Selenium

Symbol:	**Se**
Atomic Number: *(protons in nucleus)*	**34**
Atomic Weight: *(naturally occurring)*	**79**

What Is It? Selenium is a non-metallic mineral that resembles sulfur and can exist as a gray crystal, red powder, or vitreous black form. It occurs in nature as six 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.) Selenium-80 is the most prevalent, comprising about half of natural selenium. The other five stable isotopes and their relative abundances are selenium-74 (0.9%), selenium-76 (9.4%), selenium-77 (7.6%), selenium-78 (24%), and selenium-82 (8.7%).

Radioactive Properties of the Key Selenium Isotope

Isotope	Half-Life *(yr)*	Specific Activity *(Ci/g)*	Decay Mode	Radiation Energy *(MeV)*		
				Alpha *(α)*	Beta *(β)*	Gamma *(γ)*
Se-79	650,000	0.070	β	-	0.056	-

Ci = curie, g = gram, and MeV = million electron volts; 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.) Values are given to two significant figures.

Of the nine major radioactive selenium isotopes, only one – selenium-79 – has a half-life long enough to warrant concern at U.S. Department of Energy (DOE) environmental management sites such as Hanford. The half-life of selenium-75 is 120 days and the half-lives of all other isotopes are less than eight hours. Selenium-79 decays by emitting a beta particle with a half-life of 650,000 years with no attendant gamma radiation. Selenium-79 is present in spent nuclear fuel and the wastes resulting from reprocessing this fuel. The low specific activity and relatively low energy of its beta particle limits the radioactive hazards of this isotope.

Where Does It Come From? Selenium occurs naturally as a trace element in most soils, rocks and waters, and it accompanies sulfur in volcanic effluents. Higher concentrations are present in soils near volcanoes and in minerals such as clausthalite, naumannite, tiemannite, and senenosulfur, but selenium does not occur in concentrated deposits. Although it cannot be economically recovered directly from the earth, selenium is commonly generated as a byproduct of electrolytic copper refining. Selenium-79 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.) Selenium-79 is one such fission product, and it is produced with a yield of about 0.04%. That is, four atoms of selenium-79 are produced per 10,000 fissions. Selenium-79 is a component of spent nuclear fuel, high-level radioactive wastes resulting from processing spent fuel, and radioactive wastes associated with the operation of nuclear reactors and fuel reprocessing plants.

How Is It Used? Selenium has a number of industrial applications. It is used in photocells, solar cells, and exposure meters for photography and as a toner for photographic and copier uses. Selenium is also used to decolorize glass and to impart a scarlet red color to clear glass, glazes and enamels. Additional uses are in rectifiers and other electronic equipment, as a vulcanizing agent in processing of rubber, and as an additive in stainless steel and other alloys. Selenium compounds are used as an insecticide to combat insects that attack cultivated plants and also to treat various skin and scalp conditions (such as dandruff).

What's in the Environment? Selenium is naturally present in the earth's crust at an average concentration of about 0.05 milligram per kilogram (mg/kg), and its concentration in seawater is about 0.45 microgram per liter (µg/L). Trace amounts of selenium-79 are present in soil around the globe from radioactive fallout. It can also be present at certain nuclear facilities, such as reactors and facilities that process spent nuclear fuel. The highest concentrations of selenium-79 at the Hanford site are in areas that contain waste from processing irradiated fuel, such as in tanks in the central portion of the site. Selenium is generally one of the less mobile radioactive metals in soil as it preferentially adheres well to soil particles. Concentrations in sandy soil are estimated to be 150 times

higher than in interstitial water (in pore spaces between the soil particles), and it is even less mobile in clay soils where concentration ratios exceed 700. The low fission yield of selenium-79 limits its presence at DOE sites, so it is generally not a major groundwater contaminant at these sites. Its concentration in plants is typically 0.025 (or 2.5%) of that in soil, although levels are much higher in seleniferous plants. Certain foods are especially high in selenium, such as garlic.

What Happens to It in the Body? Selenium can be taken into the body by eating food, drinking water, or breathing air. Children, and to a lesser extent adults, can also be exposed by ingesting soils. Gastrointestinal absorption is the principal source of internally deposited selenium in the general population. About 80% of selenium incorporated in food and soluble inorganic compounds are absorbed from the gastrointestinal tract into the bloodstream. However, elemental selenium and selenides are relatively inactive biologically, and only about 5% of these forms are absorbed from the intestines. After reaching the blood, selenium selectively deposits in the liver (15%), kidneys (5%), spleen (1%) and pancreas (0.5%). The remainder is deposited uniformly throughout all other organs and tissues. Of the selenium deposited in any organ or tissue, 10% is retained with a biological half-life of 3 days, 40% is retained with a biological half-life of 30 days, and 50% is retained with a biological half-life of 150 days. (This information is per simplified models that do not reflect intermediate redistribution.) Selenium does not appear to be absorbed through the skin.

What Are the Primary Health Effects? Selenium is a health hazard only if it is taken into the body. External gamma exposure is not a concern because selenium-79 decays by emitting a beta particle with no gamma radiation. While inside the body, this selenium poses a health hazard from the beta particles emitted during its radioactive decay, and the main concern is associated with the increased likelihood of inducing cancer. Selenium (nonradioactive) is an essential element for humans that is required for normal enzyme function and is necessary for normal growth and metabolism. The recommended daily intakes are 55 and 70 µg for women and men, respectively. It is also an important antioxidant that helps protect cell membranes and prevent free radical generation. Some studies suggest that selenium decreases the risk of certain forms of cancer and diseases of the heart and blood vessels. Chronic exposures to moderate levels can cause selenosis, which is characterized by hair loss, brittle nails, and neurological abnormalities. A common cause of selenium poisoning in humans is overdosing on vitamins. Exposure to selenium or selenium dioxide in air can result in respiratory irritation, bronchial spasms, and coughing. Selenium can cause "blind staggers" in animals that drink water or eat plants or animals in areas of high selenium. The U.S. Environmental Protection Agency (EPA) has classified one specific form of selenium, selenium sulfide, as a probable human carcinogen. Selenium sulfide is not present in foods and is biologically different from the types of selenium compounds found in food or in the environment. Selenium may be protective against the toxic effects of mercury exposures.

What Is the Risk? Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including selenium *(see box at right)*. Ingestion is the exposure route of most concern because this risk coefficient is about three times higher than that for inhalation, and ingestion is generally the most common means of radioactive selenium intake. Similar to other radionuclides, the risk coefficient for tap water is about 75% of that for dietary ingestion. The EPA toxicity value for estimating potential for non-cancer effects from oral exposure to chemicals is called 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 selenium, shown at right, is based on studies of individuals with selenosis who live in areas with naturally high concentrations of selenium in soil. Those exposures were estimated to be at levels about 70 to 100 times higher than the recommended daily intake.

Radiological Risk Coefficients

This table provides selected risk coefficients for inhalation and ingestion. Recommended default absorption types were used for inhalation, 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^{-12} is a trillionth). Other values, including for morbidity, are also available.

Isotope	Lifetime Cancer Mortality Risk	
	Inhalation (pCi^{-1})	Ingestion (pCi^{-1})
Selenium-79	2.3×10^{-12}	6.7×10^{-12}

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

Chemical Toxicity Value

Form	Non-Cancer Effect: *Oral RfD*
Selenium and compounds	0.005 mg/kg-day