Californium

Symbol:	**Cf**
Atomic Number: *(protons in nucleus)*	**98**
Atomic Weight: *(not naturally occurring)*	**-**

What Is It? Californium is a silvery-white or gray metal with a density somewhat greater than that of lead. Californium does not occur naturally but is produced artificially in nuclear reactors and particle accelerators. Ten isotopes of californium are known to exist and all are radioactive. (Isotopes are different forms of an element that have the same number of protons in the nucleus but a different number of neutrons.) Californium was the sixth transuranic element to be discovered and was first produced in 1950 in a cyclotron at the University of California at Berkeley by bombarding curium-242 with helium ions. Californium was named for the state and the University of California.

Of the ten known isotopes, only five have half-lives long enough to warrant concern: californium-248, californium-249, californium-250, californium-251, and californium-252. The half-lives of these isotopes range from 0.91 to 900 years, while those of the other isotopes are less than two months. All five of these isotopes decay by emitting an alpha particle, and all but californium-248 also decay by spontaneous fission (SF), a process in which the atom self-disintegrates into two smaller atoms accompanied by a burst of neutrons and a release of energy. About 3% of the radioactive decays of californium-252 are by SF, while only a very small fraction of the decays of the other three isotopes are by SF. Californium is not a major radionuclide at Department of Energy legacy sites such as Hanford because it was not produced in large quantities.

Radioactive Properties of Key Californium Isotopes

Isotope	Half-Life *(yr)*	Specific Activity *(Ci/g)*	Decay Mode	Radiation Energy *(MeV)*		
				Alpha (α)	Beta (β)	Gamma (γ)
Cf-248	0.91	1,600	α	6.3	0.0060	0.0013
Cf-249	350	4.1	α	5.8	0.044	0.33
Cf-250	13	110	α	6.0	0.0057	0.0012
Cf-251	900	1.6	α	5.8	0.20	0.13
Cf-252	2.6	540	α	5.9	0.0056	0.0012

Ci = curie, g = gram, and MeV = million electron volts. (See the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients for an explanation of terms and interpretation of radiation energies.) About 3% of the decays of californium-252 are by spontaneous fission (SF), with alpha-particle decay occurring 97% of the time. A very small fraction (<0.1%) of the decays of californium-248, californium-249, and californium-250 are also by SF. Values are given to two significant figures.

Where Does It Come From? Californium is a byproduct of plutonium production and can be formed by various neutron capture and radioactive decay routes. Californium-249 results from the beta decay of berkelium-249, while the heavier (higher-numbered) isotopes are produced by intense neutron irradiation, typically in a nuclear reactor. Californium can also be produced in particle accelerators. Although it has never been detected in nature, very minute amounts of californium might exist in some uranium ores and it has been suggested (but not confirmed) that it could be produced in stellar explosions (supernova).

How Is It Used? The only californium isotope that has a commercial use is californium-252. Because this radionuclide is only available in very small quantities its uses are quite limited. Californium-252 is a very strong neutron emitter, with one microgram emitting 170 million neutrons per minute. Thin foils containing californium-252 can be used as a source of fission fragments for research purposes. Californium-252 can also be used as a portable neutron source to identify gold or silver ores through neutron activation analysis, and it can be used in moisture gauges to locate water and oil-bearing layers in oil wells. In addition, californium-252 is used in brachytherapy to treat various types of cancer.

What's in the Environment? Atmospheric testing of nuclear weapons, which ceased worldwide by 1980, would have generated a small amount of environmental californium but fallout levels are extremely low. Californium is typically quite insoluble and adheres well to soil. The concentration in soil particles is estimated to be about 500 times higher than in interstitial water.

What Happens to It in the Body? Californium can be taken into the body by eating food, drinking water, or breathing air. Gastrointestinal absorption from food or water is a likely source of internally deposited californium in the general population. After ingestion or inhalation, most californium is excreted from the body within a few days and never enters the bloodstream; only about 0.05% of the amount taken into the body by ingestion is absorbed into the blood. After leaving the intestine or lung, about 65% of the californium that does enter the bloodstream deposits in the skeleton, 25% deposits in the liver, and the rest deposits in other organs or is excreted, primarily in urine. The biological half-lives in the skeleton and liver are about 50 and 20 years, respectively. (This information is per simplified models that do not reflect intermediate redistribution.) Californium in the skeleton is deposited on bone surfaces and slowly redistributes throughout the bone volume over time.

What Is the Primary Health Effect? Californium is generally a health hazard only if it is taken into the body, although there is an external risk associated with the gamma rays emitted by californium-249 and californium-251. The main means of exposure are ingestion of food and water containing californium isotopes and inhalation of californium-contaminated dust. Ingestion is generally the exposure of concern unless there is a nearby source of contaminated airborne dust. Because californium is taken up in the body much more readily if inhaled rather than ingested, both exposure routes can be important. The major health concern is cancer resulting from the ionizing radiation emitted by californium isotopes deposited on bone surfaces and in the liver.

What Is the Risk? Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including californium *(see box at right)*. While ingestion is generally the most common route of exposure, the risk coefficients for this route are much lower than those for inhalation. Similar to other radionuclides, the risk coefficients for tap water are about 80% of those for dietary ingestion. In addition to risks from internal exposures, there is an external gamma risk associated with exposure to californium-249 and californium-251. 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, then 6 of these 100,000 people would be predicted to incur a fatal cancer if the soil contained californium-249, and 2 if it contained californium-251. (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.)

Radiological Risk Coefficients

This table provides selected risk coefficients for inhalation and ingestion. Maximum values are given for inhalation as no default absorption types were provided, and dietary values were used for ingestion. 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. Because risk values are not available for californium-252, these were estimated by multiplying the risk factors for californium-250 by the ratio of the dose conversion factors for californium-252 to californium-250.

Isotope	Lifetime Cancer Mortality Risk	
	Inhalation *(pCi^{-1})*	**Ingestion** *(pCi^{-1})*
Californium-248	2.4×10^{-8}	3.8×10^{-11}
Californium-249	4.0×10^{-8}	1.2×10^{-10}
Californium-250	3.5×10^{-8}	8.0×10^{-11}
Californium-251	4.1×10^{-8}	1.3×10^{-10}
Californium-252	2.1×10^{-8}	4.1×10^{-11}

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

Californium-252, with about 3% of the decays by spontaneous fission, is a significant source of neutrons and gamma rays. As noted in Federal Guidance Report 12, no detailed information has been compiled on the radiation field (both neutron and gamma rays) associated with distributed sources of radionuclides that decay by spontaneous fission, such as californium-252 in soil. This is because radionuclides with a significant spontaneous fission yield are not typically present in the environment, or if present they are at extremely low concentrations. Hence, no standard values are currently available to estimate the dose or risk from external exposure to californium-252 that accounts for the spontaneous fission dose component.