M E R R T T
Radiological Terminology and Units

INTRODUCTION

This module will provide you with information about four different types of ionizing radiation: alpha, beta, gamma, and neutron. Radiological terminology used in the transport of radioactive material and radioactive waste will be defined and discussed. This module also identifies the different units used for measuring radiation and radioactivity.

PURPOSE

The purpose of this module is to increase your knowledge of ionizing radiation. Knowing the terminology and measuring units associated with radioactive material will help you communicate more effectively with assisting agencies while responding to an incident involving radioactive material.

MODULE OBJECTIVES

Upon completion of this module, you will be able to:

1. Identify four basic types of ionizing radiation.
2. Identify the terms used to measure radiation and radioactivity.
3. Identify terminology and acronyms associated with shipments of radioactive material.
4. Identify commonly used Proper Shipping Names for radioactive material.

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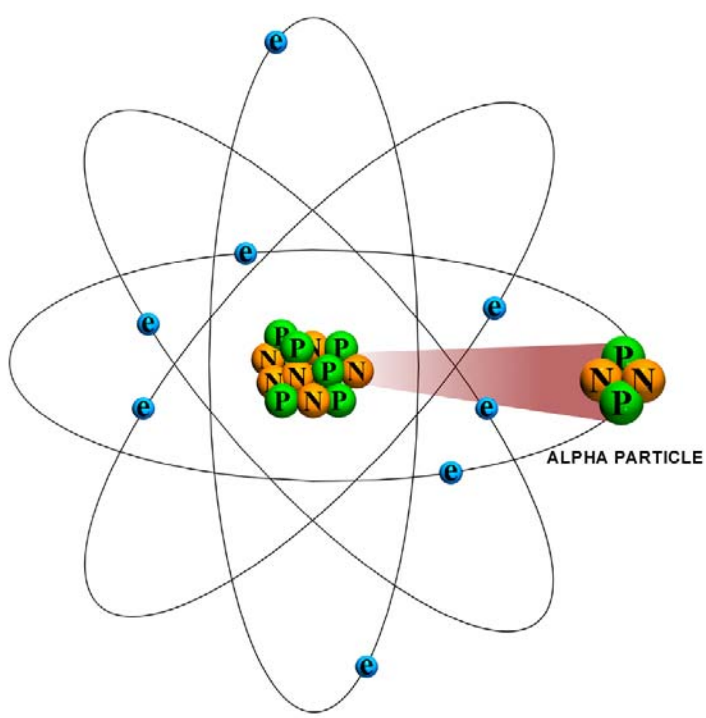
THE FOUR BASIC TYPES OF IONIZING RADIATION

Most of the commonly transported radioactive materials emit one or more forms of ionizing radiation. The four basic types of ionizing radiation are alpha radiation, beta radiation, gamma radiation, and neutron radiation. All four types differ in their penetrating power and the manner in which they affect human tissue. To give you a general understanding of each type, they are discussed here.

