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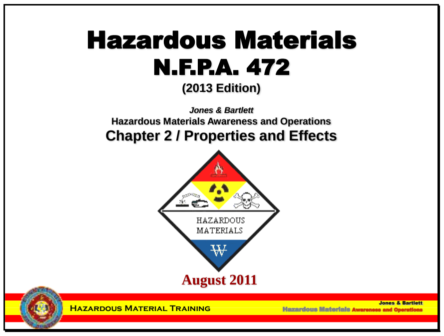

To understand hazardous materials incidents, it is important to know the chemical and physical properties of the substances involved. Chemical and physical properties are the characteristics of a substance that are measurable, such as vapor density, flammability, and water reactivity. When responding to hazardous materials/WMD incidents, responders must fully understand the hazards to minimize the potential for exposure. This includes knowing the routes of entry into the body and avoiding contamination. Caution and the use of proper equipment can offer protection and help ward off acute and chronic health effects.

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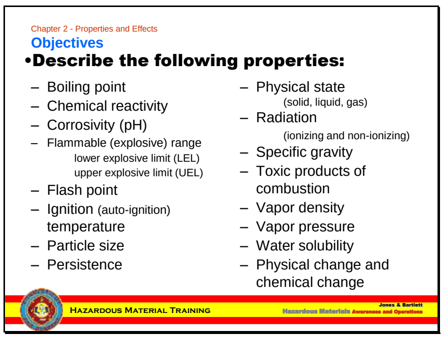

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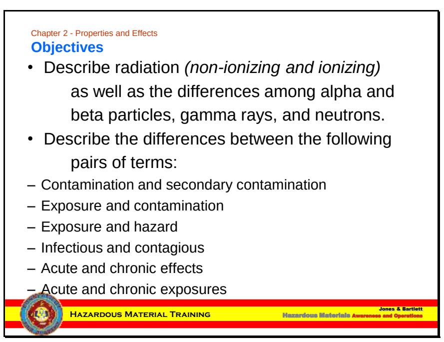

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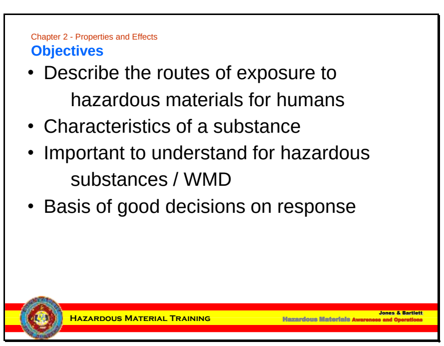

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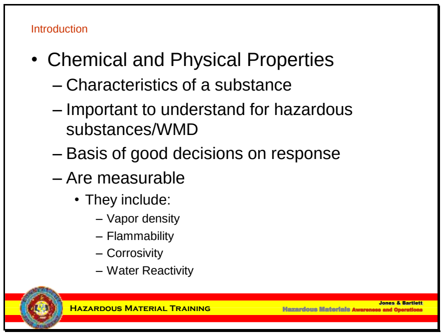

Physical and Chemical Properties
Physical properties are those that can be observed without changing the identity of the substance.
The general properties of matter such as color, density, hardness, are examples of physical properties.
Properties that describe how a substance changes into a completely different substance are called chemical properties.
Flammability and corrosion/oxidation resistance are examples of chemical properties.

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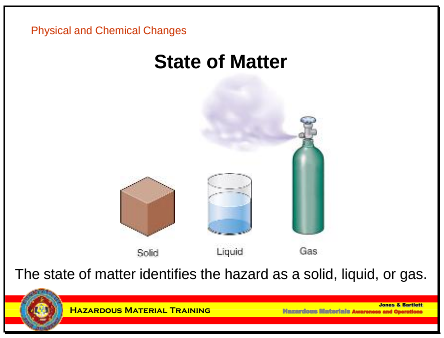

Phases of Matter Each phase of matter has its own chemical and physical properties. The phases of matter you need to know are:
Solid - a solid has a definite shape and volume
Liquid - a liquid has a definite volume, but can change shape
Gas - the shape and volume of a gas can change

Phase Changes
These phases of matter can change from one to another.
Remember the definitions of the following phase changes:
Melting - melting occurs when a substance changes from a solid to a liquid
Boiling - boiling is when a substance changes from a liquid to a gas
Condensing - condensation is when a gas changes to a liquid
Freezing - freezing is when a liquid changes to a solid

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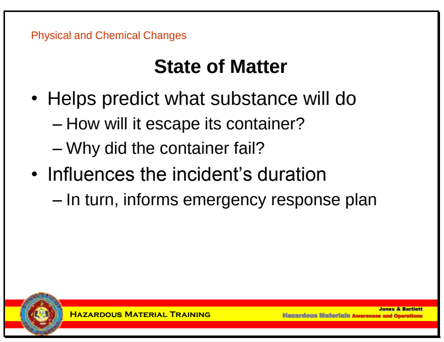

It is not necessary to be a chemist to respond safely to hazardous materials incidents.
In most cases, you can be guided by
Careful observation
Referring to your emergency response plan and/or standard operating procedure
Correctly interpreting visual clues presented

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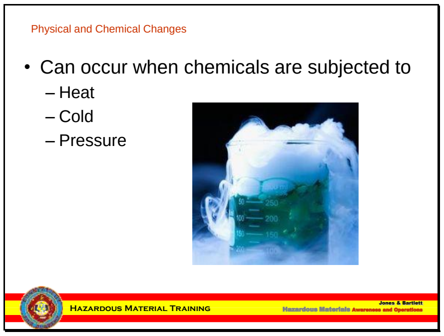

The difference between a physical and chemical property is straightforward until the phase of the material is considered.

