Radiological Basics

INTRODUCTION

The reliance upon, and use of, radioactive material in agriculture, industry, and medicine continues to increase. As the manufacture, use, and disposal of radioactive material has increased, so has the need to transport it. Consequently, the potential for you as a responder to encounter an incident involving some type of radioactive material has increased. Having knowledge of radiological hazards, and the terminology used to describe them, will increase your ability to quickly recognize, safely respond, and accurately relay information during an incident involving radioactive material.

PURPOSE

Upon completion of this module, you will have a better understanding of the basic structure of an atom and the fundamentals of radiation.

MODULE OBJECTIVES

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

1. Identify the basic components of an atom.
2. Define ionizing radiation, radioactivity, radioactive material, and radioactive contamination.
3. Distinguish between radiation and contamination.
4. Identify some commonly transported sources of radioactive material.

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BACKGROUND

Radiation is all around us and has been present since the birth of this planet. Today, both man-made and natural radioactive material are part of our daily lives. We use radioactive material for beneficial purposes, such as generating electricity and diagnosing and treating medical conditions. Radiation is used in many ways to improve our health and the quality of our lives.

In 1895, while working in his laboratory, Wilhelm Roentgen discovered a previously unknown phenomenon: rays that could penetrate solid objects. Roentgen called these rays "X-rays." The figure at right shows Roentgen's wife's left hand - the first known X-ray. The practical uses of X-rays were quickly recognized and, within a few months, a medical X-ray picture was used to locate shotgun pellets in a man's hand.

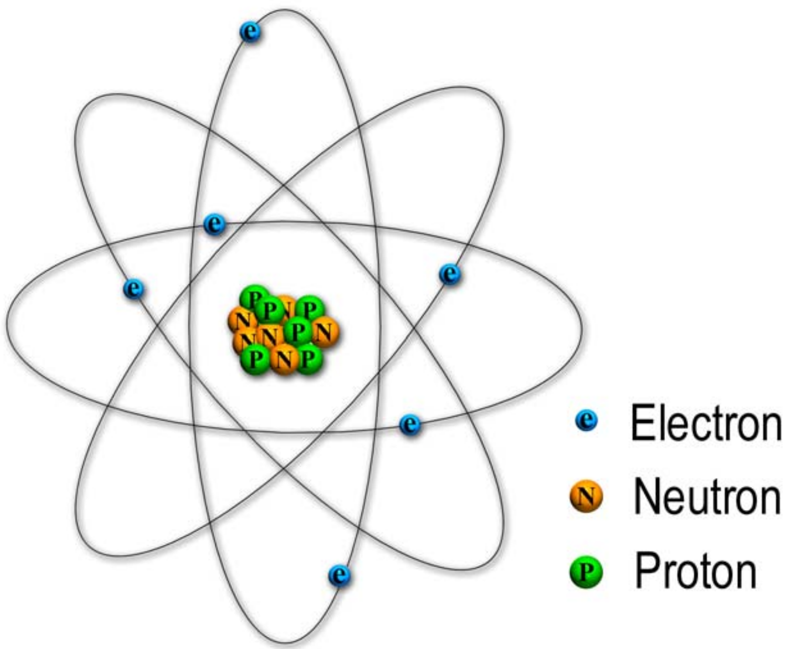
In 1896, Henri Becquerel reported observing a similar radiological phenomenon caused by uranium ore. Later that year, Pierre and Marie Curie identified the source of the radiation as a small concentration of radium, a radioactive material, in the ore.

These discoveries set the stage for using radiation in medicine, industry, and research. Since that time, scientist have developed a detailed understanding of the hazards and benefits of radiation. In fact, scientists understand radiological hazards better than hazards associated with most other physical and chemical agents.

BASIC RADIOLOGICAL CONCEPTS

Atomic Structure

All matter is made up of atoms. Atoms are invisible to the naked eye. The three basic components of the atom are protons, neutrons, and electrons. The central portion of the atom is the nucleus. The nucleus contains protons and neutrons, which are very close to each other. Electrons orbit the nucleus.



