National Emergency Training Center
16825 S. Seton Avenue
Emmitsburg, MD 21727-8998

U.S. DEPARTMENT OF HOMELAND SECURITY
FEMA

R233

Dear National Fire Academy Student:

Congratulations on being selected to attend the United States Fire Administration's National Fire Academy's course, *Chemistry for Emergency Response*.

This course is designed for emergency services personnel and inspection personnel who have an interest in understanding how and why materials act in relation to the application of science to a hazardous materials/ CBRNE incident. It seeks to convey to responders or inspectors a sound understanding of the basic chemistry of hazardous materials in order to permit them to correctly assess a potential threat and make "risk-based" decisions.

There are **no** prerequisites for the course. The focus of the course is on response chemistry, using a building-block approach for each chemical family, beginning with basics and adding and applying skills as the course progresses.

This course combines lecture, discussion, group and individual activities with problem solving sessions and proficiency-based assignments. A two-hour evening practice session is expected every day. There are quizzes every morning on material covered the previous day. Students are expected to participate and actively engage in the interactive course methodology throughout the two weeks, complete nightly homework assignments, and study for quizzes and exams. **Students should bring a calculator to class.**

To alleviate some of the time necessary to learn the material, it is advised that you memorize the following chemical symbols.

Hydrogen	H	Mercury	Hg
Sodium	Na	Tin	Sn
Lithium	Li	Copper	Cu
Potassium	K	Chromium	Cr
Magnesium	Mg	Carbon	C
Calcium	Ca	Nitrogen	N
Barium	Ba	Phosphorus	P
Boron	B	Oxygen	O
Aluminum	Al	Sulfur	S
Lead	Pb	Fluorine	F
Cobalt	Co	Chlorine	Cl
Iron	Fe	Bromine	Br
Iodine	I		

End-of-class graduation ceremonies are an important part of the course and you are expected to attend. Please do not make any travel arrangements to leave campus until after you and your classmates graduate.

Increasing numbers of students and instructors are bringing laptop computers to campus. You alone are responsible for the security and maintenance of your equipment. The Academy cannot provide you with computer software, hardware, or technical support to include disks, printers, scanners, etc. There is a limited number of 120 Volt AC outlets in the classrooms. A Student Computer Lab is located in Building D and is available for all students to use. It is open daily with technical support provided in the evenings. This lab uses Windows XP and Office 2003 as the software standard.

Should you need additional information related to the course, please contact Mr. Wayne Yoder, Hazardous Materials Curriculum Training Specialist, at (301) 447-1090 or email at Wayne.Yoder@dhs.gov

Sincerely,

Dr. Denis Onieal, Superintendent
National Fire Academy
U.S. Fire Administration

CHEMISTRY OF HAZARDOUS MATERIALS PRECOURSE READING

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CHEMISTRY OF HAZARDOUS MATERIALS

We live in a chemical world. Our society depends on science and technology. First-class medical care, sufficient and varied food supplies, comfortable housing, convenient transportation, rapid communication, and overall personal comfort are usually taken for granted. These benefits are a direct result of scientific and technological developments in the past century.

However, within the last two decades, science and technology have acquired an ambivalent reputation because some of their many contributions to our lives have had undesirable side effects. For example, even though energy is the key to our technological society, we deplore the destruction of natural beauty caused by strip mining for coal, the pollution of natural waters by oil spills, the possibility of radioactive contamination from accidents in nuclear plants, and the alarming rapid depletion of natural energy sources.

The fertilizers and insecticides that have increased food production have polluted our air and water. Automobiles and jet planes have revolutionized transportation, but they also have contaminated the air. Some medicines that have saved countless lives have created toxic side effects.

What Is Chemistry?

Welcome to the world of chemistry. The science of chemistry may be defined as the study of composition, structure, and properties of matter and of the reactions by which one form of matter may be produced from or converted into other forms. Chemical reactions may produce heat, pressure, explosions, and toxic by-products. Many chemical reactions are exothermic (heat-releasing).

Hazardous Materials Chemistry--Rules to Live By

How many times have you thought about choosing hazardous materials as a specialty, but the thought of chemistry has made you resist the notion? Or perhaps you are an experienced emergency responder or inspector, and you need to brush up on the basics of chemical hazard prediction.

This manual will serve as a chemical hazard estimation guide. Although the information that follows will help you understand your chemistry reference books, this manual is not a substitute for a chemistry course from a qualified instructor. Nor is this information a substitute for field references such as the *DOT Emergency Response Guidebook*, material safety data sheets (MSDSs), or the *NIOSH Pocket Guide to Chemical Hazards*.

THE ATOMS

There are approximately 116 types of atoms that make up the elements. These 116 types of atoms can react (combine with one another) to form an infinite number of new compounds. Some of these new compounds are flammable, some are oxidizing, some are radioactive, and all are toxic to some degree. Is there any way to predict these hazards? Yes. We can start with the periodic table.

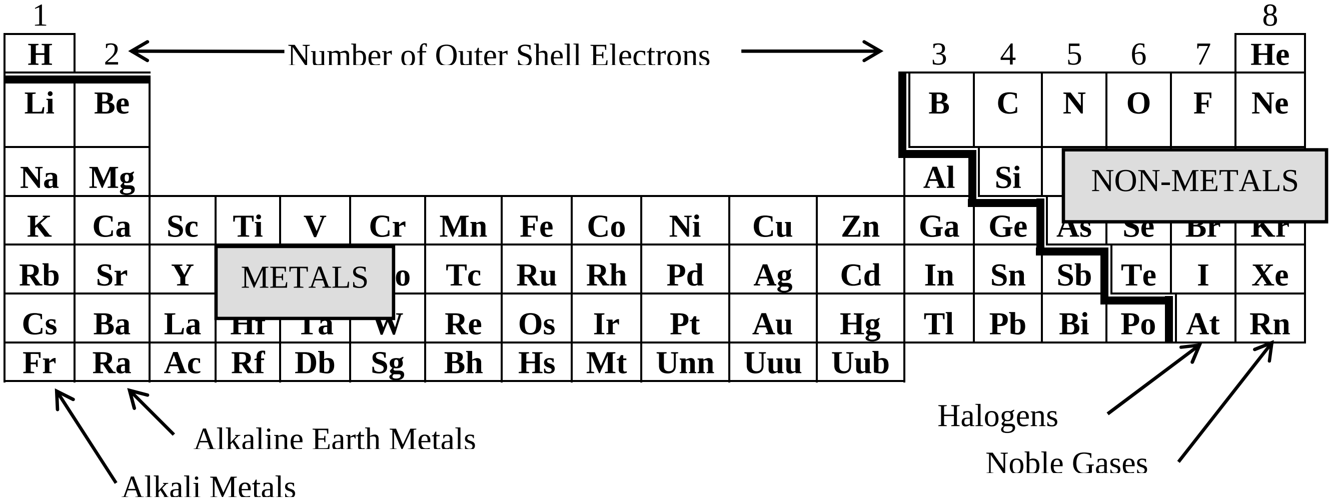


Figure 2.1: The Periodic Table

Metal Elements and Nonmetal Elements

Cutting through the right third of the periodic table is a dark stair step line. All atoms to the left of the dark stair step are considered **metals**. The remaining atoms (to the right of the dark stair step line) are considered **nonmetals**. For example, Na (sodium), Mg (magnesium), and Fe (iron - also known as ferrous or ferrum [Latin]) are **metals**. Conversely, O (oxygen), Cl (chlorine), and He (helium) are **nonmetals**. Hydrogen (H) resides at the extreme upper left of the periodic table even though it is a nonmetal. The periodic table at the end of this packet uses different colors to indicate the physical states of the atoms at normal temperatures and pressures. Solid elements are generally indicated in black, liquid elements in blue, and gaseous elements in red. For example, Hg (mercury) is a **liquid metal**.