When a material changes from a solid to a liquid to a vapor it seems like them become a difference substance. However, when a material melts, solidifies, vaporizes, condenses or sublimes, only the state of the substance changes. Consider ice, liquid water, and water vapor, they are all simply H2O.

Phase Changes
These phases of matter can change from one to another. Remember the definitions of the following phase changes:
Melting - melting occurs when a substance changes from a solid to a liquid
Boiling - boiling is when a substance changes from a liquid to a gas
Condensing - condensation is when a gas changes to a liquid
Freezing - freezing is when a liquid changes to a solid

Physical Changes
Physical changes are concerned with energy and states of matter. A physical change does not produce a new substance. Changes in state or phase (melting, freezing, vaporization, condensation, sublimation) are physical changes. Examples of physical changes include crushing a can, melting an ice cube, and breaking a bottle.

Chemical Changes
Chemical changes take place on the molecular level. A chemical change produces a new substance. Examples of chemical changes include combustion (burning), cooking an egg, rusting of an iron pan, and mixing hydrochloric acid and sodium hydroxide to make salt and water.

How to Tell Chemical & Physical Changes Apart
A chemical change makes a substance that wasn't there before. There may be clues that a chemical reaction took place, such as light, heat, color change, gas production, odor, or sound. The starting and ending materials of a physical change are the same, even though they may look different.

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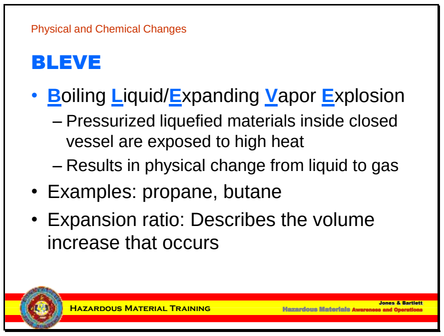

BLEVE (Boiling Liquid/Expanding Vapor Explosion)
Caused by pressurized liquefied materials inside a closed vessel exposed to high heat
This causes the substance to change from liquid to gas.
Propane and butane are examples.

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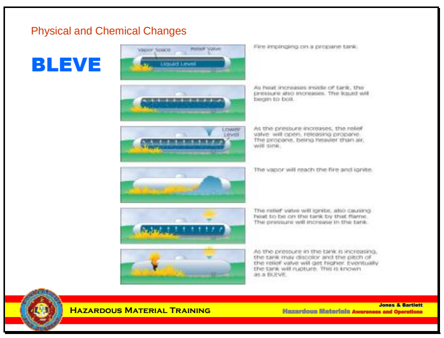

Expansion ratio is a description of the volume increase that occurs when a liquid changes to a gas.
Propane has an expansion ratio of 270 to 1.
For every 1 volume of liquid propane, 270 times that amount of propane exists as vapor.

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BLEVE (pronounced BLEV-ee), (Boiling Liquid/Expanding Vapor Explosion) occurs when a vessel containing a pressurized liquid above its boiling point ruptures.
If a vessel partly filled with liquid with vapor above filling the remainder of the container, is ruptured—for example, due to corrosion, or failure under pressure—the vapor portion may rapidly leak, lowering the pressure inside the container. This sudden drop in pressure inside the container causes violent boiling of the liquid, which rapidly liberates large amounts of vapor. The pressure of this vapor can be extremely high, causing a significant wave of overpressure (an explosion) which may completely destroy the storage vessel and project fragments over the surrounding area.

Propane and butane are examples

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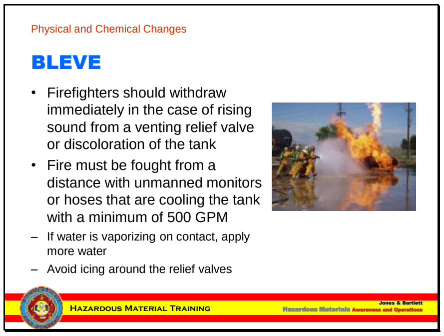

Fires: BLEVEs can be caused by an external fire near the storage vessel causing heating of the contents and pressure build-up. While tanks are often designed to withstand great pressure, constant heating can cause the metal to weaken and eventually fail. If the tank is being heated in an area where there is no liquid, it may rupture faster without the liquid to absorb the heat. Gas containers are usually equipped with relief valves that vent off excess pressure, but the tank can still fail if the pressure is not released quickly enough.
If the substance involved is flammable, it is likely that the resulting cloud of the substance will ignite after the BLEVE has occurred, forming a fireball and possibly a fuel-air explosion, also termed a vapor cloud explosion (VCE). If the materials are toxic, a large area will be contaminated.

Incidents: In August 1959 the Kansas City Fire Department was hit with their largest loss of life in the line of duty deaths to date, when a 25,000 gallon gas tank exploded during a fire on Southwest Boulevard killing five firefighters. This was the first time BLEVE was used to describe a burning fuel tank. Significant industrial BLEVEs include accidents at Sunray, Texas in 1956, Glasgow, Scotland in 1960, Feyzin, France in 1966; Crescent City, Illinois in 1970; Kingman, Arizona in 1973; Texas City, Texas in 1978; Murdock, Illinois in 1983; and San Juan Ixhuatepec, Mexico City in 1984. In 1978, a BLEVE occurred after a traffic collision involving a LPG truck in the Los Alfaques disaster in Spain.