Protons
- Are located in the atom's nucleus
- Have a positive electrical charge
- Determine the element's identity

Neutrons
- Are located in the atom's nucleus
- Have a neutral electrical charge
- Determine the nuclear properties of the atom

Electrons
- Orbit the nucleus
- Have a negative electrical charge
- Determine the chemical properties of an atom

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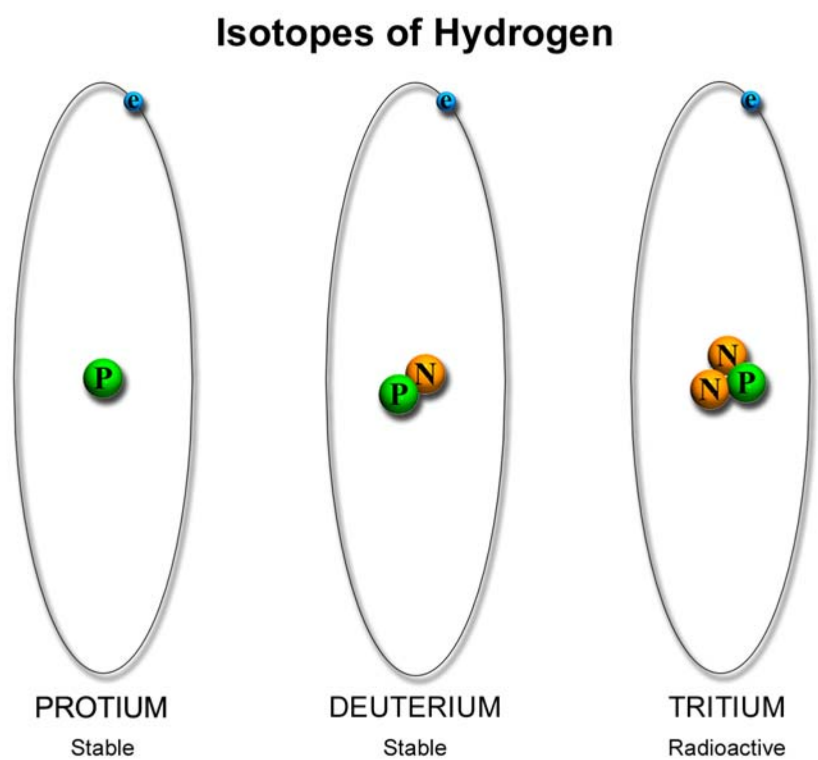
Atoms of a particular element will the same number of protons but may have a different number of neutrons. These variants are called isotopes. Isotopes of the same element have the same chemical properties, regardless of the number of neutrons. The nuclear properties of isotopes, however, can be quite different. For example, the illustration below shows three isotopes of hydrogen. All three isotopes have the same chemical properties; however, tritium is a radioactive isotope or radioisotope.



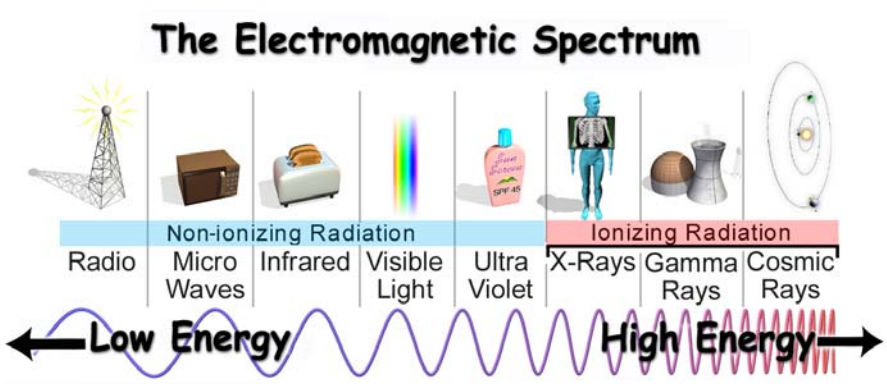
Stable and Unstable Atoms

Only certain combinations of neutrons and protons result in stable atoms.

- If there are too many or too few neutrons for a given number of protons, the resulting nucleus will have too much energy. This atom will not be stable.
- An unstable atom will try to become stable by giving off excess energy in the form of radiation (particles or waves). Unstable atoms are also known as radioactive atoms.