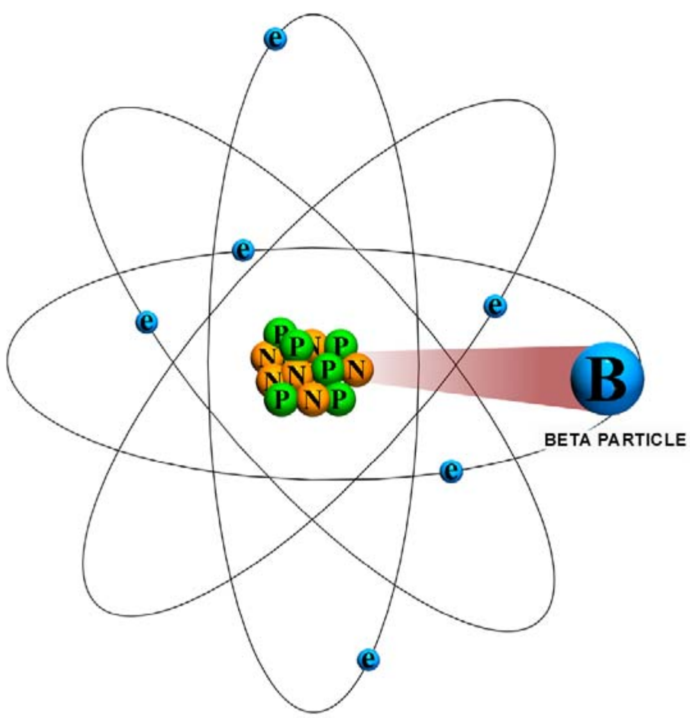
Alpha

Alpha radiation consists of high-energy particles that are relatively large, heavy, and only travel a short distance. Because they are so large and heavy, alpha particles lose their energy very rapidly, have a low penetrating ability, and short range of travel—only a few inches in air. Because of the alpha particle's short range and limited penetrating ability, external shielding is not required. A few inches of air, a sheet of paper, or the dead (outer) layer of skin that surrounds our bodies easily stops alpha particles. Alpha radiation poses minimal biological hazard outside the body. The greatest hazard from alpha-emitting material occurs when the material is inhaled or ingested. Once inside the body, the alpha radiation can cause harm to individual cells or organs.



Beta

Beta radiation consists of particles that are smaller, lighter, and travel farther than alpha radiation. Because they are smaller and lighter, beta radiation is more penetrating than alpha radiation. The range of penetration in human tissue is less than ¼ inch. In air, beta radiation can travel several feet. Beta radiation may be blocked or shielded by plastic (SCBA face shield), aluminum, thick cardboard, several layers of clothing (bunker gear) or the walls of a building.



Outside the body, beta radiation constitutes only a slight hazard. Because beta radiation penetrates only a fraction of an inch into living skin tissue, it does not reach the major organs of the body. However, exposure to high levels of beta radiation can cause damage to the skin and eyes. Internally, beta radiation is less hazardous than alpha radiation because beta particles travel farther than alpha particles and, as a result, the energy deposited by the beta radiation is spread out over a larger area. This causes less harm to individual cells or organs.