Compounds

The 116 atoms from the periodic table may bond together in a wide array of combinations to create compounds. Two of the most fundamental types of compounds are called **salt compounds** and **nonsalt compounds**. A salt compound is made of metal (M) atoms bonded to nonmetal (NM) atoms. A nonsalt compound is usually made solely of nonmetal (NM) atoms, though there are some exceptions. Salt compounds are usually solids, while nonsalt compounds may be solids, liquids, or gases.

Table 1: Salts and Nonsalt Compounds

Examples of Salts (M + NM)			Examples of Nonsalt Compounds (NM + NM)		
NaCl	Sodium chloride	solid	HNO_3	Nitric acid	liquid
CaO	Calcium oxide	solid	CH_3Br	Methyl bromide	gas

Organic and Inorganic Compounds

Compounds are then commonly subdivided into **organic** and **inorganic** compounds. Organic compounds contain carbon atoms. Most inorganic compounds do not contain carbon atoms.

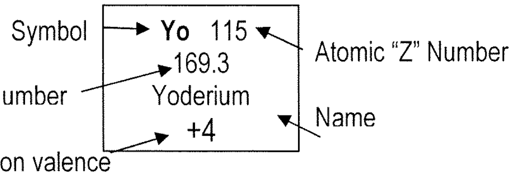
Table 2: Organic and Inorganic Compounds

Examples of Organic Compounds		Examples of Inorganic Compounds	
CH_4	Methane	H_2O	Water
C_6H_{14}	Hexane	N_2O	Nitrous oxide
C_2H_5OH	Ethanol	$HClO_4$	Perchloric acid

THE PERIODIC TABLE

On the following page, you will find a detailed periodic table. We will reference the periodic table extensively throughout the course. Try to familiarize yourself with this periodic table before the first day of class. Since we will be referencing elements by their chemical symbols extensively throughout the course (for example, we will denote carbon as 'C', and oxygen as 'O', rather than spelling out the full chemical name), the more chemical symbols you have memorized, the more easily you will be able to follow along during class.

PERIODIC TABLE OF THE ELEMENTS



Alkali Metals I	Alkali Earth Metals II	IIIB	IVB	VB	VIB	VIIB	VIII	VIII	VIII	IB	IIB	III	IV	V	VI		
H 1 1.00794 Hydrogen -1																	
Li 3 6.941 Lithium +1	Be 4 9.012182 Beryllium +2											B 5 10.811 Boron -5	C 6 12.011 Carbon -4	N 7 14.00674 Nitrogen -3	15.9 Oxy -2		
Na 11 22.98976 8 Sodium +1	Mg 12 24.3050 Magnesiu m +2				Transitional	Metals						Al 13 26.9815 Aluminu m +3	Si 14 28.0855 Silicon -4	P 15 30.973762 Phosphoru s -3	S 3 S -2,		
K 19 39.0983 Potassium +1	Ca 20 40.078 Calcium +2	Sc 21 44.95591 0 Scandium +3	Ti 22 47.88 Titanium +4	V 23 50.9415 Vanadiu m +5	Cr 24 51.9961 Chromium +3, +2	Mn 25 54.93805 Manganes e +2, +3	Fe 26 55.847 Iron +3, +2	Co 27 58.6934 Cobalt +2	Ni 28 58.6934 Nickel +2, +1	Cu 29 63.546 Copper +2	Zn 30 65.39 Zinc +2	Ga 31 69.723 Gallium +3	Ge 32 72.61 Germanium +4	As 33 74.952159 Arsenic -3	Se 7 Se -2, +		
Rb 37 85.4678 Rubidium +1	Sr 38 87.62 Strontium +2	Y 39 88.90585 Yttrium +3	Zr 40 91.224 Zirconium +4	Nb 41 92.90638 Niobium +5	Mo 42 95.94 Molybdenu m 6+	Tc 43 98.9063 Technetiu m 7+	Ru 44 101.57 Rutheniu m +3, +4	Rh 45 102.9055 Rhodium +3	Pd 46 106.42 Palladium +2	Ag 47 107.8682 Silver +1	Cd 48 112.411 Cadmium +2	In 49 114.82 Indium +3	Sn 50 118.71 Tin +4, +2	Sb 51 121.757 Antimony +3	Te 1 Tel -2, +		
Cs 55 132.9054 Cesium +1	Ba 56 137.327 Barium +2	57 – 71	Hf 72 178.49 Hafnium +4	Ta 73 180.9479 Tantalum +5	W 74 183.85 Tungsten 6+	Re 75 186.207 Rhenium 7+	Os 76 190.2 Osmium +4	Ir 77 192.22 Iridium +4	Pt 78 195.08 Platinum +4	Au 79 196.96654 Gold +3, +1	Hg 80 200.59 Mercury +2, +1	Tl 81 204.3833 Thallium +1	Pb 82 207.2 Lead +2, +4	Bi 83 208.98037 Bismuth +3	Po 20 Pol +2		
Fr 87 223.0197 Francium +1	Ra 88 226.0254 Radium +2	89 - 103	Rf 104 261.11 Rutherfordiu m	Db 105 262.11 Dubnium	Sg 106 263.12 Seaborgium	Bh 107 262.12 Bohrium	Hs 108 264 Hassium	Mt 109 266.1378 Meitneriu m	Uun 110 269 Ununniliu m	Uuu 111 272 Unununiu m	Uu 112 277 Ununbiu m		Uuq 114 289 Ununquadiu m		Uuh Unu m		

La 57 138.9855 Lanthanum +3	Ce 58 140.115 Cerium +3	Pr 59 140.90765 Praseodymium +3	Nd 60 144.24 Neodymium +3	Pm 61 144.9127 Promethium +3	Sm 62 150.36 Samarium +3	Eu 63 151.965 Gadolinium +3	Gd 64 157.25 Gadolinium +3	Tb 65 158.92534 Terbium +3	Dy 66 162.50 Dysprosium +3	Ho 67 164.93032 Holmium +3	Er 68 167.26 Erbium +3	Tm 69 168.93421 Thulium +3		
Ac 89 227.0278 Actinium +3	Th 90 232.0381 Thorium +4	Pa 91 231.03588 Protactinium +5	U 92 238.0289 Uranium +6	Np 93 237.082 Neptunium +5	Pu 94 244.0642 Plutonium +4	Am 95 243.0614 Americium +3	Cm 96 247 Curium +3	Bk 97 247.0703 Berkelium +3	Cf 98 251.0796 Californium +3	Es 99 252.03 Einsteinium	Fm 100 257.0951 Fermium	Md 101 258.01 Mendelevium		

CHEMICAL HAZARDS AND THE PERIODIC TABLE

Gas Hazards

Gases are generally shipped and stored in a compressed, liquefied, or cryogenic (liquid) state. An escaping gas may be flammable, toxic, corrosive, oxidizing, or asphyxiating.

