Radium

What Is It? Radium is a radioactive element that occurs naturally in very low concentrations (about one part per trillion) in the earth's crust. Radium in its pure form is a silvery-white heavy metal that oxidizes immediately upon exposure to air. Radium has a density about one-half that of lead and exists in nature mainly as radium-226, although several additional isotopes are present. (Isotopes are different forms of an element that have the same number of protons in the nucleus but a different number of neutrons.) Radium was first discovered in 1898 by Marie and Pierre Curie, and it served as the basis for identifying the activity of various radionuclides. One curie of activity equals the rate of radioactive decay of one gram (g) of radium-226.

Symbol: **Ra**

Atomic Number: **88**
(protons in nucleus)

Atomic Weight: **226**
(naturally occurring)

Of the 25 known isotopes of radium, only two – radium-226 and radium-228 – have half-lives greater than one year and are of concern for Department of Energy environmental management sites. Radium-226 is a radioactive decay product in the uranium-238 decay series and is the precursor of radon-222. Radium-228 is a radioactive decay product in the thorium-232 decay series. Both isotopes give rise to many additional short-lived radionuclides, resulting in a wide spectrum of alpha, beta and gamma radiations. Lead-210, which has a 22-year half-life, is included in the list of short-lived radionuclides associated with radium-226 for completeness, as this isotope and its short-lived decay products are typically present with radium-226. Radium-226 decays slowly (half-life of 1,600 years) by emitting an alpha particle. Radium-228 has a much shorter half-life (5.8 years) and decays by emitting a beta particle. While radium-226 poses a hazard due to its long half-life, radium-228 poses a long-term hazard only if its parent (thorium-232) is present.

Radioactive Properties of Key Radium Isotopes and Associated Radionuclides

Isotope	Half-Life	Natural Abundance (%)	Specific Activity (Ci/g)	Decay Mode	Radiation Energy (MeV)		
					Alpha (α)	Beta (β)	Gamma (γ)
Ra-226	1,600 yr	>99	1.0	α	4.8	0.0036	0.0067
Rn-222	*3.8 days*		*160,000*	α	*5.5*	<	<
Po-218	*3.1 min*		*290 million*	α	*6.0*	<	<
Pb-214	*27 min*		*33 million*	β	-	*0.29*	*0.25*
Bi-214	*20 min*		*45 million*	β	-	*0.66*	*1.5*
Po-214	*0.00016 sec*		*330 trillion*	α	*7.7*	<	<
Pb-210	*22 yr*		*77*	β	-	*0.038*	*0.0048*
Bi-210	*5.0 days*		*130,000*	β	-	*0.39*	-
Po-210	*140 days*		*4,500*	α	*5.3*	<	<
Ra-228	5.8 yr	<<1	280	β	-	0.017	<
Ac-228	*6.1 hr*		*2.3 million*	β	-	*0.48*	*0.97*
Th-228	*1.9 yr*		*830*	α	*5.4*	*0.021*	0.0033
Ra-224	*3.7 days*		*160,000*	α	*5.7*	*0.0022*	*0.010*
Rn-220	*56 sec*		*930 million*	α	*6.3*	<	<
Po-216	*0.15 sec*		*350 billion*	α	*6.8*	<	<
Pb-212	*11 hr*		*1.4 million*	β	-	*0.18*	*0.15*
Bi-212	*61 min*		*15 million*	α, β	*2.2*	*0.47*	*0.19*
Po-212 (64%)	*0.00000031 sec*		*180,000 trillion*	α	*8.8*	-	-
Tl-208 (36%)	*3.1 min*		*300 million*	β	-	*0.60*	*3.4*

Ci = curie, g = gram, and MeV = million electron volts; a "<" means the radiation energy is less than 0.001 MeV, and a dash means the entry is not applicable. (See the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients for an explanation of terms and interpretation of radiation energies.) Bismuth-212 decays by both emitting an alpha particle (36%) and a beta particle (64%). Certain properties of additional radionuclides are included here because they accompany the radium decays. Values are given to two significant figures.

Where Does It Come From? Radium is widely distributed in small amounts in the earth's crust. It is present in all uranium and thorium minerals; its concentration in uranium ores is about one part radium to 3 million parts uranium. The chemical properties of radium are similar to those of barium, and the two substances are removed from uranium ore by precipitation and other chemical processes. Originally, radium was obtained from the rich pitchblende ore found in Bohemia. The carnotite sands of Colorado furnish some radium, but richer ores are found in the Republic of Zaire and the Great Lake Region of Canada. Radium is a major contaminant in mine and milling wastes, such as uranium mill tailings, and is present in various radioactive wastes associated with past uranium processing activities.

How Is It Used? Radium-226 is the only radium isotope used commercially. Historically, the main use of radium has been as a component in luminous paint used on the dials of watches, clocks, and other instruments, although it is no longer used for this purpose. Radium is currently used in brachytherapy to treat various types of cancer. (Brachytherapy is a method of radiation treatment in which sealed sources are used to deliver a radiation dose at a distance of up to a few centimeters by surface, intracavitary, or interstitial application.)

