

Thorium

What Is It? Thorium is a radioactive element that occurs naturally in low concentrations (about 10 parts per million) in the earth's crust. It is about three times as abundant as uranium and about as abundant as lead or molybdenum. Thorium in its pure form is a silvery-white heavy metal that is about as dense as lead. In nature, almost all thorium is thorium-232, although several additional isotopes can be present in small amounts. (Isotopes are different forms of an element that have the same number of protons in the nucleus but a different number of neutrons.) Thorium is a soft, ductile metal that is pyrophoric in powdered form. When heated in air, thorium turnings ignite and burn brilliantly with a white light.

Symbol: Th
Atomic Number: 90
(protons in nucleus)
Atomic Weight: 232
(naturally occurring)

Of the 26 known isotopes of thorium, only 12 have half-lives greater than one second, and of these only 3 have half-lives

sufficiently long to warrant a concern. These key isotopes decay very slowly by emitting an alpha particle. The half-lives of thorium-232 and thorium-230, the isotopes of most concern, are very long. Their low specific activity means these two isotopes are not highly radioactive. Both thorium-232 and thorium-230 are present in soil and ores in secular equilibrium with radium-228 and radium-226, respectively. The health risks for these two radium isotopes (shown in the Radium fact

Radioactive Properties of Key Thorium Isotopes and Associated Radionuclides

Isotope	Half-Life	Natural Abundance (%)	Specific Activity (Ci/g)	Decay Mode	Radiation Energy (MeV)		
					Alpha (α)	Beta (β)	Gamma (γ)
Th-232	14 billion yr	>99	0.00000011	α	4.0	0.012	0.0013
Th-230	77,000 yr	<<1	0.020	α	4.7	0.015	0.0016
Th-229	7,300 yr	<<1	0.22	α	4.9	0.12	0.096
<i>Ra-225</i>	<i>15 days</i>		<i>40,000</i>	β	-	<i>0.11</i>	<i>0.014</i>
<i>Ac-225</i>	<i>10 days</i>		<i>59,000</i>	α	5.8	<i>0.022</i>	<i>0.018</i>
<i>Fr-221</i>	<i>4.8 min</i>		<i>180 million</i>	α	6.3	<i>0.010</i>	<i>0.031</i>
<i>At-217</i>	<i>0.032 sec</i>		<i>1.6 trillion</i>	α	7.1	<	<
<i>Bi-213</i>	<i>46 min</i>		<i>20 million</i>	α, β	0.13	0.44	0.13
<i>Po-213 (98%)</i>	<i>0.0000042 sec</i>		<i>13,000 trillion</i>	α	8.4	-	-
<i>Tl-209 (2%)</i>	<i>2.2 min</i>		<i>410 million</i>	β	-	0.69	2.0
<i>Pb-209</i>	<i>3.3 hr</i>		<i>4.7 million</i>	β	-	0.20	-

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 explanation of terms and interpretation of radiation energies.) Bismuth-213 decays by both emitting an alpha particle (2%) and a beta particle (98%). Certain properties of additional radionuclides are included here because they accompany the thorium decays. Values are to two significant figures.

sheet) must be added to those shown here to estimate the total risk. Thorium-229 is not generally associated with nuclear fuel cycle activities previously performed by the Department of Energy (DOE), and hence is not a radionuclide of concern at DOE environmental management sites. The health risks associated with thorium-228, which has a half-life of 1.9 years, are commonly included with those for radium-228 because thorium-228 cannot persist for an extended period of time in the absence of radium-228. (See the companion fact sheet for Radium.)

Where Does It Come From? Thorium is widely distributed in small amounts in the earth's crust. The chief commercial source is monazite sands in the United States (in North Carolina, South Carolina, Idaho, Colorado, Montana, and Florida) as well as in Brazil, India, Australia, and South Africa. The concentration of thorium oxide in monazite sands is about 3 to 10%. Thorium is also found in the minerals thorite (thorium silicate) and thorianite (mixed thorium and uranium oxides). The isotope thorium-230, a decay product of uranium-238, is found in uranium deposits as well as in uranium mill tailings.

How Is It Used? The principal use of thorium has been in the preparation of the Welsbach mantle for portable gas lanterns. These mantles contain thorium oxide with about 1% cerium oxide and other ingredients, and they glow with a dazzling light when heated in a gas flame. Thorium is an important alloying element in magnesium and is used to coat tungsten wire for components of electronic equipment. Thorium can also be added to ceramic items such as crucibles to make them more heat resistant, as well as to refractive glass to allow for smaller and more accurate camera lenses. In addition, thorium is used in welding rods and electric bulb filaments to improve product performance.