Table 3: Examples of Gases

Formula		
HCl	Hydrogen chloride	One hydrogen (gas) atom bonded to one chlorine (gas) atom
NO	Nitric oxide	One nitrogen (gas) atom bonded to one oxygen (gas) atom
CO_2	Carbon dioxide	One carbon (solid) atom bonded to two oxygen (gas) atoms

Flammability Hazards

All elements in the extreme left vertical columns of the periodic table are flammable or combustible. These flammable elements include hydrogen (H), sodium metal (Na), and magnesium metal (Mg). In addition, several nonmetals, including sulfur (S), phosphorus (P), and carbon (C), are flammable. You should suspect a **flammability hazard** whenever you encounter a compound that contains these flammable atoms within its formula.

Table 4: Examples of Flammables

Inorganic Flammables		**Organic Flammables**	
H_2	Hydrogen gas	CH_4	Methane
Na	Sodium	C_2H_4	Ethene
P	Phosphorus	CH_3OH	Methanol
CS_2	Carbon disulfide	CH_3COOH	Acetic acid
CO	Carbon monoxide	$C_2H_5OC_2H_5$	Diethyl ether
$COCN_2$	Carbonyl cyanide	$CH_3COC_2H_5$	Methyl ethyl ketone

NAMING ORGANIC COMPOUNDS

As you can see from the two right-hand columns in Table 4: Example of Flammables, many flammable materials contain carbon and are carbon-based (organic). However, carbon can also be part of an inorganic flammable compound. The shaded compounds in Table 4 are inorganic.

Hydrogen atoms are commonly bonded to carbon atoms to create **hydrocarbon compounds**. Hydrocarbon compounds are named with a prefix according to the **number of carbon atoms** in the molecule.

Table 5: Naming Organic Compounds

Number of Carbons	Prefix	Examples of Hydrocarbon Compounds and Derivatives			
1	Meth	CH_4	*Meth*ane	CH_3OH	*Meth*anol
2	Eth	C_2H_4	*Eth*ylene	C_2H_4O	*Eth*ylene oxide
3	Prop	C_3H_4	*Prop*yne		
4	But	C_4H_9OH	*But*yl alcohol		
5	Pent	C_5H_{12}	*Pent*ane		
6	Hex	C_6H_{14}	*Hex*ane		
7	Hept	$C_7H_{15}OH$	*Hept*anol		
8	Oct	C_8H_{18}	*Oct*ane		

Hydrocarbon suffixes may include "-ane," "-ene," "-yne," "-yl."

Application to the Real World

Using the rules on the previous pages, we can start to decipher a chemical's name and formula to estimate its potential hazard. Let's look at a simple example: methane (CH_4).

From the prefix **meth**, we know that this material has one carbon atom. From the suffix **ane** we may know that it contains simple, single bonds between the carbon atom and each of the hydrogen atoms. Materials with both carbon and hydrogen atoms are **organic**. Organic compounds burn. If we know that the hydrogen atom, of which there are four in methane, is a gas, we may be able to surmise that this small compound is also likely to be a gas. It then comes as little surprise when our references list methane as a **flammable gas**. These concepts may be confusing now, but by the end of this course, you will be able to recognize them easily.

OVERVIEW OF PHYSICAL AND CHEMICAL PROPERTIES

Chemical properties of substances describe how substances have the ability to undergo reactions and form new substances; **physical properties** are properties of form. In our discussion of these properties, we will consider the following properties and explain how they relate to one another, as well as how they relate to the underlying composition of a chemical:

- physical state and changes in that physical state or "phase changes";
- the variables that affect those phase changes (molecular weight, hydrogen bonding, and molecular shape);
- vapor pressure and equilibrium;
- volatility;
- flashpoint, flammable range, and ignition temperature;
- specific gravity and vapor density;
- solubility; and
- pH.

PHYSICAL STATE

We will consider the three basic states of matter: solids, liquids, and gases. The fourth, plasma, is not relevant to this discussion, and will not be considered here.

Solids

Solids have specific mass, occupy a specific volume, and have a specific shape. Molecules, atoms, or ions in solid states have very close packing. Solids have specific arrangements of molecules, atoms, or ions. If the molecules of a solid have ionic (and, in some cases, covalent) bonds, they will routinely form a crystalline lattice (crystalline structure). Atomic, ionic, or molecular movement primarily consists of vibration. Some solids will **pyrolyze** (chemically decompose with the application of heat alone, without oxygen or other reagents), while others will not.

Liquids

Liquids have specific mass, occupy a specific volume, but have no specific shape. In atomic and ionic liquids (solution mixtures), the distance between molecules varies, depending on molecular weight and polarity. In some instances, atomic or molecular distance may be reflected by viscosity. Pressure will increase due to decreasing in intermolecular distances. Atomic, ionic, or molecular movement is random, and occurs in all directions.

Gases

Gases have specific mass, but have no specific volume or shape. Atomic or molecular distance varies depending on its pressure. Pressure will compress all gases. Gases may simply compress, or liquefy, depending on their critical temperature and critical pressure.

Variables That Influence Physical State

Most materials can exist in more than one physical state. A common example is ordinary water. It is well known that liquid water will freeze and become a solid at 32 °F (0 °C) at normal atmospheric pressure. The temperature of 32 °F is known as the freezing point for this substance. Alternatively, this temperature can be referred to as its melting point. For water, the freezing point and melting point are exactly the same and are well-defined. This is true for most other substances, but there are exceptions to this general rule.

At 212 °F (100 °C), liquid water begins to boil at normal atmospheric pressure as it begins a transition or phase change from a liquid state to a vapor or gas. The specific temperature at which a liquid boils under a given set of environmental conditions is known as its boiling point temperature, or **boiling point**, for short. If the boiling takes place at normal atmospheric pressure, the more appropriate and accurate phrase to use is **normal boiling point**, or boiling point "at one atmosphere."