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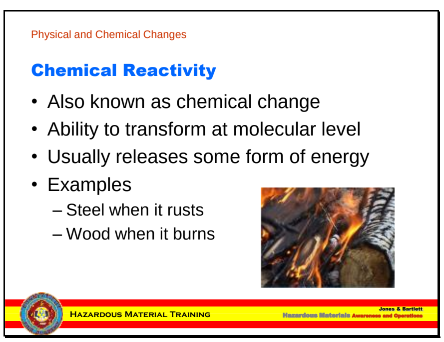

Chemical reactivity (also known as chemical change) describes the ability of a substance to undergo a transformation at the molecular level.
- Usually with a release of some form of energy
- Physical change is essentially a change in state. By contrast, a chemical change results in an alteration of the chemical nature of the material.
- Examples are steel when it rusts and wood when it burns.

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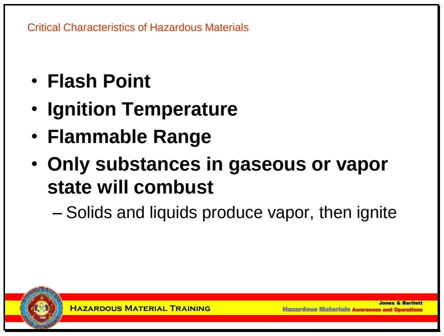

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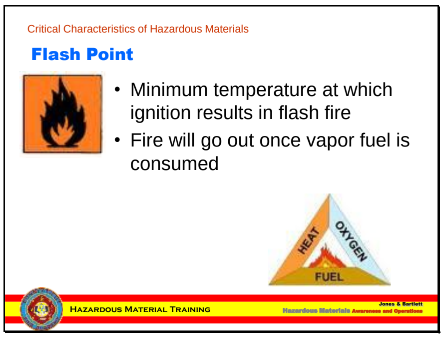

Flash point
The flash point of a volatile liquid is the lowest temperature at which it can vaporize to form an ignitable mixture in air. Measuring a liquid's flash point requires an ignition source. At the flash point, the vapor may cease to burn when the source of ignition is removed.
The flash point is not to be confused with the autoignition temperature, which does not require an ignition source.
Ignition source examples:
Flame
Electrical equipment
Lightning
Static electricity
Common substances with low flash points, resulting in higher ignition temperatures and vapor pressures:
Gasoline
Ethyl alcohol
Acetone
#2 grade diesel fuel has a high flash point, resulting in lower ignition temperature and lower vapor pressure.

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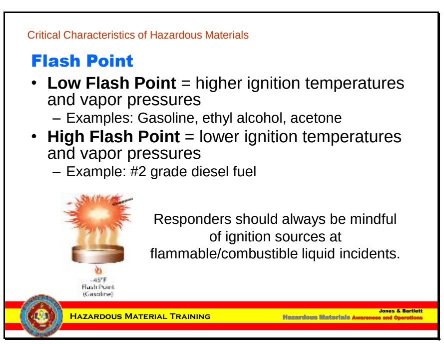

The flash point is often used as a descriptive characteristic of liquid fuel, and it is also used to help characterize the fire hazards of liquids. “Flash point” refers to both flammable liquids and combustible liquids. There are various standards for defining each term. Liquids with a flash point less than 141°F or 100°F — depending upon the standard being applied — are considered flammable, while liquids with a flash point above those temperatures are considered combustible.
Common substances with low flash points, resulting in higher ignition temperatures and vapor pressures:
Gasoline
Ethyl alcohol
Acetone
#2 grade diesel fuel has a high flash point, resulting in lower ignition temperature and lower vapor pressure.

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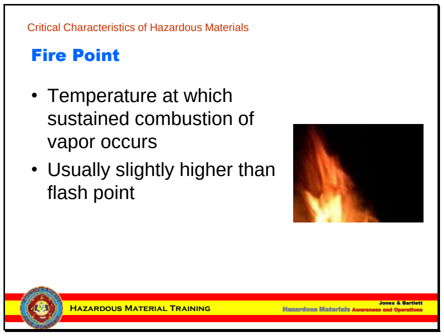

The fire point of a fuel is the temperature at which it will continue to burn for at least 5 seconds after ignition by an open flame. At the flash point, a lower temperature, a substance will ignite briefly, but vapor might not be produced at a rate to sustain the fire.
Most tables of material properties will only list material flash points, but in general the fire points can be assumed to be about 10ºC higher than the flash points.

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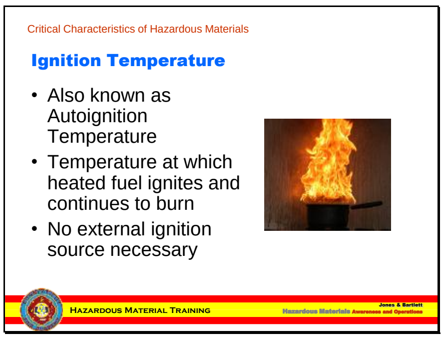

Ignition temperature
- Also referred to as Autoignition temperature
- The minimum temperature at which a fuel, when heated, will ignite in air and continue to burn
- No external ignition source is necessary.
- Example is a pan full of cooking oil on the stove, left unattended on a burner set on high
  - Once the oil is heated past 300°F (148°C)—its ignition temperature—it will ignite.
  - In fact, this is a common cause of stove fires.

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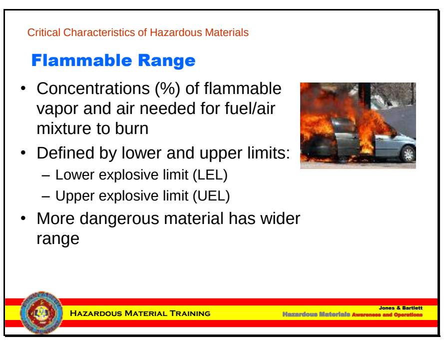

Flammable range
- Expression of fuel/air mixture, defined by upper and lower limits, that reflects an amount of flammable vapor mixed with a given volume of air
- Boundaries necessary to burn

Lower explosive limit (LEL)
Upper explosive limit (UEL)
- For gasoline, the LEL is 1.4 percent and the UEL is 7.6 percent.

