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History of Radiation Protection

Scientific Inquiry

Since ancient times, philosophers and scientists have been interested in the basic building blocks of our physical universe. In fact, it was the ancient Greeks who first believed that all matter in the universe must be made of tiny building blocks--or atoms. Beginning with the earliest scholars of science throughout history and into this century, scientists have been driven to learn more about the atom and how to control it.



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Significant Discoveries

It wasn't until the latter part of the the 19th century that scientists truly began to make advances in the study of atomic structure and radiation.



During the 1800s, Sir Issac Newton had proven his theories on gravity. Marie and Pierre Curie had begun their studies in chemistry and physics, and Dimitri Mendeleev had

introduced the periodic system of elements. Just before the turn of the century, Wilhem Conrad Roentgen discovered the basic properties of X-Rays; the properties of ionizing radiation and the possibility of using radiation in medicine.

Finally, in 1896, Henri Becquerel announced the discovery of radioactivity to the Academy of Sciences in Paris. By the early 1900s the study of radiation was a widely accepted scientific endeavor.

New Dangers Come with Discoveries

But, these discoveries did not come without a price. Scientists learned that radiation was not only a source of energy and medicine, it could also be a potential threat to human health if not handled properly. In fact, early pioneers in radiation research died from radiation-induced illnesses (too much exposure). For instance, Thomas Edison's assistant died from a radiation-induced tumor as a result of too much x-Ray exposure. As new uses for



radioactive elements were discovered, potentially fatal incidents of overexposure increased.

For

example, during World War I, radium paint (a mixture of radium and phosphor) was used on military aircraft instruments to make them glow in the dark so they would be more visible to pilots flying at night.

After the war was over, the industry that supported this technology changed their business to paint

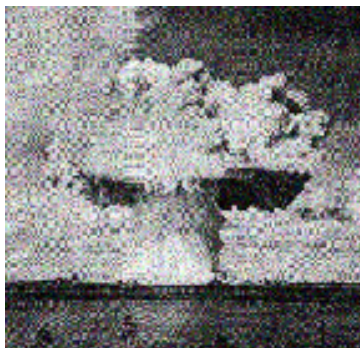
glow-in-the-dark clocks and watch faces. The young women who were employed in this vocation would form a fine point on their paint brushes by pulling the freshly-dipped brushes between their lips before applying the paint onto the watch faces. Unknowingly, they were swallowing small amounts of radium and damaging their bodies.

Over a two-year period, nine women who had worked as dial painters died of severe and unexplained anemia, accompanied by destructive lesions of the mouth and jawbones. A dentist who had treated one of these women finally made the connection between inflammation of the jawbone marrow, and the radium dial painting.

Meeting the Need for Radiation Protection

By 1915, the British Roentgen Society had adopted a resolution to protect people from overexposure to X-rays. This was probably the first organized effort at Radiation Protection.

By 1922, American organizations had adopted the British protection rules. Awareness and education grew, and throughout the 1920s and 30s, more guidelines were developed and various organizations were formed to address radiation protection in the United States and overseas.



Radiation protection was primarily a non-governmental function until the late 1940s. After World War II, the development of the atomic bomb and nuclear reactors caused the Federal government

to establish policies dealing with human exposure to radiation.

In 1959, the Federal Radiation Council was established. The Council was responsible for three things:

1. advising the President of the United States on radiological issues that affected public health
2. providing guidance to all federal agencies in setting radiation protection standards

3. working with the States on radiation issues.

In 1970, Congress created the Environmental Protection Agency (EPA) and radiation protection became a part of EPA's responsibility. Today, EPA's Radiation Protection Division (RPD) is responsible for protecting the public's health and the environment from undue exposure to radiation. This is accomplished by setting safety standards and guidelines. Now, organizations that deal with ionizing radiation must meet these standards to comply with the law.

The Radiation Protection Program is responsible for other protection activities too. For example, there is a [team of experts that respond to emergencies](#) involving radioactivity. There is also a [laboratory](#) that monitors the environment to determine how much radiation is in the air.



[EPA's Radiation Protection Programs](#)

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basic radiation science, people in the history of radiation protection, careers, quizz, puzzles, and more

[Librarians](#)

links to assist librarians in locating radiation science and radiation protection information

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terms, background information, and contacts

[All of Us](#)

general radiation information; information on radioactive materials in consumer products and the use of radiation to treat or manufacture consumer products; the roles of government and of individuals in radiation protection;

Technical Information

[Technical Users and the Regulated Community](#)

links to assessment and compliance models, regulations, links to EPA's radiation laboratories, reports and publications



**About
The Visitors' Center**

Visitors' pages are similar to Topics pages--both bring together selected information from across EPA's Radiation Protection Programs. The difference is that while Topics pages guide users to information related to a particular concept or subject, Visitors' pages guide them to information related to a particular role they fill either professionally or as an individual.