Not all substances, incidentally, can exist in all three states of matter in the natural environment. Some solids undergo a process called sublimation upon heating, whereby the solid material transforms directly to a gaseous state without first becoming a liquid. A good example is solid carbon dioxide, also known as "dry ice." Carbon dioxide can become a liquid only in confinement under special conditions of storage.

Materials also have what is called a **triple point**. The triple point is the temperature and pressure at which a material can exist in all three physical states simultaneously.

Temperature

Temperature is an indication of the amount of heat within any object or substance. The greater the amount of heat (temperature), the greater the atomic, ionic, or molecular movement. As the movement increases, so does interatomic, ionic, or molecular distance, resulting in state change. Conversely, as cooling decreases movement, it also decreases interatomic, ionic, or molecular distance, resulting in state changes.

Vibration causes a number of reactions in solids. In most natural and manmade polymeric solids, molecular vibration causes pyrolytic decomposition of molecules, as opposed to melting. In energetic and unstable solids, vibration causes chemical bond breakage, which initiates decomposition. Decomposition may range from a violent to an explosive reaction. Examples include organic peroxides and some oxidizers.

Pressure

Pressure (including ambient atmospheric) is another variable affecting physical states and state changes. In the absence of atmospheric pressure, only solids and gases (as in a vacuum or outer space) exist. Atmospheric pressure controls the boiling point of atomic, ionic, or molecular substances. As pressure decreases, the amount of vaporization increases at a given temperature. As pressure increases, the amount of vaporization decreases at a given temperature.

Molecular Weight

A third variable affecting state changes is molecular weight. Lower molecular weight hydrocarbons and derivatives tend to be gases or nonviscous liquids. Higher molecular weight hydrocarbons and derivatives tend to go from liquids to viscous liquids and, eventually, to solids.

Molecular Shape

Branched compounds generally can pack more closely due to smaller molecular size. Cyclic compounds have a middegree of closeness. Straight chain compounds are generally the least tightly packed.

Vapor pressure is the force exerted by molecules leaving the surface of a liquid and entering the atmosphere. Vapor pressure also occurs with solids that sublime. It is present, to some degree or another, in all liquids.

Polarity

Polarity is a variable affecting physical states. Intermolecular attraction caused by the polarity of atoms, molecules, or ions decrease distance. This raises the density of the substance. This phenomenon increases the viscosity of liquids.

Hydrogen bonding is the strongest form of polarity, and produces the most pronounced effect. With a molecular weight of 18, water should be a gas but is not, due to hydrogen bonding.

VAPOR PRESSURE

Mechanism

Molecular movement provides the force of vapor pressure, thus making the magnitude of vapor pressure temperature-dependant. There is a direct relationship between temperature and vapor pressure. This relationship can be stated as follows:

- The lower the temperature of the substance, the lower its vapor pressure will be.
- The greater the temperature of the substance, the greater its vapor pressure will be.

However, in a constant-condition environment, equilibrium may be reached when the number of molecules leaving a liquid equals the number being returned to the liquid by atmospheric pressure.

Variables Affecting Vapor Pressure

Molecular Weight and Polarity

More or less the same variables affecting physical states and state changes also apply to vapor pressure. Molecular weight within the hydrocarbon or derivative family plays a role. Low-molecular weight members have the highest vapor pressure. High-molecular weight members have the lowest vapor pressure.

Polarity within the hydrocarbon or derivative family also affects vapor pressure. Intermolecular attraction caused by polarity acts to reduce the degree of molecular movement and thus also reduces vapor pressure. Thus, polar substances have lower vapor pressure than nonpolar substances of the same molecular weight. Molecular weight within a given polar family is the primary predictor of relative vapor pressure within the family.

Hydrogen Bonding

Hydrogen bonding is the strongest form of intermolecular attraction. The effect of hydrogen bonding is to reduce the degree of molecular movement significantly and thus reduce the vapor pressure. For this reason, hydrogen-bonded substances have the lowest vapor pressure in comparison to nonpolar and even polar substances of the same molecular weight.

Polarity and Hydrogen Bonding

When polarity and hydrogen bonding are both present, the functional group is known as the carboxyl functional group. This functional group is found in organic acids (carboxylic) and dicarboxylic acids. Here, intermolecular attractions are at their strongest. As a result, vapor pressure is decreased significantly. Carboxyl or dicarboxylic groups also tend to produce solids at relatively low molecular weight.

Shape

Branched compounds have the highest vapor pressure because of their smaller molecular size. Cyclic compounds have a midlevel vapor pressure. Straight chain compounds have the lowest vapor pressure, especially in larger compounds, because molecules tend to intertwine.

Units of Measurement for Pressure

There are multiple options for measuring pressure in general. Standard atmospheric pressure can be measured in the following units of measurement:

- 14.75 psi;
- 760 millimeters of mercury (mm Hg);
- 29.92 inches of mercury;
- 1 bar; and
- 101.33 kiloPascals (kPa).

For an interpretation of vapor pressure (mm Hg) at 20 ^{o}C (or approximately 68 ^{o}F), here are some milestone vapor pressure comparisons:

- fuel oil #4--2 mm Hg;
- water--25 mm Hg;
- gasoline and acetone--180 mm Hg; and
- ethyl ether--430 mm Hg.

BOILING POINT

The boiling point is the temperature at which the substance's vapor pressure equals atmospheric pressure. As such, every liquid has a vapor pressure of 760 mm Hg when it is at its boiling point.

Variables Affecting Boiling Point

Molecular Weight

The same variables apply to boiling points as apply to vapor pressure. The same direct relationship with molecular weight is present. When the molecular weight is low, the boiling point is proportionally lower. Likewise, when the molecular weight is high, the boiling point is proportionally higher.

Polarity and Hydrogen Bonding

Polarity and hydrogen bonding play similar roles in affecting the boiling points of liquids and in vapor pressures and densities. Polarity increases boiling point based on molecular weight. Hydrogen bonding increases the boiling point more so than polarity.

Molecular Shape

The shape of an atom, molecule, or ion affects the boiling point. Branched compounds have the lowest boiling point. Cyclic compounds have a mid-level boiling point. Straight chain compounds have the highest boiling point.

FLASHPOINT

Flashpoint is the minimum temperature to which a substance must be heated to produce a vapor concentration that results in reaching the lower explosive limit. The flashpoint is related directly to the boiling point.

This direct relationship means that if a substance has a low boiling point, it has a correspondingly low flashpoint. Likewise a high boiling point means a high flashpoint. The flashpoint does not indicate that ignition will occur unless there is an ignition source present. When at the flashpoint, ignition may be simply a vapor flash and may not result in sustained combustion. This is based on the temperature of the liquid and not necessarily the ambient temperature. If an aerosol is produced, the flashpoint is irrelevant.

Variables Affecting Flashpoint

Molecular Weight

Molecular weight is a factor affecting flashpoint. As with boiling point, vapor pressure, and vapor density, this is a direct relationship, which can be stated as follows:

- low molecular weight, low flashpoint; and
- high molecular weight, high flashpoint.