Generally, the wider the flammable range, the more dangerous the material

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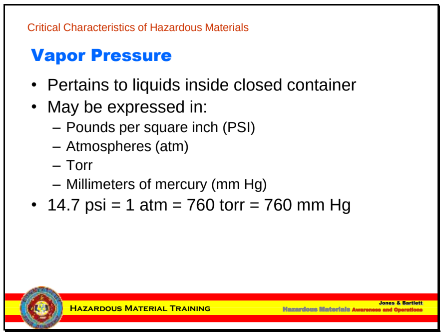

Vapor pressure
Applies to liquids held inside any type of closed container
All liquids, including water, develop a certain amount of pressure in the airspace between the top of the liquid and the container.
The vapors released from the surface of any liquid must be contained if they are to exert pressure.
Expressed in
- Pounds per square inch (psi)
- Atmospheres (atm)
- Torr
- Millimeters of mercury (mm Hg)

14.7 psi = 1 atm = 760 torr = 760 mm Hg
Vapor pressure increases as ambient temperature increases.
Liquids with higher vapor pressures evaporate more quickly than those with lower vapor pressures.

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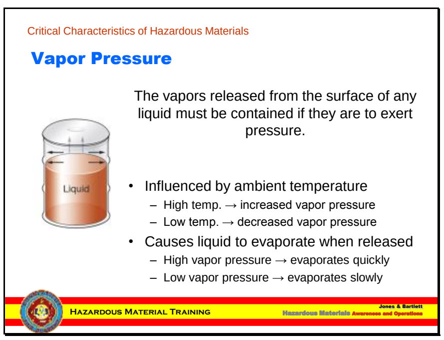

As a general trend, vapor pressures of liquids at ambient temperatures increase with decreasing boiling points.
For example, at any given temperature, propane has a high vapor pressure. It also has the low boiling point (−42.1 °C) at 1 one atmosphere (atm).

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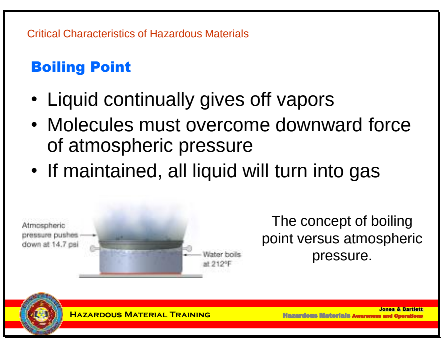

Boiling point
- Temperature at which a liquid will continually give off vapors in sustained amounts
- Open liquids must overcome the downward force of atmospheric pressure.
- If held at that temperature long enough, will turn completely into a gas
- Flammable liquids with low boiling points are dangerous because they have the potential to produce large volumes of flammable vapor at relatively low temperatures.
- Liquids at their boiling point in closed containers are a hazard—vapor pressure will build up, eventually causing a container to fail.

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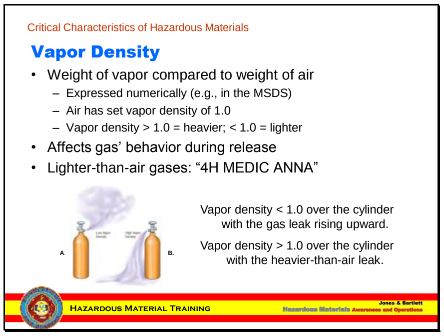

Vapor density
Weight of an airborne concentration of a vapor or gas, compared to the weight of air
- Expressed numerically (e.g., vapor density is given in the MSDS)
- Air has a set vapor density of 1.0.
- Gases with vapor density > 1.0 are heavier than air; gases with vapor density < 1.0 are lighter than air.

Affects where the gas goes when released.
In the field, in the absence of reliable reference sources, use this mnemonic to remember lighter-than-air gases: 4H MEDIC ANNA.
- H: Hydrogen
- H: Helium
- H: Hydrogen cyanide
- H: Hydrogen fluoride
- M: Methane
- E: Ethylene
- D: Diborane
- I: Illuminating gas (methane/ethane mixture)
- C: Carbon monoxide
- A: Ammonia
- N: Neon
- N: Nitrogen
- A: Acetylene

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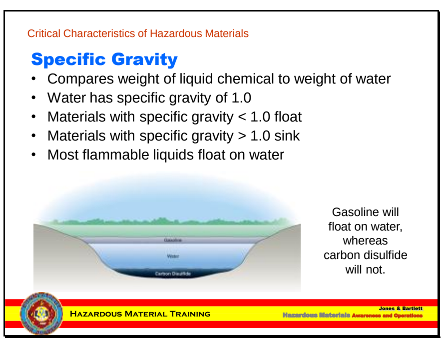

Specific gravity
- Compares weight of liquid chemical to weight of water
- Is to liquids what vapor pressure is to gases and vapors
- Water has a specific gravity of 1.0.
- Materials with a specific gravity less than 1.0 float.
- Materials with a specific gravity greater than 1.0 sink.
- Most flammable liquids float.

Examples are gasoline, diesel fuel, motor oil, and benzene.