...protecting people and the environment

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the various particles that radioactive molecules emit

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learn to recognize these warning signs

[Calculate Your Dose](#)

radiation is common in our environment; how big is your dose?


Fun Stuff

[Word Search](#)

find radiation terms among these letters

[Crossword](#)

use the terms you've learned to work this crossword puzzle



About Student and Teachers

The Radiation Protection Students and Teachers' pages explain the basic concepts of radiation and radiation protection. There is background information, such as the history of radiation protection and brief biographies of radiation researchers. There is also basic technical information, such as the types of radiation, radiation warning symbols, basic terms, and a dose calculator. You can test what you've learned with puzzles and a quiz.

[Take a Quiz](#)

show off what you've just learned with this
quiz

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People and Discoveries

Below are a few brief biographies of scientists who have dedicated their lives to the study of radiation and atomic energy. For more information on each scientist, follow the links to [Figures in Radiation History](#), which is maintained by the Office of Radiation, Chemical & Biological Safety at Michigan State University.



From the ancient Greeks who first believed that all matter was made up of atoms, to the splitting of the atom in the first half of this century, radiation has long been a source of curiosity for scientists and students alike. This curiosity has led to many scientific discoveries leaving us with a nuclear legacy of both risks and benefits.



Marie and Pierre Curie

Marie Curie (1867-1934) and Pierre Curie (1859-1906) are perhaps two of the most famous scientists known for their contributions to the study of radioactivity. Pierre was born in Paris and Marie in Poland. In 1895, they were married. They both studied at the Sorbonne, and together made significant contributions to the field of radiation studies. They studied the properties of uranium and thorium and soon discovered polonium. Pierre pursued the study of magnetism acting at high temperatures. Marie Curie continued her studies in chemistry in physics and is the only person ever to receive Nobel Awards in both disciplines. The "curie" is a unit of measure now used in radiation studies.

They combined efforts with scientist, Henri Becquerel and in 1903, they were all awarded the Nobel Prize in physics. The "becquerel" is also a unit of measure in radiation studies.



[Marie and Pierre Curie](#)



[Henri Becquerel](#)



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Otto Hahn, Lise Meitner, Fritz Strassman

Otto Hahn, 1879-1968 was born in Germany and studied chemistry. His research with other scientists, including Lise Meitner and Fritz Strassman, led to the discovery of nuclear fission.



[Otto Hahn](#)



[Lise Meitner](#)



Wilhem Roentgen



Wilhem Conrad Roentgen discovered X-rays in 1895. By February 1896, the use of X-rays had spread rapidly and most major cities had at least one X-ray facility. In 1901, he was awarded the first Nobel Prize for physics.



[Wilhem Conrad Roentgen](#)



Enrico Fermi



Enrico Fermi (1901-1954) Fermi was born in Italy in 1901. At the age of 21, he earned his doctorate by writing his thesis on X-rays. In 1938, he won the Nobel Prize in Physics. In 1939, he came to the United States and became a U.S. citizen. Fermi taught physics and worked at Los Alamos Laboratory in New Mexico. He worked with Hungarian-born, Leo Szilard (1898-1964) and others to produce the first sustained nuclear chain reaction on December 2, 1942, in a laboratory beneath the University of Chicago football stadium.



[Enrico Fermi](#)



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What is Radiation?

Radiation is in every part of our lives. It occurs naturally in the earth and can reach us through cosmic rays from outer space. Radiation may also occur naturally in the water we drink or the soils in our backyard. It even exists in food, building materials, and in our own human bodies.

Radiation is used for scientific purposes, medical reasons, and to power some submarines. We can also come into contact with radiation through sources such as X-rays, nuclear power plants, and smoke detectors.

This page covers three aspects of radiation:

1. [Frequently Used Radiation Terms](#)
2. [Sources of Radiation and How It is Measured](#)
3. [Radiation Protection Concepts](#)



Radiation Terms

Radiation can be defined as:

energy given off by the nucleus of an [atom](#) in the form of particles or rays.

Radiation is the same whether it happens in atoms that are made by nature or in atoms that scientists make.

