Neptunium

Symbol:	**Np**
Atomic Number: *(protons in nucleus)*	**93**
Atomic Weight: *(not naturally occurring)*	**-**

What Is It? Neptunium is a ductile, silver-colored metal about twice as dense as lead. It does not occur naturally but is produced artificially by neutron capture reactions by uranium. There are seventeen known isotopes of neptunium, 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.) The first neptunium isotope to be identified was neptunium-239, which has a half-life of 2.4 days. This isotope was first produced in 1940 in a cyclotron at the University of California at Berkeley by bombarding uranium-238 with high-energy neutrons. Neptunium was the first transuranic element to be formed and was named for the planet Neptune.

Of the seventeen neptunium isotopes, only three have half-lives long enough to warrant concern at Department of Energy (DOE) environmental management sites: neptunium-235, neptunium-236, and neptunium-237. The half-lives of these three isotopes range from 1.1 to 2.1 million years, while those of the other isotopes are less than five days. Of the three, neptunium-237 is the most prevalent isotope at DOE sites such as Hanford. It has a half-life of 2.1 million years and decays by emitting an alpha particle with a small amount of gamma radiation. The other two isotopes typically represent less than a few percent of the total neptunium inventory at a site. Neptunium-235 has a half-life of 1.1 years and decays by electron capture; essentially all of this isotope that was produced more than 20 years ago has long since decayed away. Neptunium-236 has a half-life of 120,000 years and decays by emitting a beta particle and electron capture.

Radioactive Properties of Key Neptunium Isotopes and an Associated Radionuclide

Isotope	Half-Life *(yr)*	Specific Activity *(Ci/g)*	Decay Mode	Radiation Energy *(MeV)*		
				Alpha (α)	Beta (β)	Gamma (γ)
Np-235	1.1	1,400	EC	<	0.010	0.0071
Np-236	120,000	0.013	β, EC	-	0.21	0.14
Pu-236 (9%)	*2.9*	*540*	α	*5.8*	*0.013*	*0.0021*
Np-237	2.1 million	0.00071	α	4.8	0.070	0.035

EC = electron capture, Ci = curie, g = gram, and MeV = million electron volts; a dash means the entry is not applicable, and a "<" means the radiation energy is less than 0.001 MeV. (See the companion fact sheet on Radioactive Properties, Internal Distribution, and Risk Coefficients for explanation of terms and interpretation of radiation energies.) The isotope neptunium-236 decays by both emitting a beta particle (9%) and electron capture (91%); a second isotope of neptunium-236 with a half-life of 23 hours also exists. Certain properties of plutonium-236 are included here because this radionuclide accompanies the neptunium-236 decays. Values are given to two significant figures.

Where Does It Come From? Neptunium is a byproduct of plutonium production activities and results from the capture of neutrons by uranium isotopes, usually in a nuclear reactor. Neptunium isotopes can be formed by a variety of neutron capture and radioactive decay routes. Neptunium is present in spent nuclear fuel, high-level radioactive wastes resulting from the processing of spent nuclear fuel, and radioactive wastes associated with the operation of reactors and fuel reprocessing plants. Although neptunium is essentially not naturally present in the environment, very minute amounts may be associated with uranium ores.

How Is It Used? There are no major commercial uses of neptunium, although neptunium-237 is used as a component in neutron detection instruments. Neptunium-237 can also be used to make plutonium-238 (by absorption of a neutron). Neptunium is considered useable in nuclear weapons, although no country is known to have used it to make a nuclear explosive device.

What's in the Environment? Atmospheric testing of nuclear weapons, which ceased worldwide by 1980, generated most environmental neptunium. The level of neptunium in soil from fallout is quite low; for example, the concentration of neptunium-237 is less than 1% of that for plutonium-239 (on the order of

0.0001 picocuries per gram, pCi/g). Accidents and other releases from weapons production facilities have caused localized contamination. Neptunium typically occurs in the environment as an oxide, although other forms can be present. It is generally more mobile than other transuranic elements such as plutonium, americium, and curium, and it can move down with percolating water to underlying layers of soil. Neptunium preferentially adheres to soil particles, with the concentration associated with sandy soil particles estimated to be about 5 times higher than in interstitial water (water in pore spaces between the soil particles); it bonds more tightly to clay soils, where concentration ratios are typically higher (55). Neptunium is readily taken up by plants, and plant concentrations are typically similar to soil concentrations. At Hanford, the highest levels of neptunium are in areas that contain waste from the processing of irradiated fuel, such as the tanks in the central portion of the site.

What Happens to It in the Body? Neptunium 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 neptunium in the general population. After ingestion or inhalation, most neptunium 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 50% of the neptunium that does enter the bloodstream deposits in the skeleton, about 10% deposits in the liver, about 5% deposits in other soft tissues, and the rest 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.) The amount deposited in the liver and skeleton depends on the age of the individual, with fractional uptake in the liver increasing with age. Neptunium in the skeleton is deposited on bone surfaces and slowly redistributes throughout the bone volume over time.

What Is the Primary Health Effect? Neptunium 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 neptunium-236 and to a lesser degree by neptunium-237. The main means of exposure are ingestion of food and water containing neptunium isotopes and inhalation of neptunium-contaminated dust. Ingestion is generally the exposure of concern unless there is a nearby source of contaminated airborne dust. Because neptunium 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 neptunium 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 neptunium *(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 70 to 75% of those for dietary ingestion.

In addition to risks from internal exposures, there is an external gamma risk associated with exposure to neptunium-236 and neptunium-237. 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 neptunium-236, then 2 of these 100,000 people would be predicted to incur a fatal cancer. (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.) The external risk for neptunium-237 is about 15% of that for neptunium-236.

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. The coefficients for neptunium-236 include the contribution from plutonium-236. 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.

Isotope	Lifetime Cancer Mortality Risk	
	Inhalation *(pCi^{-1})*	**Ingestion** *(pCi^{-1})*
Neptunium-235	1.0×10^{-12}	2.8×10^{-13}
Neptunium-236	2.6×10^{-9}	1.5×10^{-11}
Neptunium-237	1.5×10^{-8}	5.3×10^{-11}

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