Polarity and Hydrogen Bonding

Polarity and hydrogen bonding affect flashpoint. Polarity increases flashpoint due to its suppression of vapor production. Hydrogen bonding also increases flashpoint due to its suppression of vapor production.

Fire Point

The fire point is the minimum temperature to which a substance must be heated so it produces enough vapor to support sustained combustion. It is generally a few degrees above the flashpoint.

FLAMMABLE RANGE

Flammable range is the percentage of a vapor or gas in air necessary for combustion to occur. The Lower Explosive Limit (LEL) is the minimum percentage of vapor needed for combustion to occur. A percentage below LEL is too lean to burn (unless the substance is in an oxidizer-enriched environment).

The Upper Explosive Limit (UEL) is the maximum percentage of vapor needed for combustion to occur. A percentage above UEL is too rich to burn (unless the substance is in an oxidizer-enriched environment).

Variables That Affect Flammable Range

Molecular Weight

The first variable affecting flammable range is molecular weight. Lower molecular weight members of a family have the widest flammable range. Higher molecular weight members of a family have the narrowest flammable range.

Oxygen Content within the Molecule

The second variable is oxygen content within the molecule. Oxygen allows vapor to burn more richly. Alcohols, ethers, and aldehydes tend to have wide flammable ranges.

SPECIFIC GRAVITY AND VAPOR DENSITY

Specific Gravity

Every solid and liquid in the environment occupies a specific volume of space and has a certain weight. Thus, we may express the weight density of a substance as its weight divided by its volume. It is well known that water weighs 62.4 pounds per cubic foot (lb/ft^3) of volume, which is equal to 1.0 gram per cubic centimeter (g/cm^3). Different materials have different weights per volume.

An alternative way to express weight density of a solid or a liquid involves the use of a quantity known as the liquid or solid specific gravity. Simply put, this quantity is determined by dividing the density of a substance by the density of water. And since 62.4 (the weight of water) divided by 62.4 results in a value of 1, then water has a specific gravity of 1 and it serves as the reference point for all materials.

As an example, a typical motor has a weight density of 50 pounds per cubic foot. Fifty divided by 62.4 results in a specific gravity of 0.80. Sulfuric acid with a weight of 80 pounds per cubic foot divided by 62.4 results in a specific gravity of nearly 1.3.

Note that most reference sources will express specific gravity at a given temperature. This is because, just as with gases, density, and therefore specific gravity, vary with temperature. As temperature increases, materials will expand so density decreases. Therefore the weight by volume will decrease.

Vapor Density

Very much like specific gravities of solids and liquids, vapor specific gravity, or as we more commonly refer to it, "vapor density", is the ratio of the density of a pure gas or vapor to the density of air. This ratio is based upon the assumption that air has a value of 1.0. Thus, vapors or gases with vapor specific gravities less than 1.0 are presumably lighter than air in the natural environment, while those with values greater than 1.0 are presumably heavier.

If temperatures are not known, vapor density can be calculated using molecular weight. Dry air has a calculated density of 29 amu. If the molecular weight is less than 28, the gas or vapor is lighter than air. If the molecular weight is from about 28 to 30, the gas or vapor is pretty much neutrally buoyant. If the molecular weight is greater than 30, the gas or vapor is heavier than air.

It is critical when measuring vapor density that both the gas or vapor and air are at the same temperature. If the vapor and air are not at the same temperature, this comparison is invalid. If gas or vapor is at a different temperature than the air, it will behave differently due to different densities.

A shortcut method of calculating vapor density is to divide the molecular weight of the material by the molecular weight of air, approximately 29 based on the weight mixture of gases that comprise air. Therefore, benzene with a molecular weight of 78 would have a vapor density of 2.7 or would be essentially 2.7 times heavier than air. While this will work for general estimates, one must remember that the benzene vapors in the natural environment will **never** be pure. Rather, the vapors will be mixed with some percentage of air and the density will thereby change. When available in references, saturated vapor densities provided a much more accurate representation of how a gas or vapor will act in the natural environment.

SOLUBILITY

We have all observed that sugar and salt dissolve in water, alcohol mixes freely in water-based mixers, and that carbon dioxide gas dissolves in liquids, which is released when we open a can of soda. In each of these cases, the solid, liquid, or gas that has dissolved is said to be soluble. Materials are soluble to varying degrees. At one extreme, are substances that will dissolve completely in water. These also are said to be miscible. This means that any amount of the substance can be added to water, and at no point in the process will the substance form a separate layer or phase. At the other extreme, are those substances which will not dissolve whatsoever in water, and they are considered to be insoluble or immiscible.

Between these two extremes are substances that are partially soluble in water. For an example, there is only a certain amount of ordinary table salt that can be dissolved in water before any newly added salt will simply sink to the bottom of the glass. In the case of table salt, 35.7 grams of salt will dissolve in 100 grams of water at a temperature of 32 ^{o}F. This amount will increase to approximately 39 grams of salt if the water is heated to 212 ^{o}F. Therefore, solubility is also a function of temperature. Just think about the difference in the sweetness of iced tea when the sugar is added while the tea is still hot versus the sweetness when the sugar is added after adding ice.

Variables That Affect Solubility

Numerous factors come into play when determining a material's solubility. Hydrogen bonding as a result of polarity, diffusion, and thermodynamics, as well as other key characteristics and laws all influence this property. However, for our purposes, polarity and hydrogen bonding are key factors. As a material becomes "polar" in nature, water solubility increases because the hydrogen bonding that occurs between water molecules permits the polar material to dissociate and mix more freely.

pH

pH is the value taken to represent the acidity of an aqueous acid-base system.

The pH scale is a scale indicating the ratio of the number of free hydrogen (H^+) ions or hydroxyl (OH^-) ions compared to the number of water molecules. The more hydrogen ions there are in the aqueous solution, the more acidic the pH is. The more hydroxyl ions there are, the more base the pH is. A pH of 7 is considered neutral. pHs below 7 are increasingly acidic. pHs above 7 are increasingly basic.

Strength

Strength is how easily an acid ionizes in water.

Some acids and bases more freely release H or OH than others.

Examples of strong acids:

- hydrochloric acid;
- hydroflouric acid;
- hydrobromic acid;
- hydroiodic acid;
- nitric acid; and
- sulfuric acid (first hydrogen more readily than the second) H_2SO_4.

Concentration

Concentration is the weight of the acid compared to the weight of water in a mixture (e.g., mix 1 lb. of water and 1 lb. of acid and you would have a 50 percent concentration).

ASSESSING HAZARDS USING YOUR UNDERSTANDING OF PROPERTIES OF HAZARDOUS MATERIALS

The *NIOSH Pocket Guide to Chemical Hazards*

The following abbreviations are used in the *NIOSH Pocket Guide to Chemical Hazards* for the physical and chemical properties given for each chemical. If there is an "NA" in an entry, it indicates that a property is not applicable, and a question mark (?) indicates that the data is unknown.