IONIZING RADIATION

As an emergency responder, you may already be familiar with some radiation terminology and with some radiological concepts. When most people think of radiation, they think of the type we are talking about in this course—the type that comes from atoms. There are, however, many different kinds of radiation. Visible light, heat, radio waves, and microwaves are all examples of radiation that, as a group, are referred to as electromagnetic radiation. The graphic below shows the electromagnetic spectrum. As the graphic illustrates, radiation such as radio waves and microwaves are much lower in energy than X-rays or cosmic rays. These lower energy radiations are referred to as non-ionizing radiation. Higher energy radiation like X-rays or cosmic rays are referred to as ionizing radiation.



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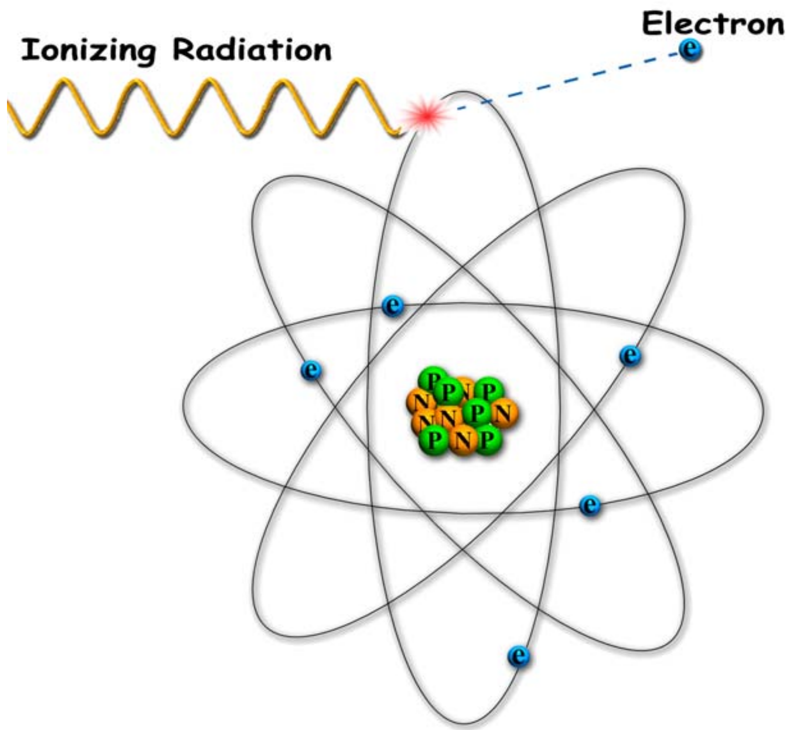
Ionizing radiation has enough energy to remove electrons from atoms. The process of removing electrons from atoms is called ionization. Ionizing radiation's ability to remove electrons from atoms is what makes it potentially hazardous. In this course, when we speak of radiation, we're talking about ionizing radiation. The ionization process is illustrated in the graphic below:



Radioactive Material and Radioactivity

Radioactive material is any material that spontaneously emits ionizing radiation. The process of an unstable atom emitting radiation is called radioactivity. Radioactive atoms can be generated through nuclear processes but they also exist naturally in material such as uranium ore, thorium rock, and some forms of potassium. When a radioactive atom goes through the process of radioactivity, also called radioactive decay, it will change to another type of atom. In fact, a radioactive atom may change from one element to another element during the decay process. For example, the element uranium will eventually change through radioactive decay to lead. This stabilizing process may take from a fraction of a second to billions of years, depending on the isotope.

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The rate of radioactive decay is unique to each type of radioactive atom and is measured in half-lives, the time it takes for half of the radioactive atoms in a sample to decay to another form. Different radioactive materials have different half-lives. For example, some radioactive pharmaceutical products (called radiopharmaceuticals) have half-lives that range from a few hours to a few months. It is important to note that radioactivity, regardless of the material, is constantly decreasing. After seven half-lives, the material will be at <1% of its original activity. The table below lists some common radioisotopes and their approximate half-life.