The atom is the smallest unit that shows the chemical behavior characteristics of an [element](#). The center of each atom has a nucleus that contains protons and neutrons. Protons are positively charged particles. Neutrons, which have no electrical charge, hold the protons together. Electrons are negatively charged particles. The electrons surround the nucleus and travel in orbits.

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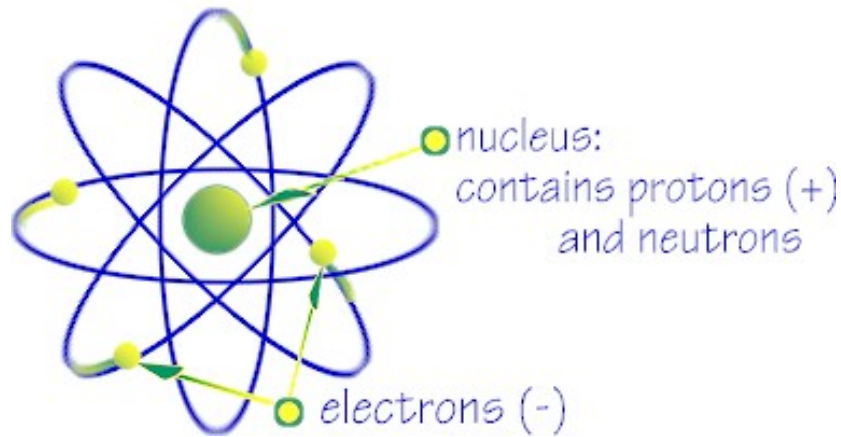
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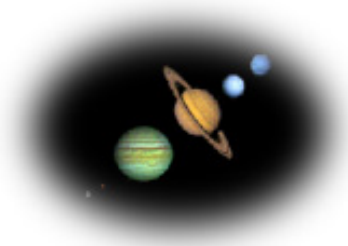
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Structure of An Atom



There is a theory called The Rutherford-Bohr Theory of atomic structure. It compares the atom to our solar system. At the center of every atom is the positively charged nucleus, which could be compared to the sun in our solar system. The electrons move around the nucleus as if in orbit. Just like the earth orbits around the sun.



Repelling forces exist between the nuclear particles. Any change in the number, position, or energy of the nucleons can upset their balance. If this happens, the nucleus becomes unstable or radioactive.

Remember the Periodic Table of the Elements?

An element is a member of a category of atoms that all have the same number of protons. Each element is represented by an atomic number on the Periodic Table. The atomic mass of an element is generally the combined mass of protons and neutrons.

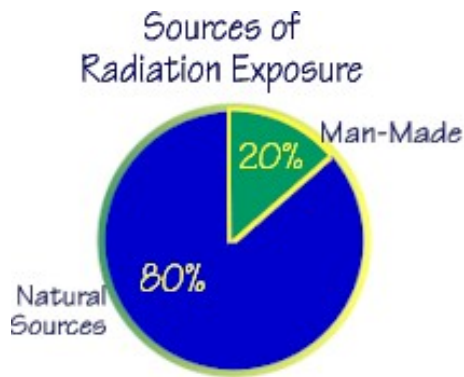
Uranium is an element. This is how it is represented on the periodic table:

92	Atomic Number
U	Symbol
Uranium	Element
238.03	Mass



Sources of Radiation

There are different types of radiation; some are more energetic than others. For example, non-ionizing radiation, has enough energy to move atoms around, but not enough to change them chemically. The most energetic form of radiation is called ionizing radiation. EPA's Radiation Protection Programs are concerned with protecting people and the environment from potentially harmful exposures to ionizing radiation.



We measure radiation dose in units called [rem](#). Scientists estimate that the average person in the United States receives a dose of about 360 millirem of radiation per year. But what are the sources of that exposure: where does it come from?

Eighty percent of human exposure comes from natural sources: radon gas, the human body, outer space, and rocks and soil. The remaining twenty percent comes from man-made radiation sources, primarily medical X-rays.

To learn more about sources and how to measure them, go to our [Calculations Page](#) and estimate how much radiation you receive in a year.



Radiation Protection Concepts

So, now that you have a basic understanding of radiation sources how do you protect yourself? There are three concepts in basic radiation protection. They are:



[time](#)



[distance](#)



[shielding](#)

time

If you decrease the amount of time you spend near the source of radiation, you will decrease the amount of radiation exposure you receive. To imagine this, think of a trip to the beach as a comparison. For instance, if you spend a lot of time on the beach, you will be exposed to the sun, and, ultimately, get a sunburn. If you spend less time in the sun and more time in the shade, your sunburn will be much less severe. This is similar to the way radiation exposure works.