MW--Molecular weight

BP--Boiling point at 1 atmosphere, °F

Sol--Solubility in water at 68 °F (unless a different temperature is noted), % by weight (i.e., g/100 ml)

Fl.P--Flash point (i.e., the temperature at which the liquid phase gives off enough vapor to flash when exposed to an external ignition source), closed cup (unless annotated "(oc)" for open cup), °F

IP--Ionization potential, eV (electron volts) [Ionization potentials are given as a guideline for the selection of photoionization detector lamps used in some direct-reading instruments.]

VP--Vapor pressure at 68 °F (unless a different temperature is noted), mm Hg; "approx" indicates approximately

MLT--Melting point for solids, °F

FRZ--Freezing point for liquids and gases, °F

UEL--Upper explosive (flammable) limit in air, % by volume (at room temperature unless otherwise noted)

LEL--Lower explosive (flammable) limit in air, % by volume (at room temperature unless otherwise noted)

MEC - Minimum explosive concentration, g/m3 (when available)

Sp. Gr--Specific gravity at 68 °F (unless a different temperature is noted) referenced to water at 39.2 °F (4 °C)

RGasD--Relative density of gases referenced to air = 1 (indicates how many times a gas is heavier than air at the same temperature)

Department of Transportation Flammable/Combustible Classifications

Flammable Liquids

For flammable liquids, the flashpoint is classified as 140 ^{o}F (60 ^{o}C) and below. With the exception of domestic use, 100 ^{o}F (37.8 ^{o}C) to 140 ^{o}F can be classified as either flammable or combustible.

Combustible Liquids

Combustible liquids are substances with a flashpoint of 141 ^{o}F (60.6 ^{o}C). With the exception of domestic use, 100 ^{o}F to 140 ^{o}F can be classified as either flammable or combustible.

National Fire Protection Association Classifications of Flammable Liquids

- Class Ia--Flammable liquids: flashpoint below 73 ^{o}F (22.8 ^{o}C) and boiling point below 100 ^{o}F.
- Class Ib-- Flammable liquids: flashpoint below 73 ^{o}F and boiling point above 100 ^{o}F.
- Class Ic--Flammable liquids: flashpoint between 73 ^{o}F and 100 ^{o}F.
- Class IIa--Combustible liquids: flashpoint between 100 ^{o}F and 140 ^{o}F.
- Class IIb--Combustible liquids: flashpoint between 140 ^{o}F and 200 ^{o}F (93.3 ^{o}C).
- Class III Combustible Liquids: flashpoint over 200 ^{o}F.

ASSESSING RISK: TOXIC LEVELS OF CONCERN AND EXPOSURE LIMITS

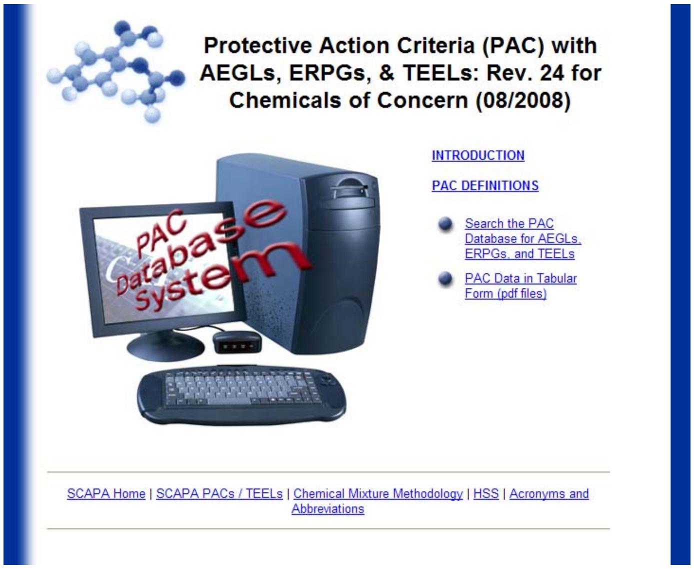
There are many different measurements for hazardous chemicals' **levels of concern** (LOCs) and chemical **exposure limits**, which have been established by OSHA and by several different industries. The search for accurate and accessible chemical exposure limit values for the purpose of protective action during a hazardous materials incident is difficult, due to the lack of a standardized, accessible source of this information in the field.

Many emergency responders rely on established workplace safety LOCs, instead of LOCs that apply to the general public, even though workplace safety is fundamentally different from rescue of victims who have been exposed to hazardous chemicals. These workplace safety LOC measurements are inflated to incorporate safety margins, so they are inaccurate for the purpose of rescue at a hazardous materials incident. Moreover, workplace safety guidelines tend to be built on exposure durations that are much longer (e.g., a 40-hour week) than those encountered at a hazardous materials incident.

The Department of Energy's Protective Action Criteria

To help responders make use of the many existing guidelines on exposure limits, a group working under the Department of Energy, called the Subcommittee on Consequence Assessment and Protective Actions (SCAPA) has begun to develop a standard measurement of exposure levels called Protective Action Criteria (PACs). PACs are meant specifically to guide emergency responders on the true exposure limits for victims exposed to hazardous chemicals. PACs are adapted using a standardized methodology from three existing exposure limit values--Acute Exposure Guideline Levels (AEGLs), Emergency Response Planning Guidelines (ERPGs), and Temporary Emergency Exposure Limit (TEEL) specifically for use by emergency responders. These exposure limit values and others are fully explained in the following sections.

The Department of Energy has also created an online, searchable database of PACs. You can find the searchable database at the following URL: http://www.atlintl.com/DOE/teels/teel.html



Protective Action Criteria (PAC) with AEGLs, ERPGs, & TEELs: Rev. 24 for Chemicals of Concern (08/2008)

The Department of Energy's PAC database home page

This database used to be called the "TEEL data set," but the title has been changed to "PAC data set" to acknowledge the inclusion of AEGL and ERPG data. Most of the data is still in TEEL, however.

Although the searchable database is only online, they do publish this information, as it evolves, in a downloadable and printable PDF format, which can be found here: http://www.atlintl.com/DOE/teels/teel/teel_pdf.html

NOAA's CAMEO Chemicals

Under the U.S. Department of Commerce, the National Oceanic and Atmospheric Administration's Office of Response and Restoration (NOAA OR&R) publishes a widely used database, CAMEO Chemicals. "CAMEO" stands for "Computer Aided Management of Emergency Operations." The URL to the CAMEO Chemicals database is: http://www.cameochemicals.noaa.gov/

This database does a great job of integrating all of the major sources of information on hazardous chemicals. The CAMEO Chemicals database even includes AEGLs and TEELs for each chemical, whenever they are available. Although it may change in the future, currently, the CAMEO database is only available online, or if downloaded and installed on a computer. It is not yet available as a hand-held, printed field guide.