Radioisotope	Half-life
Nitrogen-16	7 seconds
Technetium-99m	6 hours
Thallium-201	73 hours
Cobalt-60	5 years
Cesium-137	30 years
Americium-247	432 years
Uranium-238	4.5 billion years

Radioactive Contamination

Any material that spontaneously emits ionizing radiation is a radioactive material. If radioactive material is in a place where we don't want it (e.g., deposited on the surfaces of or inside structures, areas, objects, or people) it is called radioactive contamination. The photo below illustrates contamination by showing a radiopharmaceutical package broken open with the contents spilled on the ground.

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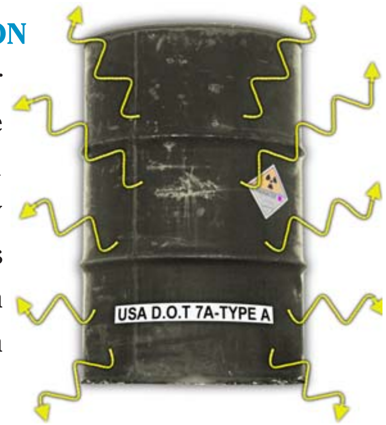
When radioactive material is properly used and controlled, there are many beneficial applications. Most smoke detectors, for instance, use radioactive material, as do certain medical diagnostic tools and treatment procedures. It is only when radioactive material is where it is not wanted (e.g., on the ground, in water, or on you) that we refer to it as contamination.

RADIATION VERSUS CONTAMINATION

One of the most important concepts for the responder to understand is the difference between radiation and contamination. Radiation is energy emitted by radioactive material (as illustrated by arrows). Contamination is radioactive material in a location where it is not wanted.



A person can be exposed to radiation and not become contaminated. On the other hand, radioactive contamination emits radiation. If a person is contaminated with radioactive material, the person continues to be exposed to radiation until the contamination is removed.

Put another way, radiation exposure is like being in front of a heat lamp. When the lamp is on, you can feel the heat. When you turn the lamp off, the heat is no longer felt. The heat is similar to exposure. The source of the energy is not in or on you and the exposure stops when you turn off the lamp. Contamination of a person happens when the source of radiation (radioactive material) gets on or in the person. You can be exposed to radiation and not be contaminated. However, if you become contaminated, you will continue to be exposed to radiation until the contamination is removed.

Exposure to Radioactive Material

If you encounter radioactive material at an incident scene, you may be exposed to radiation. Even with the tightest package and the best protection, low levels of radiation can pass through the package. This radiation is at a level that is (based on numerous scientific studies by a variety of industry, scientific, and government organizations) considered safe for people working near the packages. If the packages are intact, you should not expect unsafe exposure.

You should remember that we are exposed to radiation every day from common sources such as cosmic rays, X-rays, and even the bricks used to make buildings. Being exposed to radiation at these controlled levels is a very low hazard and should not prevent you from taking normal emergency actions. Exposure to radiation alone will not contaminate you.

Radioactive Contamination Types

A more serious concern is the possibility of radioactive contamination. The probability of radioactive material being released during an incident is extremely low. If radioactive material is released (as illustrated in the photo below), it is possible for responders, victims, and onlookers to become contaminated. This is especially true where the material is in the form of a liquid or powder.

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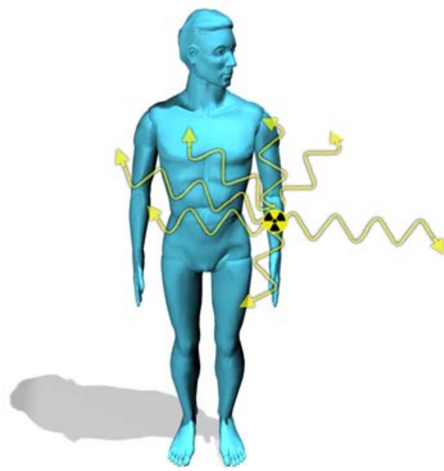
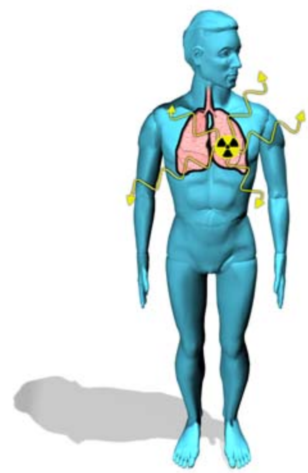
There are two basic types of radioactive contamination: external or internal. Radioactive contamination is serious because as long as the material is on you, your clothing, or inside your body, you are still being exposed. While a short exposure to these materials may be safe, prolonged or very close exposure may not be.