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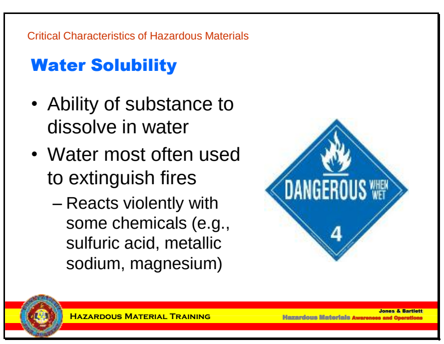

Water solubility
- The ability of a substance to dissolve in water
- Water is the predominant agent used to extinguish fire.
  - But when dealing with chemical emergencies, it may not always be the best and safest choice.
  - Can react violently with certain chemicals, such as concentrated sulfuric acid, metallic sodium, and magnesium

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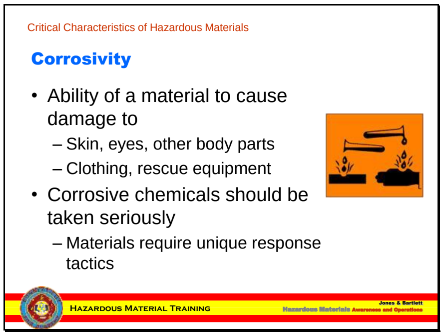

Corrosivity

The ability of a material to cause damage (on contact) to skin, eyes, and other parts of the body.

Also often damaging to clothing, rescue equipment, and other physical objects in the environment.

Corrosives are a complex group of chemicals that should not be taken lightly.

Tens of thousands of corrosive chemicals are used in general industry, semiconductor manufacturing, and biotechnology.

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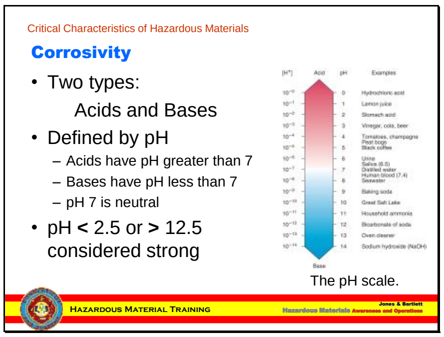

Two classes of corrosive chemicals: Acids and bases

Measured by pH

Acids have pH greater than 7

Bases have pH less than 7

pH 7 is neutral

pH values of 2.5 or less and of 12.5 or more are considered strong.

Strong corrosives—acids or bases—will react more aggressively with metals, skin, other chemicals, and water.

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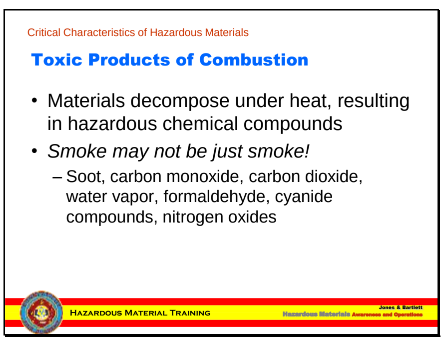

Toxic products of combustion

Hazardous chemical compounds released when a material decomposes under heat

Combustion is a chemical reaction, and like other reactions generates byproducts.

Smoke produced by a structure fire is familiar.

But what is in the smoke?

Toxic gases may be liberated during a residential structure fire.

Most fire smoke includes soot, carbon monoxide, carbon dioxide, water vapor, formaldehyde, cyanide compounds, and many oxides of nitrogen.

Most of these are toxic even in small doses.

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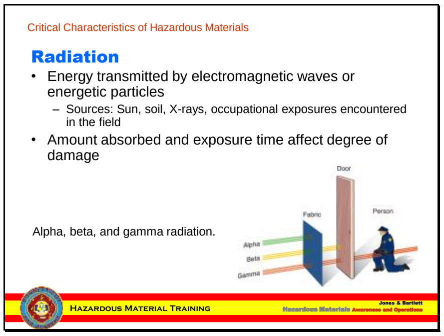

Radiation
Energy transmitted through space in the form of electromagnetic waves or energetic particles
Radiation comes from many sources.
- Sun
- Soil
- X-rays
- Occupational exposures encountered in the field

Health hazards posed determined by
- Amount of radiation absorbed by your body
- Exposure time to the radiation

Radioactivity is the process by which unstable atoms (isotopes) of an element decay to a different state and emit or radiate excess energy.
Typically, you will encounter a combination of alpha, beta, and gamma radiation.

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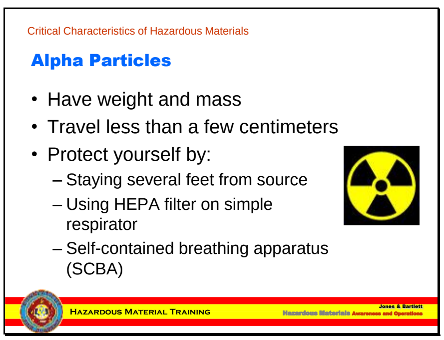

Alpha particles
- Have weight and mass
- As a consequence, cannot travel far—less than a few centimeters
- You can protect yourself by staying several feet from the source and wearing a HEPA filter on a simple respirator or a self-contained breathing apparatus (SCBA).

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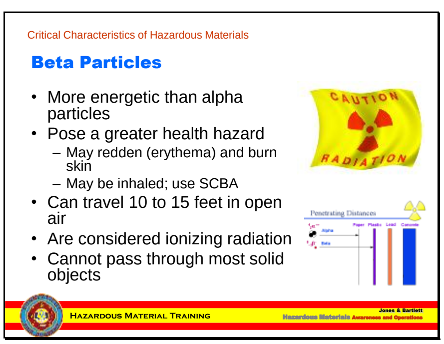

Beta particles
- Beta particles are high-energy, high-speed electrons or positrons emitted by certain types of radioactive nuclei such as potassium-40. The beta particles emitted are a form of ionizing radiation also known as beta rays.
- More energetic than alpha particles
- Therefore pose a greater health hazard
  - May redden (erythema) and burn skin
  - May cause damage to tissue when inhaled
- Can travel 10 to 15 feet in open air
- Are considered ionizing radiation
- Solid objects provide protection, and wearing an SCBA should provide respiratory protection.

