Cobalt

Symbol:	**Co**
Atomic Number: *(protons in nucleus)*	**27**
Atomic Weight: *(naturally occurring)*	**59**

What Is It? Cobalt is a hard, silvery-white metal that occurs in nature as cobalt-59. Cobalt is a constituent of the minerals cobaltite, smaltite, erythrite, and other ores, and it is usually found in association with nickel, silver, lead, copper, and iron. Pure cobalt metal is prepared by reducing its compounds with aluminum, carbon, or hydrogen. It is similar to iron and nickel in its physical properties. Cobalt has relatively low strength and little ductility at normal temperatures and is a component of several alloys.

Radioactive Properties of Key Cobalt Isotopes

Isotope	Half-Life	Specific Activity *(Ci/g)*	Decay Mode	Radiation Energy *(MeV)*		
				Alpha (α)	Beta (β)	Gamma (γ)
Co-57	270 days	8,600	EC	-	0.019	0.13
Co-60	5.3 yr	1,100	β	-	0.097	2.5

EC = electron capture, 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.

There are nine major radioactive cobalt isotopes. (Isotopes are different forms of an element that have the same number of protons in the nucleus but a different number of neutrons.) Of these, only cobalt-57 and cobalt-60 have half-lives long enough to warrant concern. The half-lives of all other isotopes are less than 80 days. Cobalt-57 decays with a half-life of 270 days by electron capture and cobalt-60 decays with a half-life of 5.3 years by emitting a beta particle with two energetic gamma rays; the combined energy of these two gamma rays is 2.5 MeV (one has an energy of 1.2 MeV and the other has an energy of 1.3 MeV). Cobalt-60 is the isotope of most concern at Department of Energy (DOE) environmental management sites such as Hanford, for the cobalt-57 produced more than 20 years ago has long since decayed away. The two energetic gamma rays that accompany the radioactive decay of cobalt-60 make this isotope an external hazard (that is, it can be hazardous without being taken into the body).

Where Does It Come From? Cobalt is naturally present as the isotope 59 in various ores and to a lesser extent in soil. Cobalt-60 is produced by neutron activation of components in nuclear reactors; it can also be produced in a particle accelerator. 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.) These neutrons can cause additional fissions (producing a chain reaction), escape from the reactor, or irradiate nearby materials. A number of reactor components are made of various alloys of steel that contain chromium, manganese, nickel, iron and cobalt, and these elements can absorb neutrons to produce radioactive isotopes, including cobalt-60. Cobalt-60 is a radionuclide of concern in spent nuclear fuel (as a component of the fuel hardware) and in the radioactive wastes associated with nuclear reactors and fuel reprocessing plants.

How Is It Used? Cobalt is used as a component of several alloys, including carboloy and stellite that are used to make very hard cutting tools. Cobalt is also used in some stainless steels. Alnico, an alloy of aluminum, nickel, cobalt, and other metals, is used to make high-strength, permanent magnets. Cobalt is also used in electroplating to give a hard surface that is resistant to oxidation, and as a blue colorant in pottery enamels and glass. High-energy gamma rays emitted during the radioactive decay of cobalt-60 can be used to detect flaws in metal components and in brachytherapy to treat various types of cancer. (Brachytherapy is a method of radiation treatment in which sealed sources are used to deliver a radiation dose at a distance of up to a few centimeters by surface, intracavitary, or interstitial application.)

What's in the Environment? Cobalt-59 is present in soil as a stable isotope at a concentration of about 1 to 2 milligram per kilogram (mg/kg). Trace amounts of cobalt-60 are also present around the globe from radioactive fallout as a result of past atmospheric weapons tests. It may also be present as a contaminant at certain locations, such as in nuclear reactors and facilities that process spent nuclear fuel, principally in the hardware associated with the spent fuel. Transport of cobalt in the environment is strongly influenced by its chemical form. It is generally one of the less mobile radioactive metals in soil, although certain forms can move downward with percolating water into underlying layers of soil. Under certain conditions, mobility can be enhanced based on the form and environmental setting, for example, when complexes form with cyanide or ferrocyanide. In other settings, cobalt has been found to preferentially adhere to soil. For sandy soil, the concentration in soil particles is estimated to be about 60 times higher than in water between the soil particles, and cobalt binds even more tightly to loam where the estimated concentration ratio is 1,300.

What Happens to It in the Body? Cobalt can be taken into the body by eating food, drinking water, or breathing air. Gastrointestinal absorption from food or water is the principal source of internally deposited cobalt in the general population. Estimates of the gastrointestinal absorption of cobalt range from 5 to 30%, depending on the chemical form and amount ingested; 10% is a typical value for adults and 30% for children. Cobalt is an essential element found in most body tissues, with the highest concentration in the liver. Vitamin B12 is a cobalt-containing vitamin essential for red blood cell formation in humans, and the intestinal absorption of cobalt in this vitamin is high. Fifty percent of cobalt that reaches the blood is excreted right away, mainly in urine; 5% deposits in the liver, and the remaining 45% deposits evenly in other tissues of the body. Of the cobalt that deposits in the liver and other tissues, 60% leaves the body with a biological half-life of 6 days and 20% clears with a biological half-life of 60 days; the last 20% is retained much longer, with a biological half-life of 800 days. On the basis of animal studies, retention of cobalt was determined to be the same for all age groups. Inhaled cobalt oxide moves from the lung to body tissues quite readily.

What Are the Primary Health Effects? Cobalt-60 poses both an internal and external hazard, and the main health concern is associated with the increased likelihood of cancer. External exposure is a concern because of the strong external gamma radiation, and shielding is often needed to handle wastes and other materials with high concentrations of this isotope. Inside the body, cobalt presents a hazard from both beta and gamma radiation.

What Is the Risk? Lifetime cancer mortality risk coefficients have been calculated for nearly all radionuclides, including cobalt *(see box at right)*. While the coefficients for ingestion are somewhat lower than for inhalation, ingestion is generally the most common means of entry into the body. Similar to other radionuclides, the risk coefficients for tap water are about 70% of those for dietary ingestion. In addition to the risk from internal exposure, there is a risk from external gamma exposure. Using the external gamma risk coefficient 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 cobalt-60, then 6 of these 100,000 people would be predicted to incur a fatal cancer. (This is compared to the 20,000 people from the group predicted to die of cancer from all other causes per the U.S. average.) The external risk for cobalt-57 is less than 1% of this risk.

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. (See text at left for information on the external gamma exposure.pathway) 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})
Cobalt-57	1.7×10^{-12}	9.0×10^{-13}
Cobalt-60	3.0×10^{-11}	1.4×10^{-11}

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