

Strontium

What Is It? Strontium is a soft, silver-gray metal that occurs in nature as four stable isotopes. (Isotopes are different forms of an element that have the same number of protons in the nucleus but a different number of neutrons.) Strontium-88 is the most prevalent form, comprising about 83% of natural strontium. The other three stable isotopes and their relative abundance are strontium-84 (0.6%), strontium-86 (9.9%), and strontium-87 (7.0%). Strontium is present in nature chiefly as celestite (SrSO_4) and strontianite (SrCO_3), and it comprises about 0.025% of the earth's crust.

Symbol: Sr

Atomic Number: 38
(protons in nucleus)

Atomic Weight: 88
(naturally occurring)

Sixteen major radioactive isotopes of strontium exist, but only strontium-90 has a half-life sufficiently long (29 years) to warrant concern for nuclear facilities such as the U.S. Department of Energy Hanford site. The half-lives of all other strontium radionuclides are less than 65 days. Strontium-90 decays to yttrium-90 by emitting a beta particle, and yttrium-90 decays by emitting a more energetic beta particle with a half-life of 64 hours to zirconium-90. The main health concerns for strontium-90 are related to the energetic beta particle from yttrium-90.

Radioactive Properties of the Key Strontium Isotope and an Associated Radionuclide

Isotope	Half-Life	Specific Activity (Ci/g)	Decay Mode	Radiation Energy (MeV)		
				Alpha (α)	Beta (β)	Gamma (γ)
Sr-90	29 yr	140	β	-	0.20	-
Y-90	64 hr	550,000	β	-	0.94	<

Ci = curie, g = gram, and MeV = million electron volts; a dash means the entry is not applicable, and a "<" means the radiation energy is less than 0.001 MeV. (See the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients for an explanation of terms and interpretation of radiation energies.) Properties of yttrium-90 are included here because this radionuclide accompanies strontium decays. Values are given to two significant figures.

Where Does It Come From? While four stable isotopes of strontium occur naturally, strontium-90 is produced by nuclear fission. When an atom of uranium-235 (or other fissile nuclide) fissions, it generally splits asymmetrically into two large fragments – fission products with mass numbers in the range of about 90 and 140 – and two or three neutrons. (The mass number is the sum of the number of protons and neutrons in the nucleus of the atom.) Strontium-90 is such a fission product, and it is produced with a yield of about 6%. That is, about six atoms of strontium-90 are produced per 100 fissions. Strontium-90 is a major radionuclide in spent nuclear fuel, high-level radioactive wastes resulting from processing spent nuclear fuel, and radioactive wastes associated with the operation of reactors and fuel reprocessing plants.

How Is It Used? Strontium has a variety of commercial and research uses. It has been used in certain optical materials, and it produces the red flame color of pyrotechnic devices such as fireworks and signal flares. Strontium has also been used as an oxygen eliminator in electron tubes and to produce glass for color television tubes. In addition, strontium-90 has been used as an isotopic energy source in various governmental research applications, including in radiothermal generators to produce electricity for a variety of purposes including devices to power remote weather stations, navigational buoys, and satellites.

What's in the Environment? Beyond the four stable isotopes naturally present in soil, strontium-90 is also present in surface soil around the world as a result of fallout from past atmospheric nuclear weapons tests. Current strontium-90 levels in surface soil typically range from 0.01 to 1 picocurie per gram (pCi/g), reflecting various rainfall and wind patterns, elevation, and terrain; most levels fall between 0.05 and 0.5 pCi/g, with 0.1 pCi/g as a general average. Strontium-90 is relatively mobile and can move down through soil with percolating water to groundwater. Environmental transport of strontium is strongly influenced by its chemical form. Strontium preferentially adheres to soil particles, and the amount in sandy soil is typically about 15 times higher than in interstitial



water (in the pore spaces between soil particles); concentration ratios are typically higher (110) in clay soil. As a note, many years ago the U.S. Environmental Protection Agency (EPA) established a maximum contaminant level for strontium-90 in public drinking water supplies. That value based on extant dosimetry models is 8 pCi per liter (pCi/L). The value using current, improved dosimetry models would be 36 pCi/L.

What Happens to It in the Body? Strontium can be taken into the body by eating food, drinking water, or breathing air. Gastrointestinal absorption from food or water is the principal source of internally deposited strontium in the general population. On average, 30 to 40% of ingested strontium is absorbed into the bloodstream. The amount absorbed tends to decrease with age, and is higher (about 60%) in children in their first year of life. Adults on fasting and low-calcium diets can also increase intestinal absorption to these levels, as the body views strontium as a replacement for calcium. Strontium behaves similarly to calcium (although it is not homeostatically controlled, i.e., the body does not actively regulate levels within the cells), but living organisms generally use and retain it less effectively. For adults, about 31% of the activity entering the blood (plasma) from the gastrointestinal tract is retained by bone surfaces; the remainder goes to soft tissues or is excreted in urine and feces. Much of the activity initially deposited on bone surfaces is returned to plasma within a few days based on an updated biokinetic model that accounts for redistribution in the body. About 8% of the ingested activity remains in the body after 30 days, and this decreases to about 4% after 1 year. This activity is mainly in the skeleton.

What Are the Primary Health Effects? Strontium is a health hazard only if it is taken into the body. External gamma exposure is not a major concern because strontium-90 emits no gamma radiation and its decay product yttrium-90 emits only a small amount. Strontium-90 concentrates in bone surfaces and bone marrow, and its relatively long radioactive half-life (29 years) make it one of the more hazardous products of radioactive fallout. The health effects associated with strontium-90 were studied concurrent with development of the atomic bomb during World War II by the Manhattan Engineer District. Bone tumors and tumors of the blood-cell forming organs are the main health concern. These tumors are associated with the beta particles emitted during the radioactive decay of strontium-90 and yttrium-90.

What Is the Risk? Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including strontium-90 (*see box at right*). Most of the risk is associated with the high-energy beta particle emitted by yttrium-90. Although the risk coefficient for ingestion is lower than for inhalation, ingestion is generally the most common way this radioisotope enters the body. Similar to other radionuclides, the risk coefficient for tap water is about 80% of that for dietary ingestion. In addition to potential radiogenic effects, strontium has been shown to inhibit calcification and cause bone deformities in animals, notably at high doses. The EPA toxicity value for estimating the potential for non-cancer effects from oral exposure is termed a reference dose (RfD), which is an estimate of the highest dose that can be taken in every day without causing an adverse non-cancer effect. The RfD for ingested strontium (*see box at right*) based on rachitic bone effects was developed by studying test animals given relatively high doses over their lifetimes, then adjusting and normalizing those results to a milligram per kilogram per day (mg/kg-day) basis for humans. A noncancer toxicity value for inhalation exposure has not been developed.

Radiological Risk Coefficients		
<i>This table provides selected risk coefficients for inhalation and ingestion. The recommended default absorption type was used for inhalation, and the dietary value was used for ingestion. These values include the contribution from the decay product yttrium-90. Risks are for lifetime cancer mortality per unit intake (pCi), averaged over all ages and both genders (10⁻⁹ is a billionth, and 10⁻¹² is a trillionth). Other values, including for morbidity, are also available.</i>		
Isotope	Lifetime Cancer Mortality Risk	
	Inhalation (pCi ⁻¹)	Ingestion (pCi ⁻¹)
Strontium-90	1.0 × 10 ⁻¹⁰	7.5 × 10 ⁻¹¹
<i>For more information, see the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients and the accompanying Table 1.</i>		
Chemical Toxicity Value		
Non-Cancer Effect: Oral RfD		
0.6 mg/kg-day		