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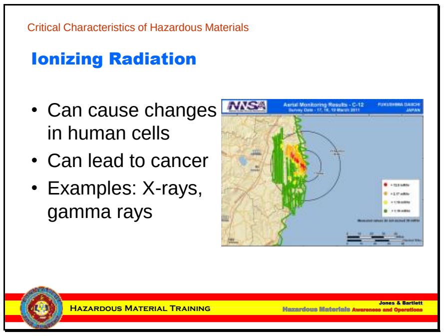

Non-ionizing radiation is thought to be essentially harmless below the levels that cause heating. Ionizing radiation is dangerous in direct exposure,

Ionizing radiation

Can cause changes in human cells

Lower doses may cause cancer or other long-term problems

Examples include X-rays and gamma rays.

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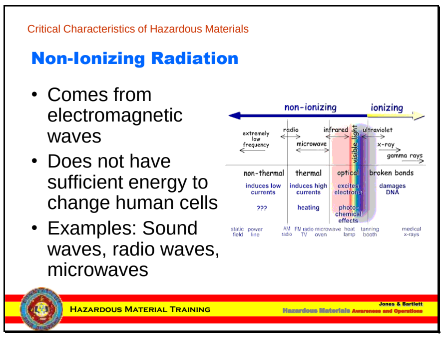

Non-ionizing radiation

Non-ionizing radiation refers to any type of electromagnetic radiation that does not carry enough energy to ionize atoms or molecules—that is, to completely remove an electron from an atom or molecule.

Comes from electromagnetic waves

Non-ionizing radiation can produce non-mutagenic effects such as inciting thermal energy in biological tissue that can lead to burns.

Does not have sufficient energy to change human cells

Examples include: Near ultraviolet, visible light, infrared, microwave, radio waves, and low-frequency RF (long wave) are all examples of non-ionizing radiation.

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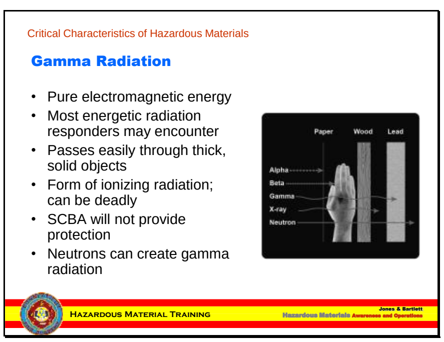

Gamma radiation

Gamma radiation, also known as gamma-rays (especially in astronomy), is electromagnetic radiation of high frequency (very short wavelength). Gamma rays are produced by decay of high energy states in atomic nuclei (gamma decay) and also high energy sub-atomic particle interactions in natural processes and man-made mechanisms.

Pure electromagnetic energy

The most energetic radiation that responders may encounter

Has no mass, no electrical charge, and travels at the speed of light

Shielding from gamma rays requires large amounts of mass

Passes easily through thick solid objects

All ionizing radiation causes similar damage at a cellular level, but because rays of alpha particles and beta particles are relatively non-penetrating, external exposure to them causes only localized damage, e.g. radiation burns to the skin. Gamma rays and neutrons are more penetrating, causing diffuse damage throughout the body (e.g. radiation sickness), increasing incidence of cancer rather than burns.

SCBA will not provide protection.

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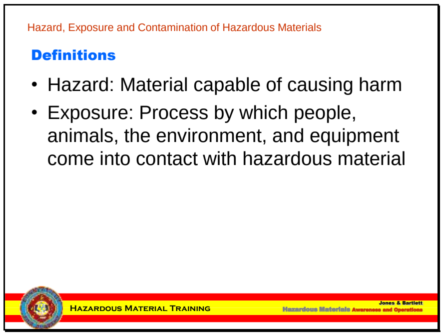

A hazard is a material capable of posing an unreasonable risk to health, safety, or the environment—that is, capable of causing harm.
Exposure is the process by which people, animals, the environment, and equipment are subjected to or come into contact with a hazardous material.

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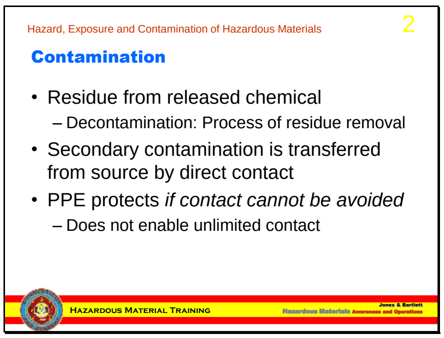

Contamination is the residue of a released chemical.
Decontamination is the process of removing the residue resulting from a chemical release.
Secondary contamination
Also known as cross-contamination
Occurs when a person or object transfers the contamination, or the source of contamination, to another person or object by direct contact
Responders often have the misperception that PPE is worn to enable them to contact the product at will.
In fact, PPE is worn to protect you in the event that you cannot avoid product contact.

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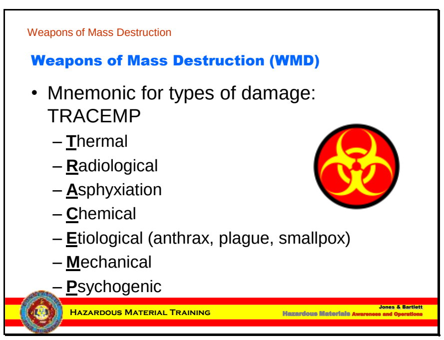

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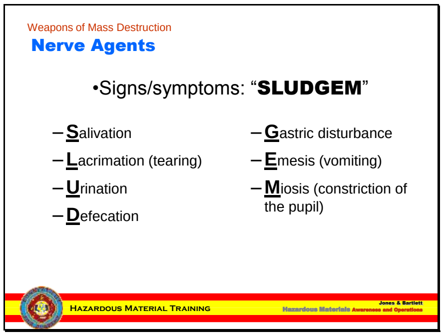