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distance

The farther away you are from a radiation source, the less exposure you will receive. Compare this to an outdoor concert. You can sit directly in front of a speaker, 50 yards from the stage, or on the grass in the park across the street. If you sit in front of the speaker, you will probably suffer some damage to your hearing. If you sit 50 yards from the stage, you will be exposed to an average amount of music. If you sit in the park across the street, the noise is even further reduced and you might not even hear the concert, or even know what song they are

playing.

Radiation exposure is similar. The closer you are to the source, the greater your chances for developing some damage to your body. If you are far from the source, your exposure would be much lower.

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shielding

If you increase the shielding around a radiation source, it will decrease your exposure. For example, if you stand out in the rain without an umbrella, you will get wet. But, if you use an umbrella to shield you from the rain, you will remain dry and protected. This is similar to the idea of shielding in radiation protection. To learn more about shielding and radiation protection, go to the [Types of Radiation Page](#).

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EPA sets radiation protection standards and guidelines that incorporate all aspects of these three basic rules. They are designed to protect our nation's people and the environment from the harmful exposure to radiation.

Read a [booklet](#) about the science of radiation and EPA's role in protecting

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Types of Radiation

Before reading this page, it might be helpful to read the "shielding section" on the [What is Radiation](#) Page.

There are three main types of ionizing radiation. They may be found in sources of man-made radiation as well as natural radiation sources. They are called: [alpha](#), [beta](#), [gamma](#).



Alpha

Alpha particles can be shielded by a sheet of paper or by human skin. However, if radionuclides that emit alpha particles are inhaled, ingested, or enter your body through a cut in your skin, they can be very harmful.



Beta

Beta particles cannot be stopped by a sheet of paper. Some beta particles can be stopped by human skin, but some need a thicker shield (like wood) to stop them. Just like alpha particles, beta particles can also cause serious damage to your health if they enter your body. For example, if ingested, some radionuclides that emit beta particles might be absorbed into your bones and cause damage.



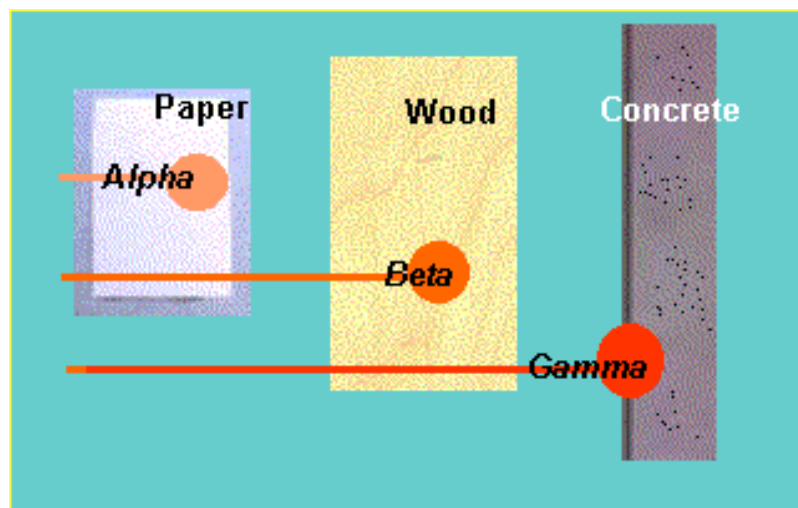
Gamma

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Gamma rays are the most penetrating of the three types of radiation listed here. Gamma rays usually accompany beta, and some alpha rays. Gamma rays will penetrate paper, skin, wood, and other substances. To protect yourself from gamma rays, you need a shield at least as thick as a concrete wall. This type of radiation causes severe damage to your internal organs. (X-rays fall into this category, but they are less penetrating than gamma rays.)

the penetrating power of the three types of ionizing radiation.



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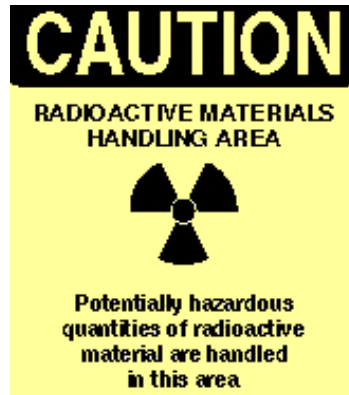
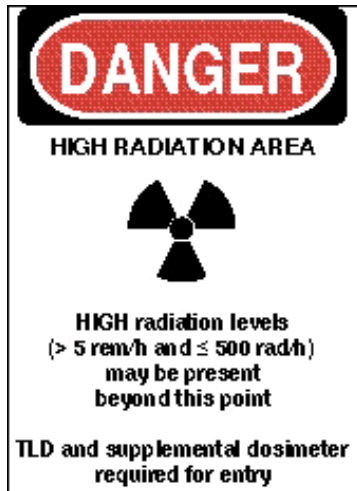
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Radiation Symbols



Have you ever seen this symbol? It is called a tri-foil and it is the international symbol for radiation. The symbol can be magenta or black, on a yellow background. This sign is posted where radioactive materials are handled, or where radiation-producing equipment is used. This sign is used as a warning to protect people from being exposed to radioactivity.