Thorium can also be used as a fuel in nuclear reactors. While thorium-232 itself is not fissile, it transforms into the fissile isotope uranium-233 upon absorption of a neutron. Although use of the thorium-232/uranium-233 fuel cycle has been demonstrated in pilot-scale studies, it has not been proven to be economically or technically viable for use in commercial nuclear power plants.

What's in the Environment? Thorium is naturally present in soil, rocks, surface water, groundwater, plants, and animals at low concentrations, on the order of ten parts per million. Higher levels are present in certain geological materials such as monazite sands. Essentially all naturally occurring thorium is present as thorium-232. Thorium-230 is a radioactive decay product of uranium-238 and is found in low concentrations in uranium deposits and mill tailings. In its natural state, thorium occurs as an oxide (ThO₂), phosphate (ThPO₄), and silicate (ThSiO₄). Thorium preferentially adheres very tightly to soil particles, with concentrations in sandy soil generally more than 3,000 times higher than in interstitial water (water in the pore spaces between soil particles); it is even less mobile in clay soils, with concentration ratios over 5,000. The concentration of thorium in plants is typically about 0.0042 (or 0.42%) of that in soil. Data have not indicated that it biomagnifies in terrestrial or aquatic food chains. Because of its low solubility, thorium is not generally a major groundwater contaminant at DOE sites.



What Happens to It in the Body? Thorium can be taken into the body by eating food, drinking water, or breathing air. Most thorium that is inhaled or ingested in food and water is excreted within a few days, with only a small fraction being absorbed into the bloodstream. Gastrointestinal absorption from food or water is the principal source of internally deposited thorium in the general population. About 0.02 to 0.05% of the amount ingested is absorbed into the bloodstream through the intestines. Of the amount entering the blood, about 70% deposits in bone where it is retained with a biological half-life of about 22 years, 4% deposits in the liver where it is retained with a biological half-life of 700 days, and 16% is uniformly distributed to all other organs and tissues of the body where it is cleared with a biological half-life of 700 days. (per simplified models that do not reflect intermediate redistribution). Most of the remaining 10% is directly excreted. Thorium is predominantly deposited on the endosteal surfaces of mineral bone and only slowly redistributes throughout the bone volume.

What Are the Primary Health Effects? Thorium is generally a health hazard only if it is taken into the body. External gamma exposure is not a major concern because thorium emits only a small amount of gamma radiation. Although thorium-229 has a much higher gamma component than either thorium-232 or thorium-230, thorium-229 comprises a very small fraction of natural thorium. (Note that if significant concentrations of radium occur along with thorium, which is common, the external gamma dose associated with the radium must also be addressed.) The major means of exposure to thorium are ingestion of food and water containing thorium and inhalation of thorium-contaminated dust. Ingestion is generally the main exposure concern, unless there is a nearby source of airborne dust containing thorium such as uranium mill tailings. Thorium is taken up in the body much more readily if inhaled rather than ingested (see table below), so both exposure routes can be important. The main health concern for environmental exposures is generally bone cancer.

Most of the human data for thorium exposure comes from diagnostic studies. Colloidal thorium-232 dioxide (Thorotrast) was injected into patients as a radiographic contrast medium between 1928 and 1955. The epidemiological data from these studies show that the primary health effects of high doses of injected Thorotrast are blood disorders and liver tumors. Some evidence of increased incidence of lung, pancreatic, and hematopoietic cancers was found in workers occupationally exposed to thorium via inhalation. However, these workers were also exposed to several other toxic agents, so direct causation cannot be inferred. Few data are available regarding the health effects associated with low (e.g., environmental) levels of exposure from either inhalation or ingestion.

What Is the Risk? Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including thorium (see box at right). The risk coefficients for the isotopes of most concern (thorium-230 and thorium-232) are similar. While the coefficients for thorium-229 are about five to eight times higher, this isotope is generally not of concern at DOE sites. The risk coefficients for ingestion, the most common type of exposure, are much lower than those for inhalation for all three isotopes. Similar to other radionuclides, the risk coefficients for tap water are nearly 80% of those for dietary ingestion.

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. These values include the contributions from the short-lived thorium decay products. 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)
Th-229	2.2 × 10 ⁻⁷	4.7 × 10 ⁻¹⁰
Th-230	2.7 × 10 ⁻⁸	8.0 × 10 ⁻¹¹
Th-232	4.1 × 10 ⁻⁸	9.1 × 10 ⁻¹¹

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