The Need for a Field Guide

Responders still often use a printed information source in the field, including sources published under OSHA (such as the *NIOSH Guide*), the Department of Transportation (the DOT *Emergency Response Guidebook*), or various industries. These are great information sources for hazardous chemicals; they simply lack a standard, indexed measurement for chemical exposure limits that is relevant to emergency responders. In the event that you use one of these sources, you will need to have a road map to all of the many disparate indexes of exposure limits and levels of concern for hazardous chemicals.

The following is a "levels of concern field guide" to help you distill the many different systems used to measure levels of concern and exposure limits. This field guide will explain all of these terms, what they measure, and how to choose which ones are most useful to emergency responders.

TOXIC LEVELS OF CONCERN FIELD GUIDE

A toxic LOC tells you what level (threshold concentration) of exposure to a chemical could hurt you or other people if you breathe it in for a defined length of time (exposure duration). LOCs also may be referred to as exposure limits, exposure guidelines, or toxic endpoints. Generally, the lower the LOC for a substance, the more toxic the substance is by inhalation.

A common use of LOCs during a response is to identify the area where a toxic threat to people could exist. This guide describes the LOCs that are often used in emergency response.

An LOC is a way to measure the toxicity (poisonousness, or the ability to injure or kill people or other organisms) of a gas or an evaporating vapor. An LOC for a particular substance is usually the "threshold concentration" of a substance in air, above which a toxic hazard to people is believed to exist.

Each LOC is designed to reflect hazard either (1) to the general public (including children and elders, people who are ill, and pregnant women) or (2) to adult workers.

Most LOCs have two components: a **threshold concentration** and an **exposure duration**. The exposure duration for an LOC is part of the definition of that LOC. When the threshold concentration exceeds the exposure duration, exposed people might experience the symptoms represented by the LOC.

Choosing and Using an LOC

You need an LOC to estimate the area where a toxic hazard to people might exist, or to find out whether the concentration of an airborne gas is high enough to be hazardous to people. For example, during a response to a toxic gas release you might need to determine whether gas concentrations measured by portable sensors exceed an LOC for the chemical.

Rules for Choosing an LOC

Choose an LOC appropriate for the population you're concerned about: either response workers or the general public.

Match the LOC's exposure duration to the situation as much as you can. For example, if you've selected AEGL as your LOC:

1. Consider using a 10- or 30-minute AEGL if the threat is a pressurized release that lasts only a short time.

2. Consider a 1- or 4-hour AEGL if the threat is a slowly-evaporating puddle.

PUBLIC EXPOSURE GUIDELINES

Public Exposure Guidelines attempt to predict how the general public could be affected if exposed to a particular hazardous chemical.

Acute Exposure Guideline Levels

AEGLs are considered the best public exposure guidelines to date, because they undergo a rigorous review process, and are designed as guidelines for nearly all members of the general public--including sensitive individuals. The disadvantage of using AEGLs is only that final AEGLs have been defined for only a few dozen chemicals.

Each AEGL includes three tiers, defined as follows:

- **AEGL-1**: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience notable discomfort, irritation, or certain asymptomatic non-sensory effects. However, the effects are not disabling and are transient and reversible upon cessation of exposure.

- **AEGL-2**: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience irreversible or other serious, long-lasting adverse health effects or an impaired ability to escape.

- **AEGL-3**: The airborne concentration of a substance above which it is predicted that the general population, including susceptible individuals, could experience life-threatening health effects or death.

Each of the three levels of AEGL--AEGL-1, AEGL-2, and AEGL-3--is developed for each of five exposure periods: 10 minutes, 30 minutes, 1 hour, 4 hours, and 8 hours.

The AEGLs are under development by the National Research Council's National Advisory Committee on AEGLs. AEGLs take into account sensitive individuals and are meant to protect nearly all people.

AEGLs, when available, may be the best choice to use as a Toxic Level of Concern. However personal judgment and experience should be used both for selecting an LOC and for interpreting the data obtained from using it.

Emergency Response Planning Guidelines

ERPGs are intended to be a planning tool to help you anticipate human adverse health effects to the general public caused by toxic chemical exposure. These exposure guidelines were developed by a committee of the American Industrial Hygiene Association. ERPGs are based on experimental data.

Unlike AEGLs, ERPGs are only available for a 1-hour exposure duration. ERPGs are not designed as guidelines for hypersensitive individuals, who could suffer adverse reactions to concentrations far below those suggested in the guidelines.

The ERPGs are three-tiered guidelines, with the tiers defined as follows:

- **ERPG-1**: The maximum airborne concentration [of a toxic gas] below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.

- **ERPG-2**: The maximum airborne concentration [of a toxic gas] below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

- **ERPG-3**: The maximum airborne concentration [of a toxic gas] below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

While exposure in the field may be longer or shorter than the 1- hour ERPG exposure duration, the ERPG committee strongly advises against trying to extrapolate ERPG values to longer periods of time.

ERPGs do not contain safety factors usually incorporated into workplace exposure guidelines such as the TLV. Rather, ERPGs estimate how the general public would react to chemical exposure. Just below the ERPG-1, for example, most people would detect the chemical and may experience temporary mild effects. Just below the ERPG-3, on the other hand, it is estimated that the effects would be severe, although not life-threatening. The TLV, on the other hand, incorporates a safety factor to prevent ill effects to exposed workers.

ERPGs, like other toxic levels of concern (exposure guidelines), are based mostly on animal studies, thus raising the question of applicability to humans. The ERPG should serve as a planning tool, not a standard to protect the public.

Temporary Emergency Exposure Limit

TEELs are temporary levels of concern designed to be used as toxic exposure limits for chemicals for which AEGLs or ERPGs have not yet been defined. Like AEGLs and ERPGs, they are designed to represent the predicted response of members of the general public to different concentrations of a chemical during an incident. TEELs do not incorporate safety margins.

Each TEEL includes four tiers, defined as follows:

- **TEEL-1**: The maximum airborne concentration [of a toxic gas] below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.

- **TEEL-2**: The maximum airborne concentration [of a toxic gas] below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms which could impair an individual's ability to take protective action.

- **TEEL-3**: The maximum airborne concentration [of a toxic gas] below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

WORKPLACE EXPOSURE LIMITS

Workplace exposure limits are meant to protect worker safety and health over a working lifetime. They are usually defined for healthy adult workers. They typically incorporate safety margins to ensure that workers won't be overexposed to hazardous chemicals in the workplace. Generally, employers must ensure that these limits are not exceeded in the workplace.

Immediately Dangerous to Life or Health

An IDLH (Immediately Dangerous to Life or Health) is a condition that poses a threat of exposure to airborne contaminants when that exposure is likely to cause death or immediate or delayed permanent health effects or prevent escape from such an environment.

A chemical's IDLH is an estimate of the maximum concentration in the air to which a healthy worker could be exposed without suffering permanent or escape-impairing health effects.