There are different versions of this symbol, as shown here, and they may be displayed at potentially dangerous sites. For example, the signs would be posted where radioactive materials have been found and a site clean-up is happening. You might also see the radiation symbol in a hospital where radioactive medicine is used, or in a university, or research facility.



Watch for these signs!

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This sign shows the symbol for a fallout shelter. Although the designs are similar, the fallout symbol is not the same as the radiation symbol.

Fallout shelters were principally the work of the Defense Civil Preparedness Agency, in conjunction with state and local officials. The shelters were part of a comprehensive program created to prepare U.S. citizens in the event of a nuclear attack.

The Federal Emergency Management Agency took over the Defense Civil Preparedness Agency responsibilities in 1979 (along with a few other Federal agencies). FEMA is still involved in disaster and emergency response along with state and local governments, and other federal agencies include the Environmental Protection Agency (EPA). For more information on EPA's role, visit the [radiological emergency response pages](#).

For more information about the radiation symbol and fallout shelter image, read an article by Paul Frame, Ph.D., CHP, on the University of Michigan's [Radiation and Health Physics Page](#). 

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Careers

The Radiation Protection Program at the Environmental Protection Agency employs scientists, engineers, statisticians, economists, lawyers, policy analysts, and public affairs professionals, just to name a few.

These professionals work together to protect people and the environment from harmful radiation exposure. This is accomplished by working on numerous projects across the United States. Below you will find a summary of some of these projects, followed by a list of the careers that are employed to carry out these projects.



Responsibilities

The professionals in EPA's Radiation Protection Program are responsible for establishing levels to reduce health risks from exposure to radioactive contaminants in the environment. EPA's radiation protection program consists of the staff at our headquarter's in Washington, DC, at regional offices around the county, and two laboratories in Las Vegas, Nevada and Montgomery Alabama. The program also has responsibilities for the safe management of radioactive waste, and for responding to radiological emergencies. Below are some of the projects and responsibilities carried out by EPA's radiation protection professionals.



[Radiation Protection Programs](#)

Guidance on Cleanup Levels

There are places in the United States that have become contaminated by radioactivity from a variety of sources. EPA provides guidance so these places can be cleaned up to a level that makes them safe again.

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Site-Specific Standards

The Department of Energy has built a facility called the Waste Isolation Pilot Plant (WIPP). It was built to serve as a disposal site for transuranic waste, or nuclear waste, created as a result of nuclear weapons production in the 1940s.



Congress gave EPA the responsibility for making sure that the WIPP meets EPA's requirements for environmentally protective radioactive waste disposal. After an intensive effort lasting several years, EPA recently determined that the WIPP could manage and store the waste in a way that ensures it will not pose a risk to people now or in the future.



[WIPP Home Page](#)

General Guidance



EPA is responsible for providing general guidance and related technical information on radiation protection to states and other federal agencies. This guidance is important for the protection of people who work with, and around radiation every day.



[EPA's Federal Guidance Page.](#)

Emergency Response

In the event of a nuclear emergency, EPA has emergency response capabilities and can deploy specially trained staff, sophisticated equipment, and mobile and fixed laboratories to help protect people from exposure to radiation caused by an emergency.



[RERT home page](#)

For complete information on all of our radiation protection activities, visit the [Radiation Protection Programs](#).

Careers in Science

[health physicist](#) | [radiobiologist](#) | [radiochemist](#) | [radioecologist](#) | [biostatistician](#)

Health Physicist

This term originated during the Manhattan Project, which was the name of the effort to develop the atomic bomb during the 1940s. Most of the scientists involved in that project were physicists. Those physicists responsible for health and safety concerns were called health physicists.



The name stuck and today they can be found at work at nuclear power plants, on military submarines, in hospitals (where they are called medical physicists), and at research universities, to name just a few.