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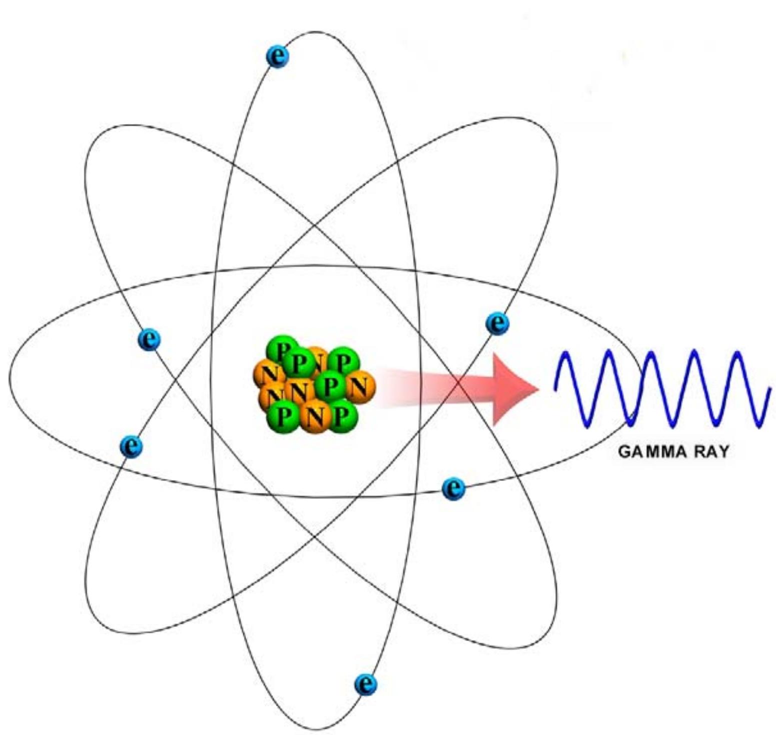
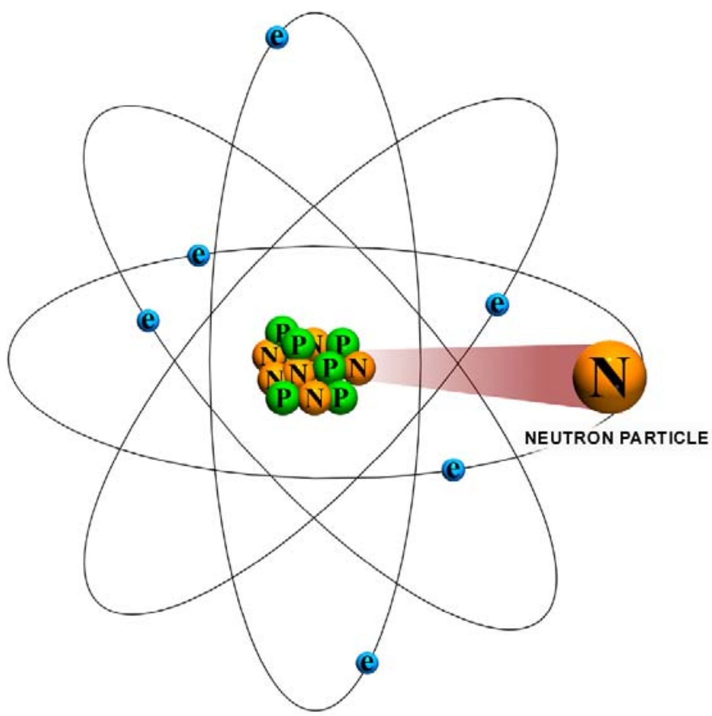
Gamma

Gamma radiation, like X-rays, is electromagnetic radiation. This means that it does not consist of particles like alpha and beta radiation but, rather, waves of energy that have no mass and no electrical charge. Because they have no mass and no electrical charge, they are able to travel great distances and require dense material as shielding. Gamma radiation poses a hazard to the entire body because it can easily penetrate human tissue. Lead, steel, and concrete are commonly used to shield gamma radiation.



Neutron

Neutron radiation consists of neutron particles that are ejected from an atom's nucleus. Neutron radiation can travel great distances and is highly penetrating like gamma radiation. It is best shielded with high hydrogen content material (e.g., water, plastic). In transportation situations, neutron radiation is not commonly encountered.



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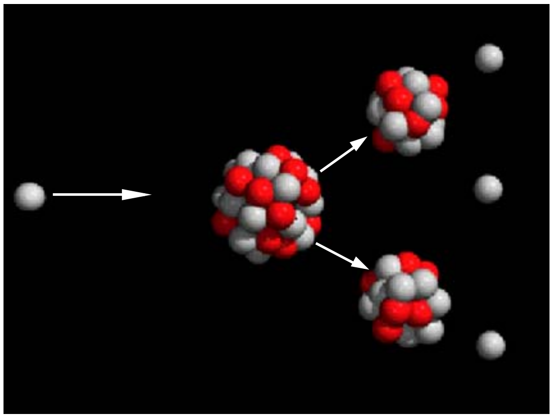
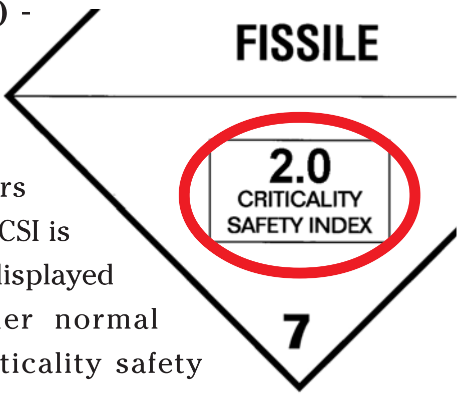
TERMINOLOGY ASSOCIATED WITH RADIOACTIVE MATERIAL SHIPMENTS