What's in the Environment? Essentially all naturally occurring radium is present as radium-226. Radium exists naturally in soil, rocks, surface water, groundwater, plants, and animals in generally low concentrations – on the order of one part per trillion, or 1 picocurie (pCi)/g. Higher levels are present in uranium ores and other geologic materials. Because of the separation process used to extract uranium from ores, radium-226 is a major contaminant in uranium mill tailings. The concentration of radium in plants is typically about 0.03 (or 3%) of that in soil. However, Brazil nuts in areas of high natural radium have much higher (orders of magnitude) concentration ratios. The average concentration of radium in food has been estimated at less than 0.01 to 0.03 pCi/g. Radium preferentially adheres well to soil particles, with concentrations in sandy soil generally on the order of 500 times higher than in interstitial water (water in the pore spaces between soil particles); it is even less mobile in clay soils, with concentration ratios over 9,000. The maximum contaminant level developed by the U.S. Environmental Protection Agency for radium (as radium-226 and radium-228, combined) in drinking water supplies is 5 pCi per liter (pCi/L).

What Happens to It in the Body? Radium can be taken into the body by eating food, drinking water, or breathing air. Most of the radium taken in by ingestion (about 80%) will promptly leave the body in feces. The remaining 20% enters the bloodstream and is carried to all parts of the body. Inhaled radium can remain in the lungs for several months and will gradually enter the bloodstream and be carried throughout the body. The metabolic behavior of radium in the body is similar to that of calcium. For this reason, an appreciable fraction is preferentially deposited in bone and teeth. The amount in bone decreases with time from the exposure, generally dropping below 10% in a few months to 1% and less in a few years. Release from the bone is slow, so a portion of inhaled and ingested radium will remain in the bones throughout a person's lifetime.

What Are the Primary Health Effects? Radium poses an external as well as an internal health hazard. The strong external gamma radiation associated with several short-lived decay products of radium-226 and radium-228 makes external exposure a concern, and shielding is often needed to handle waste and other materials containing large concentrations of these radionuclides. The majority of epidemiological data on the health effects of radium-226 and radium-228 in humans comes from studies of radium dial painters, radium chemists, and technicians exposed through medical procedures in the early 1900s. These studies, as well as studies on experimental animals, indicate that chronic exposure to radium can induce bone sarcomas. The minimum latency period is seven years after the first exposure, but tumors can continue to appear throughout a lifetime.

The inhalation risk is associated primarily with radium decay products, i.e., radon and its short-lived daughters. Each of the two radium isotopes decays into a gaseous radon isotope. Radon-222 is a short-lived decay product of radium-226, and radon-220 is a short-lived decay product of radium-228. The primary hazard associated with radon arises from the inhalation of its short-lived decay products, which are charged ions that readily attach to dust particles. These particles can be inhaled into the lungs and deposited on the mucous lining of the respiratory tract. Unattached decay products tend to be inhaled deeper into the lungs where the residence time is longer. When alpha particles are then emitted within the lung, the cells lining the airways can be damaged, potentially leading to lung cancer over time.

What Is the Risk? Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including radium *(see box at right)*. The ingestion and inhalation coefficients for radium-226 and radium-228 are generally comparable. While ingestion is the most common means of radium entry into the body, risk coefficients for that exposure route are lower than for inhalation. Similar to other radionuclides, the risk coefficients for tap water are about 75% of those shown for dietary ingestion.

Radiological Risk Coefficients

This table provides selected risk coefficients for inhalation and absorption. Recommended default absorption types were used for inhalation, and dietary values were used for ingestion. These values include the contributions from the short-lived radium decay products. (See text for information on the external exposure pathway.) Risks are for lifetime cancer mortality per unit intake (pCi), averaged over all ages and both genders (10^{-9} is a billionth). Other values, including for morbidity, are also available.

Isotope	Lifetime Cancer Mortality Risk	
	Inhalation *(pCi^{-1})*	Ingestion *(pCi^{-1})*
Ra-226	2.4×10^{-8}	2.9×10^{-9}
Ra-228	9.0×10^{-8}	1.3×10^{-9}

For more information, see the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients and the accompanying Table 1.

In addition to risks from internal exposures, a risk from external gamma exposure is associated with these two isotopes. Using the external gamma risk coefficients to estimate lifetime cancer mortality risks, if it is assumed that 100,000 persons were continuously exposed to a thick layer of soil with an initial average concentration of 1 pCi/g, then 40 of these 100,000 people would be predicted to incur a fatal cancer if the soil contained radium-226, and 7 if it contained radium-228. (This is in comparison to the 20,000 people from the group predicted to die of cancer from all other causes per the U.S. average.) These risks are associated with the gamma rays emitted by various decay products of these two radium isotopes.