Health physics provides the practical means for protecting workers, the general public, and the environment from harmful radiation exposures. At EPA, health physicists work with other scientists to provide the technical basis for radiation protection policies and regulations.

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Radiobiologist

If you like biology, particularly at the cellular and sub-cellular level, the field of radiobiology might be for you. Radiobiology is a specialized branch of biology that studies the effects of ionizing radiation on cells and organisms. The work of radiobiologists contributes significantly to our understanding of how radiation can cause cancer, genetic effects, and damage to fetuses. At EPA, radiobiologists have helped interpret the recommendations of national and international scientific organizations, such as the National Academy of Sciences, into new guidance and policy for radiation protection. [back to](#)

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Radiochemist:

Radiochemistry is the branch of chemistry that uses a combination of standard analytical techniques ("wet chemistry") along with sophisticated radiation measurement techniques to determine the presence of or, in many cases to quantify the activity of, individual radionuclides at extremely low levels.

At EPA's radiation laboratories, radiochemists are often called upon to determine whether radioactive material is present in the environment at levels higher than what is normally known as natural background levels. [back to careers in science](#)



Radioecologist

EPA employs Radioecologists and other environmental scientists to help determine how radioactive material is transported through the physical environment (ground, water, and air) and through ecosystems (e.g., through bioaccumulation). The information they provide can be critical in setting safe clean-up levels at contaminated sites.

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Biostatistician

Biostatistics is the field that makes sense of the tremendous amounts of environmental data that EPA receives. For example, a biostatistician will be asked to determine how many samples need to be taken to determine whether radioactivity is present above a specific level, and to make other recommendations as needed. [back to careers in science](#)

Careers Outside Science

[generalist](#) | [economist](#) | [public affairs](#) | [lawyer](#)

Generalist

There are opportunities for non-science professionals too. If you have a degree in political science, public policy/administration, resources management, or some other cross-discipline degree, you might be employed as an environmental protection specialist or program analyst working to evaluate situations and recommend solutions to a number of environmental challenges.

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Economist

Economists work with scientists and policy makers at EPA to determine the costs of a potential regulation or recommendation to individuals, industries, or society in general. This function is required by Congress and the United States Office of Management and Budget to ensure that EPA knows how much it will cost people to achieve environmental protection. [back to careers outside science](#)



Public Affairs

If you are interested in journalism, education, or general environmental issues, you might consider a career as a public affairs professional.



EPA employs public affairs professionals to develop educational materials about radiation protection activities, and to write about radiation in easy-to-understand terms. Aspects of their job may include writing press releases about important environmental news, meeting with the public at community meetings, or even designing web sites such as this one.

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Lawyer

Within the Radiation Protection Program, there are lawyers who are responsible for making certain that EPA's responsibilities fall within the scope of our authority. For example, when Congress passes a law and EPA is the Agency responsible for implementing that law, a lawyer would review all the documents to make sure EPA is living up to their responsibility, and not overstepping their authority.

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This is just a sampling of the professionals working at EPA in support of its radiation protection activities. If you are interested in any of these careers, we encourage you to talk with your school's guidance counselor about academic degree programs or professional development programs in your area of interest.

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Links

Thanks for visiting the Students and Teachers Pages for Radiation Protection. If you did not find what you were looking for on our site, try one of these other sites for general radiation protection information.

 *Please be aware that we do not control or guarantee the accuracy, relevance, timeliness, or completeness of this outside information.*

- Michigan State University has a great page if you are looking for biographies of [scientists in radiation studies](#).
- [What is the rad symbol?](#) Read a short essay on its history by Paul Frame, Ph.D., at Oak Ridge Institute for Science and Education.
- [What is Nuclear Physics](#). This section of a site under long-term construction, has some good technical information and graphics about nuclear physics.
- [The Nuclear Web](#), of the American Nuclear Society has a lengthy list of resources to numerous sites for radiation information. (...and an extremely cool animated logo)
- [PBS's Frontline produced Nuclear Reaction](#), a documentary about nuclear power.
- [Health Physics Society](#) has an "ask the expert" feature.
- The University of Michigan's [Radiation and Health Physics Site](#) has an extensive list of resources.
- The [Tech Museum of Innovation](#) discusses radiation and related topics--a very cool site!
- The Denver Earth Science Project offers [Do You Know Your 3 R's? Radiation, Radioactivity, and Radon](#), a teaching module that brings together physical, earth, and biological sciences.

EPA Links

- For detailed information on EPA radiation protection programs, policies, and technical information, visit the [Radiation Protection Program Home Page](#).
- If you are looking for other environment information for students and teachers check out [EPA's web page for Students and Teachers](#).