The IDLH level is a limit originally established for selecting respirators for use in workplaces by the National Institute for Occupational Safety and Health (NIOSH). In the 1980s, before public exposure guidelines were available for most common chemicals, the IDLH limit was used in public exposure situations.

The IDLH was not designed to be an exposure limit for the general population. It does not take into account the greater sensitivity of some people, such as children and the elderly. One should not use IDLH values to definitively identify hazardous conditions.

Threshold Limit Value

The TLV (Threshold Limit Value) is a workplace exposure standard recommended by a committee of the American Conference of Governmental Industrial Hygienists (ACGIH). A TLV is a level below which nearly all workers may be repeatedly exposed without respiratory protection and without suffering any adverse health effects. A TLV may be expressed as a Time Weighed Average (TLV-TWA), a Short Term Exposure Limit (TLV-STEL) or as a Ceiling limit (TLV-C).

A TLV has three components:

1. A time-weighted average (TLV-TWA) concentration that ACGIH recommends not be exceeded for up to an 8-hour workday during a 40-hour workweek.

2. A ceiling limit value (TLV-C), which ACGIH recommends not be exceeded at any time during the workday.

3. A short-term (STEL) value (TLV-STEL), which ACGIH recommends not be exceeded for longer than a specified brief period of time (usually 15 minutes) during a workday.

TLVs have been recommended for more than 700 hazardous substances, and are based on available animal and human exposure studies. The goal is to minimize workers' exposure to hazardous concentrations as much as possible.

TLVs are recommended values that should not be exceeded in a workplace, rather than legal limits. They do not guarantee protection to all workers and are not intended to be used for community (general public) exposure.

Recommended Exposure Limit

The REL (Recommended Exposure Limit, also called NIOSH REL), is an exposure limit recommended by NIOSH scientists to OSHA. RELs are science-based recommendations rather than legal standards. They are based on animal and human studies.

A REL is defined in up to three ways:

1. A time-weighted average (TWA) concentration that NIOSH recommends not be exceeded for up to a 10-hour workday during a 40-hour workweek.

2. A ceiling value, which NIOSH recommends not be exceeded at any time during the workday (unless noted otherwise).

3. A short-term (STEL) value, which NIOSH recommends not be exceeded for longer than 15 minutes during a workday (unless noted otherwise).

NIOSH RELs are often more conservative than the corresponding TLV values, and NIOSH's consideration of available research and studies is regarded as thorough.

An Example Interpretation of a NIOSH REL:

In the *NIOSH Pocket Guide to Chemical Hazards*, REL values for phenol are shown as follows:

> "NIOSH REL: TWA 5 ppm (19 mg/m3) C 15.6 ppm (60 mg/m3) [15-minute] [skin]"

What this means is that for this chemical, the recommended exposure limit is 5 ppm averaged over a 10-hour workday, and 15.6 ppm averaged over an exposure of up to 15 minutes.

Permissible Exposure Limit

The PEL (Permissible Exposure Limit), also called the "OSHA PEL," is the maximum amount or airborne concentration of a substance to which a worker may be legally exposed. Most PELs have been defined for substances that are dangerous when inhaled, but some are for substances that are dangerous when absorbed through the skin or eyes.

A PEL may be defined in either of two ways:

1. A time-weighted average (TWA) concentration. This average concentration must not be exceeded during any 8-hour workshift of a 40-hour workweek.

2. A ceiling value, which must not be exceeded at any time during the workday.

Current PELs are listed in the Code of Federal Regulations. PELs are set by OSHA, the main Federal agency enforcing safety and health legislation and are the law of the land in the United States. Workers' exposure may not exceed these standards and OSHA has the power to warn, cite, and fine violators.

OTHER TOXICOLOGY MEASUREMENTS AND TERMS

EEGL: Emergency Exposure Guidance Level. Concentration of a substance in air judged to be acceptable for the performance of specific tasks by military personnel during emergency conditions lasting 1-24 hours. Acceptable only to perform tasks necessary to prevent greater risks. Developed by the National Research Council (NRC) for the Department of Defense (DOD). Ceiling limit for single substances considered acceptable for rare situations. Acceptable, but not safe, level of exposure. Acute toxicity is primary concern.

LC_{50}: Lethal Concentration, 50% kill. Concentration level at which 50% of the test animals died when exposed by inhalation for a specified period of time. Standard measurement used by descriptive toxicologists.

LD_{50}: Lethal Dose, 50% kill. Median Lethal Dose at which half of the test animals died following exposure. Standard measurement used by descriptive toxicologists. Dose is usually given in milligrams per kilogram of body weight of the test animal and refers to dosages administered by ingestion, absorption or injection as a route of exposure.

Odor Threshold: Level at which most people can detect the odor of a substance. Great variation in individual responses to odors and in data from various reference sources. Average figure normally based on empirical research. Usually expressed in parts per million (ppm).

ppm: Parts per million. Units used to express the concentration of a gas or vapor in air (as molecules of chemical per million molecules of air).

SPEGL: Short-Term Public Exposure Guidance Level. Acceptable ceiling concentration for a single, unpredicted short-term exposure to the public. Developed by the NRC primarily for materials used as rocket fuels. Usually one tenth to one half of the EEGL. Ceiling level for a single substance. Exposure period usually 1 hour or less; never more than 24 hours. Takes into account sensitive populations.

STEL: Short Term Exposure Limit. Unless otherwise stated, an exposure limit for a short period of time. Usually can't exceed this level during any part of the work period. (Usually measured over a short period of time because it's often impossible to obtain an instantaneous measurement of an airborne concentration). Time weighted average. Maximum 15-minute exposure without respiratory protection in place.

Threat zone: A threat zone encloses the area around the location of a hazardous chemical release, within which concentrations of the chemical could reach or exceed a specified LOC (level of concern).

WEEL: Workplace Environmental Exposure Level. Exposure limits recommended by the American Industrial Hygienists Association. Used in the absence of a TLV-TWA or a PEL. Time weighed average 8-hour workday, 40-hour workweek.

REFERENCES

This precourse reading for the National Fire Academy's *Chemistry for Emergency Response* course was adapted in part from the following sources:

Module 1a, Basic Chemistry Course. Governor's Office of Emergency Services, California Specialized Training Institute.

"Levels of Concern Field Guide," Chemical Response Tool: The Companion Quick Reference to the CAMEO Chemical's Database, developed originally for the US Coast Guard. http://chemresponsetool.noaa.gov/

The two online databases on hazardous chemicals referenced are:

PACs for Chemicals of Concern Database

U.S. Department of Energy, Chemical Safety Program, SCAPA, http://www.atlintl.com/DOE/teels/teel.html

CAMEO Chemicals Database

Developed jointly by the National Oceanic and Atmospheric Administration (NOAA) Office of Response and Restoration, the Environmental Protection Agency (EPA) Office of Emergency Management, and the U.S. Coast Guard (USCG) Research and Development Center. http://www.cameochemicals.noaa.gov/