

Potassium-40

What Is It? Potassium is a soft, silver-white metal. An important constituent of soil, it is widely distributed in nature and is present in all plant and animal tissues. Potassium-40 is a naturally occurring radioactive isotope of potassium. (An isotope is a different form of an element that has the same number of protons in the nucleus but a different number of neutrons.) Two stable (nonradioactive) isotopes of potassium exist, potassium-39 and potassium-41. Potassium-39 comprises most (about 93%) of naturally occurring potassium, and potassium-41 accounts for essentially all the rest. Radioactive potassium-40 comprises a very small fraction (about 0.012%) of naturally occurring potassium.

Symbol:	K(-40)
Atomic Number: (protons in nucleus)	19
Atomic Weight: (naturally occurring)	39

Several radioactive isotopes of potassium exist in addition to potassium-40. These isotopes all have half-lives of less than one day so they are not of concern for Department of Energy (DOE) environmental management sites such as Hanford. The half-life of potassium-40

Radioactive Properties of Potassium-40							
Isotope	Half-Life (yr)	Natural Abundance (%)	Specific Activity (Ci/g)	Decay Mode	Radiation Energy (MeV)		
					Alpha (α)	Beta (β)	Gamma (γ)
K-40	1.3 billion	0.012	0.0000071	β , EC	-	0.52	0.16

EC = electron capture, Ci = curie, g = gram, and MeV = million electron volts; a dash means that the entry is not applicable. (See the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients for explanation of terms and interpretation of radiation energies.) Potassium-40 decays by both emitting a beta particle (89%) and electron capture (11%). Values are given to two significant figures.

is 1.3 billion years, and it decays to calcium-40 by emitting a beta particle with no attendant gamma radiation (89% of the time) and to the gas argon-40 by electron capture with emission of an energetic gamma ray (11% of the time). Potassium-40 is an important radionuclide in terms of the dose associated with naturally occurring radionuclides.

Where Does It Come From? Potassium-40 is present as a very small fraction of naturally occurring potassium, which is an element found in large amounts throughout nature. Potassium is the seventh most abundant element in the crust of the earth and the sixth most abundant element in solution in the oceans. It is present in mineral waters and brines, and in various minerals such as carnallite, feldspar, saltpeter, greensand, and sylvite. Potassium is an important constituent of fertile soil and is an essential nutrient for plant growth and in the human diet.

How Is It Used? Potassium metal, which is so soft it can be cut with a knife, is used in photoelectric cells. Potassium is one of the most reactive metals in nature, and it forms a number of compounds that have many more commercial uses. For example, the white solid potassium bromide is used in photography, engraving, and lithography. The red crystal potassium chromate and yellow crystal potassium bichromate are powerful oxidizing agents used in matches and fireworks, and they are also used to dye textiles and tan leather. The white crystal potassium iodide is very soluble in water and is used in photography to prepare gelatin emulsions. It is also used in medicine to treat rheumatism and overactive thyroid glands. Potassium nitrate is a white solid used in matches, explosives, and fireworks, and it is also used to pickle meat. The purple crystal potassium permanganate is used as a disinfectant and germicide and as an oxidizing agent in various chemical reactions. The white solid potassium carbonate is used to make glass and soft soap. The white solids potassium sulfate and potassium chloride are used to fertilize soil, because potassium (along with nitrogen and phosphorous) is an essential element for plant growth. Potassium is also an essential element for humans, as a key electrolyte for maintaining basic cardiovascular functions; many people take potassium supplements as capsules or tablets. There are no specific commercial or medical uses associated with the radioactive properties of potassium-40.

What's in the Environment? Potassium is present in the earth's crust, oceans, and all organic material. Its concentration in the earth's crust is about 15,000 milligrams per kilogram (mg/kg) or 1.5%, and its concentration in seawater is about 416 mg per liter (mg/L). Because potassium-40 represents 0.012% of naturally occurring potassium, its concentration in the earth's crust is about 1.8 mg/kg, or 13 picocurie per gram (pCi/g). Potassium binds preferentially to soil, with the concentration associated with sandy soil particles estimated to be 15 times higher than in the interstitial water (in pore spaces between soil particles); it binds more tightly to loam and clay soil, so those concentration ratios are higher (above 50). Together with nitrogen and phosphorous, potassium is a major soil fertilizer, so levels of potassium-40 in soils are strongly influenced by fertilizer use; it is estimated that about 3,000 Ci of potassium-40 are added annually to U.S. soils. Potassium-40 behaves in the environment the same as other potassium isotopes, being assimilated into the tissues of all plants and animals through normal biological processes. It is the predominant radioactive component in human tissues and in most food. For example, milk contains about 2,000 pCi/L of natural potassium-40.



What Happens to It in the Body? Potassium-40 can be taken into the body by drinking water, eating food, or breathing air. Once taken in, potassium-40 behaves in the body in the same manner as other potassium isotopes. Humans require potassium to sustain biological processes, with most (including potassium-40) being almost completely absorbed upon ingestion, moving quickly from the gastrointestinal tract to the bloodstream. The potassium-40 that enters the bloodstream after ingestion or inhalation is quickly distributed to all organs and tissues. Potassium-40 is eliminated from the body with a biological half-life of 30 days. The potassium content of the body is under strict homeostatic control (in which the amount retained is actively regulated by the body to achieve the normal range required for system functions), and it is not influenced by variations in environmental levels. Hence, the potassium-40 content in the body is constant, with an adult male having about 0.1 microcurie (μCi). Each year, this isotope delivers doses of about 18 millirem (mrem) to the soft tissues of the body and 14 mrem to bone.

What Is the Primary Health Effect? Potassium-40 can present both an external and an internal health hazard. The strong gamma radiation associated with the electron-capture decay process (which occurs 11% of the time) makes external exposure to this isotope a concern. While in the body, potassium-40 poses a health hazard from both the beta particles and gamma rays. Potassium-40 behaves the same as ordinary potassium, both in the environment and within the human body – it is an essential element for both. Hence, what is taken in is readily absorbed into the bloodstream and distributed throughout the body, with homeostatic controls regulating how much is retained or cleared. The health hazard of potassium-40 is associated with cell damage caused by the ionizing radiation that results from radioactive decay, with the general potential for subsequent cancer induction.

What Is the Risk? Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including potassium-40 (see box at right). While ingestion is generally the most common type of exposure, the risk coefficients for this route are lower than those for inhalation. As for other radionuclides, the risk coefficient for tap water is about 70% of that for dietary ingestion. In addition to risks from internal exposures, an external gamma exposure risk also exists for potassium-40. To estimate a lifetime cancer mortality risk, if it is assumed that 100,000 people were continuously exposed to a thick layer of soil with an initial average concentration of 1 pCi/g potassium-40, then 4 of these 100,000 people would be predicted to incur a fatal cancer over their lifetime. (This is in comparison to the 25,000 people from the group predicted to die of cancer from all other causes per the U.S. average.)

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})
Potassium-40	2.1×10^{-10}	2.2×10^{-11}

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