

Samarium

What Is It? Samarium is a very hard, silvery-white metal. It is a member of the lanthanide series and ignites in air at high temperatures (150°C). In nature, samarium occurs as seven isotopes, three of which are radioactive with extremely long half-lives. (Isotopes are different forms of an element that have the same number of protons in the nucleus but a different number of neutrons.) The isotopes and their natural occurrences are samarium-144 (3.1%), samarium-147 (15%), samarium-148 (11%), samarium-149 (14%), samarium-150 (7.4%), samarium-152 (27%), and samarium-154 (23%). The three naturally occurring radioactive isotopes and their half-lives are samarium-147 (110 billion years), samarium-148 (8,000 trillion years), and samarium-149 (10,000 trillion years). Their extremely long half-lives make these three radioactive isotopes essentially indistinguishable from the stable (nonradioactive) isotopes.

Symbol:	Sm
Atomic Number: (protons in nucleus)	62
Atomic Weight: (naturally occurring)	150

Nine major radioactive isotopes of samarium exist in addition to the three naturally occurring ones. Of these nine, only two have half-lives long enough to warrant concern at Department of Energy (DOE) environmental management sites such as Hanford. The half-lives of the other samarium isotopes are less than one year. Radioactive samarium isotopes are produced by the fissioning of uranium and plutonium, generally in nuclear reactors. The shorter-lived samarium isotopes (those with half-lives less than one year) produced more than 20 years ago have long since decayed away. Of the two longer-lived isotopes, samarium-146 is not a major concern at DOE sites because of its low prevalence and very long half-life (and hence low specific activity) that limits its radioactive hazards. The isotope of most concern is samarium-151, a radionuclide with a half-life of 90 years that decays by emitting a relatively low-energy beta particle.

Radioactive Properties of Key Samarium Isotopes						
Isotope	Half-Life (yr)	Specific Activity (Ci/g)	Decay Mode	Radiation Energy (MeV)		
				Alpha (α)	Beta (β)	Gamma (γ)
Sm-146	100,000,000	0.000024	α	2.5	-	-
Sm-151	90	27	β	-	0.020	<

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.) The three naturally occurring samarium isotopes are not included here. Values are given to two significant figures.

Where Does It Come From? Samarium is found in a variety of minerals such as monazite, bastnasite, cerite, gadolinite, and samarskite. These minerals contain different mixes of rare earth metals, which are the elements from lanthanum through lutetium in the periodic table. Samarium generally makes up less than a few percent of these minerals. China currently produces the vast majority of the rare earth metals, totaling about 70,000 metric tons (MT) annually. The United States comes in a distant second, producing around 5,000 MT annually, and samarium makes up only a small fraction of this amount.

Samarium-151 is produced by nuclear fission. When an atom of uranium-235 (or another 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.) The fission yield of samarium-151 is about 0.4%. That is, about four atoms of samarium-151 are produced per 1,000 fissions. Samarium-151 is a significant radionuclide in spent nuclear fuel, high-level radioactive wastes resulting from the processing of spent nuclear fuel, and radioactive wastes associated with the operation of nuclear reactors and fuel reprocessing plants. In addition, samarium-149 is a very good absorber of neutrons and is therefore often used in nuclear reactor control rods; capture of two neutrons by samarium-149 results in samarium-151.

How Is It Used? Samarium has a variety of commercial uses. It is used as a catalyst for certain organic reactions and in pyrophoric alloys for cigarette lighter flints. Samarium oxide is also used in special infrared absorbing glass and in the cores of carbon arc-lamp electrodes. An alloy of samarium with cobalt is used to make a magnetic material with the highest resistance to demagnetization of any known material. Because one isotope (samarium-149) is a very good neutron absorber, this element has also been used as a component in nuclear reactor control rods

What's in the Environment? Samarium is present in the earth's crust at a concentration of about 6 milligram per kilogram (mg/kg), while its concentration in seawater is about 0.00045 micrograms per liter (µg/L). Trace amounts of samarium-151 are present in soil around the globe from radioactive fallout. It can also be present at certain nuclear facilities, such as reactors and spent fuel reprocessing plants.

The transport of samarium in the environment is strongly influenced by its chemical form. It is generally one of the less mobile radioactive metals in soil, although certain forms can move downward with percolating water some distance to underlying layers of soil. Samarium preferentially adheres well to soil particles, with concentrations in sandy soil generally more than 200 times higher than in interstitial water (the water in the pore space between soil particles); it is even less mobile in clay soils, with concentration ratios over 1,000. Thus, samarium is generally not a major contaminant in groundwater at DOE sites.



What Happens to It in the Body? Samarium 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 samarium in the general population. Samarium is not well absorbed into the body after intake. Only about 0.05% of the amount ingested being absorbed into the bloodstream through the digestive tract, with the rest being excreted. Of the samarium that reaches the blood, 45% is deposited in the liver and another 45% is deposited on the surface of the bone, where it can irradiate the bone-forming cells; the remaining 10% is excreted. The samarium that is internally deposited is retained in the body with a biological half-life of almost 10 years (3,500 days). (This information is per simplified models that do not reflect intermediate redistribution.)

What Are the Primary Health Effects?

Samarium-151 is a health hazard only if it is taken into the body. External gamma exposure is not a major concern because samarium-151 emits only a small amount of low-energy gamma radiation. While in the body, samarium-151 poses a health hazard from both the beta particles and gamma rays it emits, and the main health concern is associated with the increased likelihood of inducing cancer in the liver and bone.

What Is the Risk? Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including samarium (*see box at right*). While the coefficients for ingestion are somewhat lower than for inhalation, ingestion is generally the most common means of samarium entry into the body. Similar to other radionuclides, the risk coefficients for tap water are about 70% of those for dietary ingestion.

Radiological Risk Coefficients

This table provides selected risk coefficients for inhalation and ingestion. Maximum values are given for inhalation since no default absorption types were provided, and dietary values were used for ingestion. Risks are for lifetime cancer mortality per unit intake (picocurie, 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.

Isotope	Lifetime Cancer Mortality Risk	
	Inhalation (pCi^{-1})	Ingestion (pCi^{-1})
Samarium-146	1.2×10^{-8}	4.0×10^{-11}
Samarium-151	8.6×10^{-12}	4.6×10^{-13}

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