External Contamination


Internal Contamination

A special concern is the possibility of internal contamination. This happens when a radioactive material—usually a liquid, powder, or gas—is accidentally ingested or inhaled or otherwise gets inside the body. Once inside the body, it can be difficult to remove.

Radioactive material that might not be very dangerous outside the body may be dangerous if allowed to enter the body. For this reason, throughout this training, we will emphasize the use of personal protective equipment (PPE) and the importance of not eating, drinking, smoking, or chewing while on the scene of a radioactive material incident.

Another concern is that people who are contaminated externally may contaminate others, either directly or by secondary contamination. Secondary contamination occurs when a contaminated person or object touches something, that is then touched by another, who then becomes contaminated.

The following example describes how contamination is often spread. Imagine chalk on a blackboard as being radioactive material. If the chalk dust is transferred to your hands, you are considered contaminated. From your hand, the chalk dust can then be transferred to your shirt. The transfer of contamination from your hands to your shirt is an example of secondary or cross contamination.

COMMON SOURCES OF RADIOACTIVE MATERIAL

Everything is exposed to background ionizing radiation from naturally occurring sources. Radiation comes from many sources: the earth's crust, water, the air, and cosmic rays and particles. A portion of the world's population is also exposed to man-made sources of radiation through medical procedures that use radioactive material and X-rays. Even our bodies contain naturally occurring radioactive material.

What does radioactive material look like? As with other hazardous material, radioactive material exists in all physical forms–solids, liquids, and gases. The following are some commonly used and transported radioactive materials that you may be likely to encounter as a first responder.

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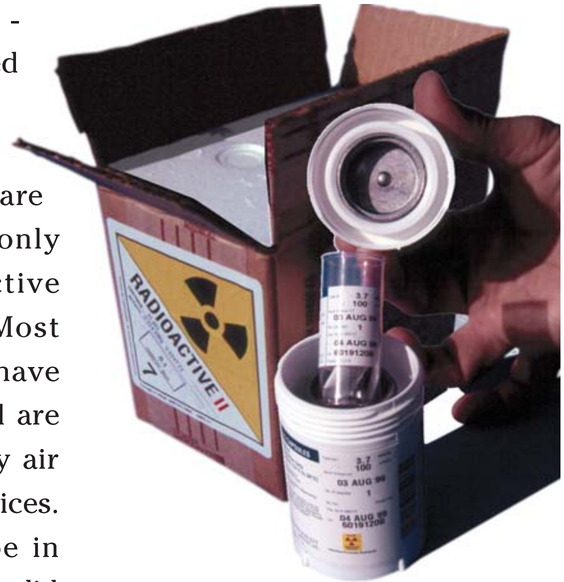
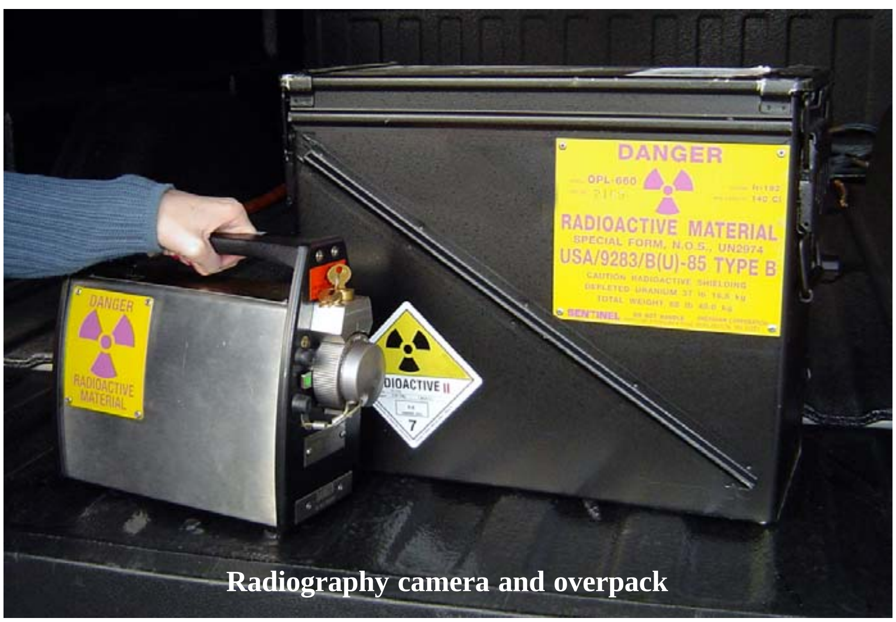
Radiopharmaceuticals - are radioactive drugs used for medical diagnoses and in radiation therapy. Radiopharmaceuticals are the most commonly transported radioactive material in the U.S. Most radiopharmaceuticals have very short half-lives and are typically transported by air and express delivery services. These materials can be in liquid, gas, powdered, or solid form.