Familiarity with terminology used for describing radioactive material in transport will help you function and communicate more effectively during a transportation incident involving radioactive material. The following terms are often associated with radioactive material shipments. These terms can be seen as a part of a Proper Shipping Name (e.g., Radioactive Material, Type A package, fissile) and/or on shipping papers:



Fissile Material - material whose atoms are capable of nuclear fission (capable of being split). Department of Transportation (DOT) regulations define fissile material as plutonium-239, plutonium-241, uranium-233, uranium-235, or any combination of these radionuclides. This material is usually transported with additional shipping controls that limit the quantity of material in any one shipment. Packages used for fissile material are designed and tested to prevent a fission reaction from occurring during normal transport conditions as well as hypothetical accident conditions.



Criticality Safety Index (CSI) - means a number which is used to provide control over the accumulation of packages, overpacks, or freight containers containing fissile material. The CSI is assigned by the shipper and is displayed on the FISSILE label. Under normal conditions, the aggregate criticality safety indices of all fissile material packages on a shipment will not exceed 50.

LSA - an acronym that stands for low specific activity. This means radioactive material with a limited amount of radioactivity in relationship to the total amount of material present. Material such as uranium and thorium ores, mill tailings, and contaminated earth are often transported as LSA material. Radioactive waste is commonly transported as LSA material. The photo below shows 55-gallon drums containing radioactive waste. Notice that the drums are marked “Radioactive-LSA.”

Special Form Radioactive Material - radioactive material which is either a single solid piece or a sealed capsule that can be opened only by destroying the capsule. During accident conditions, special form radioactive material would be non-dispersible and would therefore not present a contamination hazard. Though not a contamination hazard, special form sources may pose a significant radiation hazard. A sealed radioactive source used in radiography operations (like the one pictured below) is an example of a special form radioactive material.

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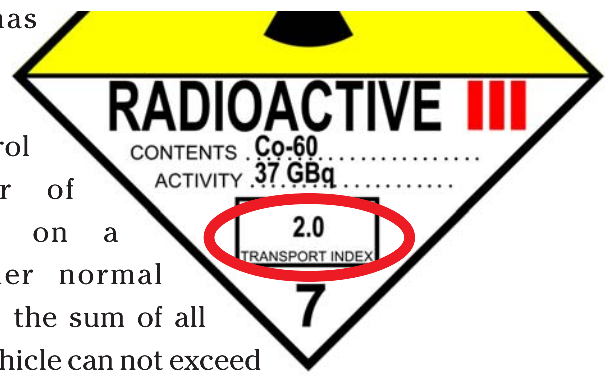
SCO - an acronym that stands for Surface Contaminated Objects. SCO means a solid object that is not in and of itself radioactive, but has radioactive material deposited on any of its surfaces (i.e., contamination). Examples of SCO material would include equipment (pumps, drills, etc.) used in decommissioning activities or contaminated protective clothing.

Transport Index (TI) - The transport index is a single number, determined by the shipper, that is used to provide control over radiation exposure and establish transport controls. The TI appears on Radioactive Yellow II and III labels (see example below) and on the shipping papers. The Transport Index is determined by taking the maximum radiation level (as measured in mrem/hr) at one meter (3.3 feet) from an undamaged package. The transport index can be used by the responder as a good starting point for determining whether damage has occurred to a package. The carrier uses the TI to control the total number of packages allowed on a conveyance. Under normal transport conditions, the sum of all TIs in the transport vehicle can not exceed 50.