SLUDGEM syndrome is a mnemonic of a syndrome (often a toxidrome) of pathological effects indicative of massive discharge of the parasympathetic nervous system. Unlikely to occur naturally, SLUDGEM is usually encountered only in cases of drug overdose, ingestion of certain poisonous mushrooms (particularly the muscarine-containing members of the genera *Inocybe* and *Clitocybe*), or exposure to nerve gases. Nerve gases irreversibly inhibit the enzyme acetylcholinesterase; this results in a chronically high level of acetylcholine at cholinergic synapses throughout the body, thus chronically stimulating acetylcholine receptors throughout the body. The symptoms of "SLUDGE" are due to chronic stimulation of muscarinic acetylcholine receptors, in organs and muscles innervated by the parasympathetic nervous system. It is useful to remember some of the symptoms of increased cholinergic stimulation through the mnemonic

SLUDGEM:
•Salivation: stimulation of the salivary glands
•Lacrimation: stimulation of the lacrimal glands
•Urination: relaxation of the internal sphincter muscle of urethra, and contraction of the detrusor muscles
•Defecation: relaxation of the internal anal sphincter
•Gastrointestinal upset: Smooth muscle tone changes causing gastrointestinal problems, including diarrhea
•Emesis: Vomiting
•Miosis: stimulation of the pupillary constrictor muscles or Muscle spasm: stimulation of skeletal muscle

•Nerve Gas or Sarin

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Blister agents
Also known as vesicants
Have ability to cause blistering of the skin
Interact in harmful ways with the human body
Examples include sulfur mustard and Lewisite.

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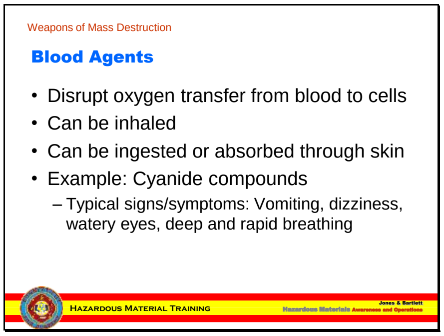

Blood agents

Chemicals that, when absorbed the body, interfere with transfer of oxygen from the blood to the cells

Can be inhaled or ingested or absorbed through the skin

Cyanide compounds are examples.

Typical signs/symptoms of exposure to cyanide compounds: Vomiting, dizziness, watery eyes, as well as deep and rapid breathing

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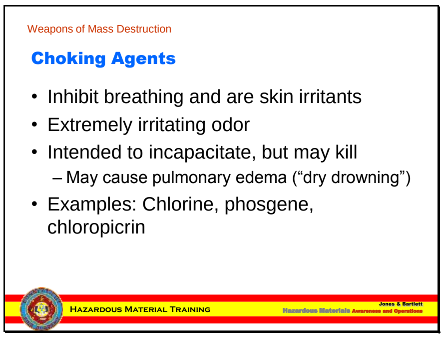

Choking agents

Inhibit breathing

Have an extremely irritating odor

Are intended to incapacitate, but may in fact kill or cause serious injuries (e.g., pulmonary edema or "dry drowning")

Examples include chlorine, phosgene, and chloropicrin.

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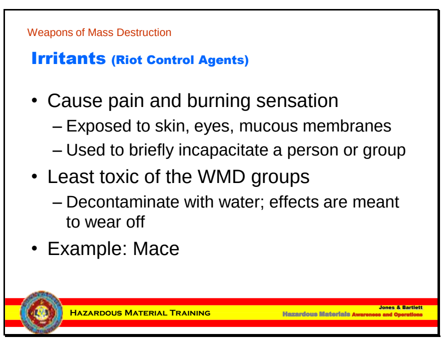

Irritants (riot control agents)

Cause pain and a burning sensation when exposed to skin, eyes, and mucous membranes

Used to temporarily incapacitate a person or a group of people

From a terrorism perspective, may be employed to incapacitate rescuers or to drive a group of people into another area where a more dangerous substance can be released

Least toxic of the WMD groups

Decontamination can be performed with clean water.

Effects are meant to wear off

An example is mace.

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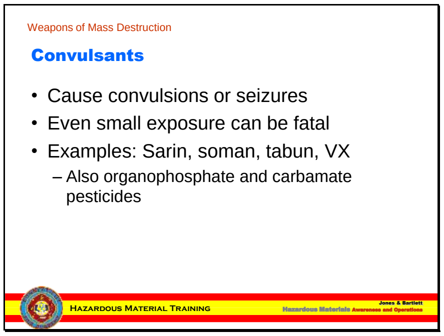

Convulsants
Cause convulsions or seizures when absorbed by the body
Can be fatal even in small doses
Examples include sarin, soman, tabun, VX, as well as organophosphate and carbamate pesticides.

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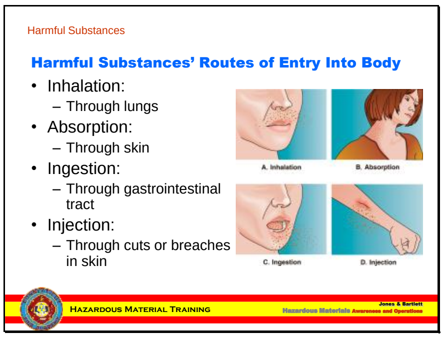

Routes of entry are inhalation, absorption, ingestion, and injection.