Consumer products - smoke detectors are an example of a commonly transported consumer product. The amount of radioactivity in the household smoke detector falls below regulatory limits and therefore these materials will not be marked or labeled as "radioactive material" during transport.

Industrial sources - are specially designed and sealed sources of radiation used in construction and other industrial applications to check welds and metal for flaws, to check concrete and asphalt, and to test the density of soil. Soil density gauges are one example of a commonly transported industrial source. They usually contain a cesium-137 and/or americium-241:beryllium source. These types of gauges do not typically contain life-endangering amounts of radioactive material. Radiography sources, on the other hand, often contain a very high level source (commonly iridium-192 or cobalt-60) that could pose a high exposure risk if the source were outside of its packaging. When these sources are transported, they are shipped in very robust shipping packages.

Pictured below from top to bottom are: a soil density gauge sitting outside of its shipping/carrying case; a radiography camera outside its shipping/carrying case; and an example of a radiography source (commonly referred to as a "pigtail"). The pigtail is secured inside the radiography camera.



Radiography camera and overpack

Source of radiation

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Nuclear fuels - nuclear fuel may be either new fuel being transported to a nuclear power station or spent (used) fuel being transported for reprocessing, storage, or disposal. These materials are solid in form and transported in specially designed packages called shipping casks. Pictured below is a spent fuel shipping cask being surveyed by radiological control personnel.

Radioactive waste - waste material comes from nuclear power generating facilities, nuclear processing plants, research institutions, medical facilities, or other locations. Radioactive waste is commonly transported by highway and rail. Pictured below are 55-gallon drums of radioactive waste (typically containing items such as contaminated protective clothing, rags, etc.) and, on the following page, a railcar loaded with contaminated soil from cleanup operations at a DOE facility.

Radioactive material is one of the most highly regulated hazardous materials transported. The U.S. Department of Transportation regulates domestic shipments of radioactive material. Both the U.S. Nuclear Regulatory Commission and the U.S. Environmental Protection Agency have a role in assisting with development of the hazardous material shipping regulations. The philosophy for managing the transport of radioactive material is highly proactive. Radioactive material has been moved across this country for more than 50 years and, to date, there has never been a death or injury resulting from exposure to this material during transport.

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Check Your Understanding

1. Atoms are made up of ______, ______, and ______.

2. The process of removing ________ from atoms is called ionization.

3. Radioactive material is any material that spontaneously emits ______ ________.

4. The process of an unstable atom emitting radiation is called __________.

5. Radioactive material in an unwanted location is called __________.

6. ________ can pass through the body; __________ can be deposited in or on the surface of the body.

7. One commonly transported source of radioactive material is (pick one):
   a) Radio waves
   b) Visible light
   c) Radiopharmaceuticals
   d) Microwaves

M E R R T T

ANSWERS

1. protons
   neutrons
   electrons
2. electrons
3. ionizing
   radiation
4. radioactivity
5. contamination
6. radiation
   contamination
7. c