COMMON RADIOACTIVE MATERIAL PROPER SHIPPING NAMES

Title 49 of the Code of Federal Regulations (CFR) is where the regulatory requirements for the transport of radioactive materials are found. Title 49 contains the Hazardous Materials Table (HMT), which categorizes material the DOT has designated as hazardous material for purposes of transportation. For each material listed, the HMT provides information on the hazard class, the United Nations Identification Number (UN ID), gives the Proper Shipping Name (PSN), and other information for preparing hazardous material shipments. The PSNs for radioactive material are listed in the table on the following page. These PSNs are also found in the blue pages of the ERG. Note that the words “radioactive material” appear as a part of the PSN for all material listed in the table. Many of the definitions listed on page 6 through 8 of this module appear as part of the PSN.

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Proper Shipping Names	UN ID Number
Radioactive material, excepted package-articles manufactured from natural uranium *or* depleted uranium *or* natural thorium.	UN2909
Radioactive material, excepted package-empty packaging.	UN2908
Radioactive material, excepted package-instruments *or* articles.	UN2911
Radioactive material, excepted package-limited quantity of material.	UN2910
Radioactive material, low specific activity (LSA-I) *non fissile or fissile-excepted.*	UN2912
Radioactive material, low specific activity (LSA-II) *non fissile or fissile-excepted.*	UN3321
Radioactive material, low specific activity (LSA-III) *non fissile or fissile-excepted.*	UN3322
Radioactive material, surface contaminated objects (SCO-I *or* SCO-II) *non fissile or fissile-excepted.*	UN2913
Radioactive material, transported under special arrangement, *non fissile or fissile-excepted.*	UN2919
Radioactive material, transported under special arrangement, fissile.	UN3331
Radioactive material, Type A package, fissile *non-special form.*	UN3327
Radioactive material, Type A package *non-special form, non fissile or fissile-excepted.*	UN2915
Radioactive material, Type A package, special form *non fissile or fissile-excepted.*	UN3332
Radioactive material, Type A package, special form, fissile.	UN3333
Radioactive material, Type B(M) package, fissile.	UN3329
Radioactive material, Type B(M) package *non fissile or fissile-excepted.*	UN2917
Radioactive material, Type B(U) package, fissile.	UN3328
Radioactive material, Type B(U) package *non fissile or fissile-excepted.*	UN2916
Radioactive material, uranium hexafluoride *non fissile or fissile-excepted.*	UN2978
Radioactive material, uranium hexafluoride, fissile.	UN2977

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RADIOLOGICAL UNITS

In 1975, the 15th General Conference of Weights and Measures adopted new names for certain basic units in radiation protection technology. These new units are consistent with the metric system or with the International System of Units (SI system) developed by the International Committee for Weights and Measures.

Measuring Radiation

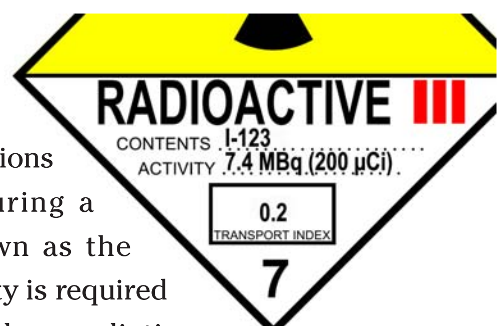
The Roentgen (R) and Rem (Roentgen Equivalent Man)

Radiation exposure is measured in units of roentgen and rem. For our purposes, one roentgen is equal to one rem. Because one roentgen or one rem of radiation is a fairly large amount of radiation, the prefix milli is often used. Milli means one one-thousandth (1/1,000). In other words, there are 1,000 milliroentgens (mR) in one roentgen, or 1,000 millirem (mrem) in one rem. A typical radiation dose from a medical x-ray is about 40 mrem.

According to the National Council on Radiation Protection and Measurements (NCRP), the average person in the United States is exposed to a dose of approximately 360 mrem per year from both man-made and natural sources (NCRP Report No. 93).

In this section, we focus on the traditional units for radiation measurement because they are still widely used in the response community. The SI unit for radiation exposure is the sievert. One sievert is equal to 100 rem.