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Take a Quiz



Radiation is created by a process of:

- atomic decay
- unexplainable forces
- elemental neutralization
- atomic stretching



Ionizing radiation:

- is always something to be avoided.
- is a new health miracle medicine.
- has both benefits and risks.
- has no medical or commercial applications.



This profession's name was first given during World War II and the profession's goal is to use practical means for protecting people from harmful radiation exposures.

- economist
- rocket scientist
- radiobiologist
- health physicist



The three main types of ionizing radiation are:

- positive, negative, and neutral
- alpha, beta, and gamma
- up, down, and left
- up, down, and right



The three basic concepts in radiation protection are:

- exposure, energy, and decay
- exposure, time, and decay
- energy, distance, and shielding
- time, distance, and shielding



What percentage of human radiation exposure comes from natural sources?

0%
20%
80%
100%



When did radiation protection first become an important issue in the United States?

During the 1920s and 1930s
During the 1940s
During the 1960s
During the 1990s



Who is the only person ever to receive the Nobel Prize in both chemistry and physics?

Albert Einstein
Marie Curie
Wilhelm Conrad Roentgen
Enrico Fermi



William Conrad Roentgen discovered:

atoms
natural radioactivity
X-rays
neutrons



The U.S. Environmental Protection Agency was founded in:

1960s
1970s
1980s
1990s

Score =

Correct answers:

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Calculate Your Radiation Dose

Directions

1. Enter values or select entries where options are provided. (Some entries for the annual dose calculator are already filled in.)
2. Click the "calculate dose" button.

Source

Your Average Annual Dose (mrem)

Cosmic radiation at sea level (from outer space) 26

What is the elevation (in feet) of your town?

Terrestrial (from the ground):

What region of the US do you live in?

Internal radiation (in your body):

From food and water, (e.g. potassium) 40

From air, (radon) 200

Do you wear a plutonium powered pacemaker?

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Do you have
porcelain crowns or
false teeth?

Travel Related Sources:

Add 1 for each 1000
miles traveled by jet
this year:

Are X-ray luggage
inspection machines
used at your airport?

Do you use gas
lantern mantles
when camping?

Miscellaneous Sources:

Weapons test fallout 1

House construction:
Do you live in a
stone, brick, or
concrete building?

Do you wear a
luminous wristwatch
(LCD)?

Do you watch TV?

Do you use a
computer terminal?

Do you have a
smoke detector in
your home?

How many medical
x-rays do you
receive per year? (40
mrem each)

How many nuclear
medical procedures
do you receive per
year? (14 mrem
each)

Do you live within
50 miles of a nuclear
power plant?

Do you live within
50 miles of a coal
fired power plant?

**TOTAL YEARLY
DOSE
(in mrem)**

Notes

- The amount of radiation exposure is usually expressed in a unit called millirem (mrem). In the United States, the average person is exposed to an effective dose equivalent of approximately 360 mrem (whole-body exposure) per year from all sources (NCRP Report No. 93).]
- The dose calculator is based on the American Nuclear Society's brochure, "Personal Radiation Dose Chart". The primary sources of information we relied on are the National Council on Radiation Protection and Measurements Reports #92-#95, and #100. Please remember that the values used in the calculator are general averages and do not provide precise individual dose calculations.



[National Council on Radiation
Protection and Measurements](#)



- Special thanks to UT-ANS group for providing the CGI script that was used to construct this yearly dose calculator web page.



[Radiation: Risks and Realities](#)

information on radiation, radiation uses
and risks

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...protecting people and the environment

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Word Search

Print out this page and see if you can find all of the words listed below.

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 D U A Y W W O A N L R N C J A
 I I N K G W T E E A O W H W C
 L D N L G E U R N A M M A G E
 C A I M B G E I A T B E J P D
 U R D W S U U N L L G C O E P
 N G E O Q M Y I O F P E M F W
 O Y L C P B T I F R R H N N X
 I R E V N O Y M E L T O A R L
 D B C L I O F I R T M U A Y N
 A T T Z W H D Q M C O Y E O H
 R Y R P C Q W A I W S E T N C
 O U O W Z M V O R R N O L V X
 B L N W P L B Z Q M R W F I K
 P L U T O N I U M P D M O B N

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- | | | |
|-----------|-----------|--------------|
| ALPHA | BECQUEREL | BETA |
| CURIE | DECAY | ELECTRON |
| FERMI | GAMMA | NEUTRON |
| PLUTONIUM | PROTON | RADIONUCLIDE |
| RADIUM | RADON | ROENTGEN |
| TRIFOIL | URANIUM | XRAYS |