- Inhalation: Through the lungs
- Absorption: By permeating the skin
- Ingestion: Via the gastrointestinal tract
- Injection: Through cuts or other breaches in the skin

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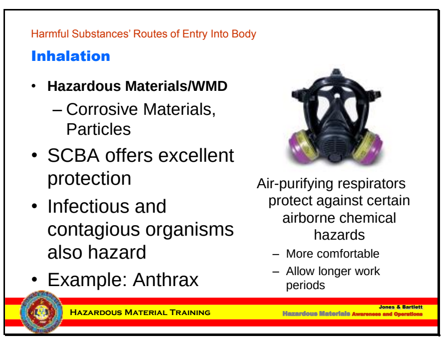

Inhalation
Exposures occur when harmful substances are brought into the body through the respiratory system.
Hazardous Materials / WMD

- Corrosive materials, such as chlorine and ammonia
- Solvent vapors, such as gasoline and acetone
- Superheated air
- Small particles of dust and smoke
- Infectious and contagious organisms, such as anthrax

SCBA offers excellent protection.

- Full-face and half-face air purifying respirators (APRs) can offer protection, depending on the hazard.
- More comfortable
- Allow for longer work periods, because they do not rely on a limited supply of air

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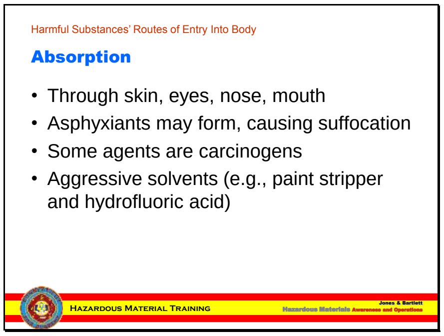

Absorption

Process by which substances travel through body tissues until they reach the bloodstream

Occurs through skin, eyes, nose, mouth, and, to a certain extent, through the intestinal tract

The body, in attempting to metabolize the substance after it is absorbed, may produce an asphyxiant as a byproduct.

Asphyxiants prevent the body (at the cellular level) from using oxygen, thereby causing suffocation.

Some agents are carcinogens.

Aggressive solvents, such as paint stripper and hydrofluoric acid, are readily absorbed.

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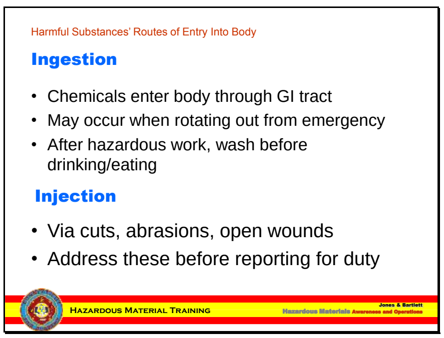

Ingestion

Chemicals are brought into the body through the gastrointestinal tract.

May inadvertently occur when rotating out from an emergency response for rest and refreshment, when not taking the time to wash up prior to eating or drinking

Injection

Chemicals enter the body through open cuts and abrasions.

Address any cuts or open wounds before reporting for duty.

If significant, you may be excluded from operating in contaminated environments.

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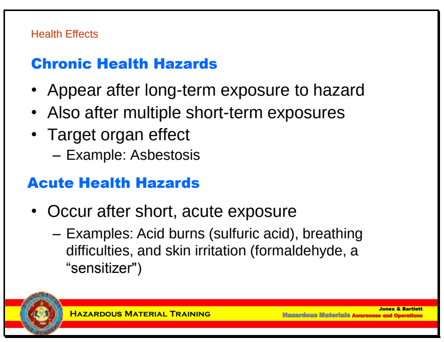

Chronic health hazards

Appear after long-term, or chronic, exposure to a hazardous substance

Also appear after multiple short-term exposures

Have a target organ effect

Chronic asbestosis exposures target the lungs.

Acute health effects

Occur after relatively short-term, or acute, exposure

Acid burns from sulfuric acid, as well as breathing difficulties and skin irritation resulting from exposure to formaldehyde (a "sensitizer") are two examples.

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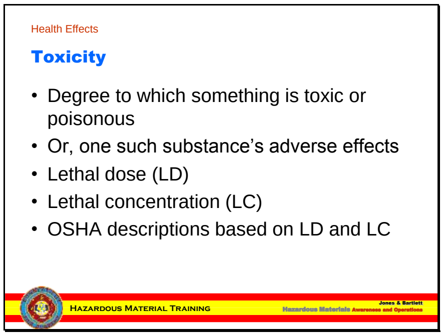

Toxicology is the study of adverse effects of chemical or physical agents on living organisms.

Toxicity

A measure of the degree that something is toxic or poisonous
Also describes one such substance's adverse effects
Lethal dose (LD) is a single dose that causes death by any route other than inhalation.
Lethal concentration (LC) is the concentration in air that causes death.
OSHA descriptions are based on the LD and LC.

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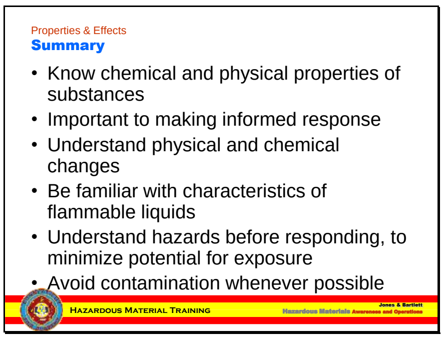

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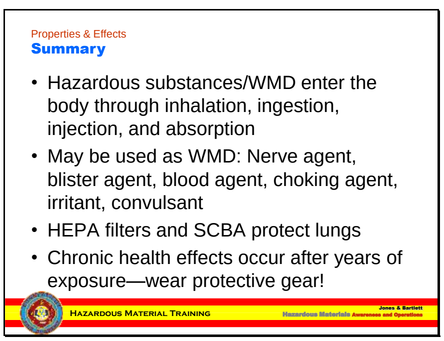

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