Measuring Radioactivity



Radioactivity is measured in the number of nuclear transformations or disintegrations that occur in a sample during a specific time. This is known as the activity of the sample. Activity is required (by federal law) to be listed on radiation-warning labels and shipping papers in the SI units. The example above shows a warning label listing the activity of the material inside the package.

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The SI unit for activity is the becquerel (Bq), which equals 1 disintegration per second (dps). The conventional unit of activity is the curie (Ci), which is 3.7 x 1010 or 37 billion (37,000,000,000) disintegrations per second. Both the curie and becquerel measure the same thing—activity. Although not required, the activity in curies is sometimes shown on warning labels and/or shipping papers in parentheses after the activity in becquerels. For example, in the illustration on the previous page, the activity listed on the label of 7.4 MBq is equal to 200 µCi. The "M" and "µ" shown before the Becquerel and Curie abbreviations are prefixes. One curie is considered to be a large amount of activity, whereas one becquerel is a very small amount of activity. To account for this, prefixes are often used to change the size of the unit. Many of the commonly used prefixes are shown in the table below.

Symbol	Prefix	Prefix Value	Example
p	pico	1 trillionth, or10^{-12}	pCi = one trillionth of a curie
n	nano	1 billionth, or 10^{-9}	nCi = one billionth of a curie
µ	micro	1 millionth, or 10^{-6}	µCi = one millionth of a curie
m	milli	1 thousandth, or 10^{-3}	mCi = one thousandth of a curie
k	kilo	1 thousand, or 10^{3}	kBq = one thousand becquerel
M	Mega	1 million, or 10^{6}	MBq = one million becquerel
G	Giga	1 billion, or 10^{9}	GBq = one billion becquerel
T	Tera	1 trillion, or 10^{12}	TBq = one trillion becquerel
P	Peta	1 quadrillion, or 10^{15}	PBq = one quadrillion becquerel

Exposure Conversion Table

µSv 0.01	µSv 0.1	µSv 1	µSv 10	µSv 100	mSv 1	mSv 10	mSv 100	Sv 1
0.001 mrem	0.01 mrem	0.1 mrem	1 mrem	10 mrem	100 mrem	1 rem	10 rem	100 rem

Activity Conversion Table

pCi 27	nCi 1	nCi 27	µCi 1	µCi 27	mCi 1	mCi 27	Ci 1	Ci 27	kCi 1
1 Bq	37 Bq	1 kBq	37 kBq	1 MBq	37 MBq	1 GBq	37 GBq	1 TBq	37 TBq

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Activity may also be expressed as a measure of its concentration or specific activity. Common terms for measuring specific activity are Ci/g (curies per gram) and Bq/kg (becquerels per kilogram). It is important to note that there is no direct relationship between activity and the physical quantity of material present. Very high activity material can come in very small packages. For example, one gram of cobalt-60 (commonly used in radiation therapy) has an activity of about 42 TBq or 42 trillion disintegrations per second. On the other hand, one gram of thorium-232 (the radioactive material found in some lantern mantles) has an activity of about 4 kBq or 4,000 disintegrations per second. Therefore, you would need to have well over 10 billion grams (23,000 pounds) of thorium-232 to equal the activity in one gram of cobalt-60.

Check Your Understanding

1. The four basic types of ionizing radiation are ______, _____, _______and ________.

2. _______ ________ is defined by DOT regulations as plutonium-239, plutonium-241, uranium-233, uranium-235, or any combination of these radionuclides.

3. ________ form radioactive material is radioactive material which is either a single solid piece or a sealed capsule that can be opened only by destroying the capsule.

4. The _________ ______ is assigned to a package by taking the maximum radiation level (as measured in mrem/hr) at one meter (3.3 feet) from an undamaged package.

5. The ________ and ____ are two units used to measure radiation exposure.

6. The SI unit for measuring radioactivity (activity) is the _________.

M E R R T T

ANSWERS

1. alpha
   beta
   gamma
   neutron
2. Fissile material
3. Special
4. transport index
5. roentgen
   rem
6. becquerel