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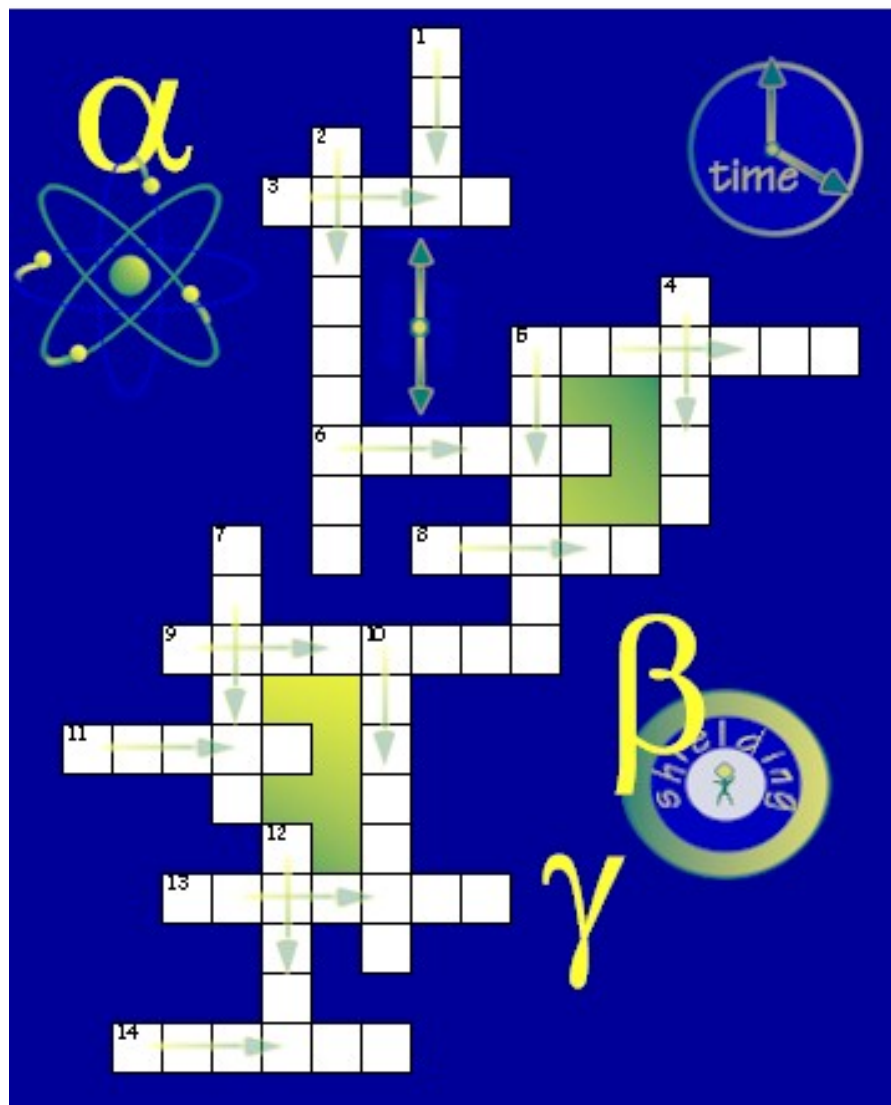
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Cross Word Puzzle

First take a tour through the [Students and Teachers Page for Radiation Protection](#). Then print out this page and see if you can complete the following cross word puzzle.



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Across

3. This is the name of the disintegration process for an unstable nucleus
5. This part of the atom contains neutrons and protons
6. This substance was ingested by paint dial workers in the early 1920s and ultimately led to serious radiation exposures
8. This measurement unit of radioactivity was named after the discoverers of radium
9. This scientist made the first discovery of x-rays in 1896
11. This is a natural colorless, odorless, radioactive gas that is the second leading cause of lung cancer
13. This is the heaviest natural element and is used in making electric power
14. This type of ionizing radiation is useful for investigating broken bones

Down

1. This type of radiation emission has the same charge and mass of an electron
2. This scientist discovered natural radioactivity from the salts of uranium
4. This type of radiation emission can be stopped by a sheet of paper
5. This sub-atomic particle has no charge and helps keep the nucleus of the atom "glued" together
7. This sub-atomic particle determines the atomic number of the atom
10. The name given to the magenta or black on yellow background sign used as a radiation protection warning
12. This type of radiation emission requires thick lead shielding to reduce exposure

[Answers](#)

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