product(s) involved and the hazards present as well as determine the need for decontamination and medical care. Exposures are addressed in greater detail in the Exposure/Contact section of this chapter; protective actions are detailed in Chapter 7.

**Weather**
If an incident is outdoors, the weather can dramatically affect how an incident progresses and is mitigated. For instance, if temperatures are below freezing, it may be impractical or impossible to use water for decontamination or dilution processes. Hot temperatures may cause liquids to evaporate more rapidly, producing more vapors or potentially raising a flammable material’s temperature to its ignition point. Wind direction may determine where and how far gases, vapors, or solid particulates travel. Rain or high humidity may cause water-reactive materials to burn or explode.
As explained in Chapter 3, Table 1 section, the time of day can also influence chemical behavior due to the conditions typically present. At night, winds tend to be lighter, so gases and vapors will not typically travel as far. Nights also tend to be cooler, so liquids tend not to evaporate as rapidly. In addition, temperature gradients may be significantly different in an area due to topography and bodies of water.

**Topography**

Topography makes a significant difference in the considerations needed to determine the appropriate isolation distance. The ERG (green-bordered pages) defines isolation distances. Topography is a factor in rural environments, such as flat plains or passes through mountains, as well as in developed environments such as wind tunnels between tall buildings and chemical processing areas. Topography may play an important role in where liquid and gaseous hazardous materials travel. If an outdoor incident involves a liquid, topography and gravity determine where the liquid might go, such as into culverts and ditches. These drainage areas may lead to the following environmentally sensitive areas that require protection:

- Streams and rivers
- Ponds, lakes, or wetlands
- Storm and sewer drains

Topography may also affect the travel of gases and vapors, with heavier-than-air vapors and gases following the contours of the land. When determining potential movement of hazardous vapors and gases, consider:

- Local thermal winds
- Upslope winds
- Downslope winds
- Breezes
- Aspect (for instance, if the incident aspect is facing the sun, a rise in temperature may affect the material and/or the container)
- Mountain or valley elevation, which can become an issue in relation to vapor density

**Building Information**

For incidents occurring indoors, the following information may be relevant:

- Location of floor drains
- Air handling ducts, returns, and units
- Location and components of fire protection and detection equipment
- Location of gas, electric, and water shut-off locations
- Presence of potential backup generators

**Emergency Response Centers**

Emergency response centers can provide useful information and guidance to first responders. The ERG provides contact information for emergency response centers in the U.S., Canada, Mexico, Argentina, Brazil, and Colombia. Contact
numbers are provided in the white pages in both the front and the back of the ERG.

In the U.S., several emergency response centers, such as the Chemical Transportation Emergency Center (CHEMTREC®), are not government-operated. CHEMTREC® was established by the chemical industry as a public service hotline for firefighters, law enforcement responders, and other emergency service responders to obtain information and assistance for emergency incidents involving chemicals and hazardous materials (Figure 4.86). The experts staffing these centers can provide 24-hour assistance to personnel responding to hazmat incidents.

Transport Canada operates the Canadian Transport Emergency Centre (CANUTEC). This national, bilingual (English and French) advisory center is part of the Transportation of Dangerous Goods Directorate. CANUTEC has a scientific data bank on chemicals manufactured, stored, and transported in Canada and is staffed by professional scientists who specialize in emergency response.

Mexico has two emergency response centers: (1) National Center for Communications of the Civil Protection Agency (CENACOM) and (2) Emergency Transportation System for the Chemical Industry (SETIQ), which is operated by the National Association of Chemical Industries.

NOTE: CENACOM has phone numbers dedicated to calls originating in Mexico City and its metropolitan area. Do not call these numbers if you are not in that area.

Before you contact the emergency response center, collect as much of the following information as safely possible:

• Caller’s name, callback telephone number, and fax number
• Location and nature of problem (such as spill or fire)
• Name and identification number of material(s) involved
• Shipper/consignee/point of origin
• Carrier name, railcar reporting marks (letters and numbers), or truck number
• Container type and size
• Quantity of material transported/released
• Local conditions (such as weather, terrain, proximity to schools, hospitals, or waterways)
• Injuries, exposures, current conditions involving spills, leaks, fires, explosions, and vapor clouds
• Local emergency services that have been notified

The emergency response center will:

• Confirm that a chemical emergency exists.
• Record details electronically and in written form.
• Provide immediate technical assistance to the caller.
• Contact the shipper of the material or other experts.
• Provide the shipper/manufacturer with the caller’s name and callback number so that the shipper/manufacturer can deal directly with the party involved.

**Chapter Review**

Answer the following questions to review the information provided in this chapter.

1. What are the different hazards for gases, liquids, and solids?
2. List the physical properties of materials and explain how they help to determine hazards.
3. List the chemical properties of materials and explain how they help to determine hazards.
4. List the hazard classes and give examples of each class that a first responder might commonly encounter.
5. What types of information do you need to collect at a hazmat incident?