

= 14 @. @ 1 years) , ^{115}mCd ($t_{1/2} =$

44 @. @ 6 days) , and ^{117}mCd ($t_{1/2} = 3 @. @ 36 \text{ hours}$) .

The known isotopes of cadmium range in atomic mass from 94 @. @ 950 u (^{95}Cd) to 131 @. @ 946 u (^{132}Cd) . For isotopes lighter than 112 u , the primary decay mode is electron capture and the dominant decay product is element 47 (silver) . Heavier isotopes decay mostly through beta emission producing element 49 (indium) .

One isotope of cadmium , ^{113}Cd , absorbs neutrons with high selectivity : With very high probability , neutrons with energy below the cadmium cut @-@ off will be absorbed ; those higher than the cut @-@ off will be transmitted . The cadmium cut @-@ off is about 0 @. @ 5 eV , and neutrons below that level are deemed slow neutrons , distinct from intermediate and fast neutrons .

Cadmium is created via the long s @-@ process in low @-@ medium mass stars with masses of 0 @. @ 6 to 10 solar masses , taking thousands of years . In that process , a silver atom captures a neutron and then undergoes beta decay .

= = History = =

Cadmium (Latin *cadmia* , Greek ???????? meaning " calamine " , a cadmium @-@ bearing mixture of minerals that was named after the Greek mythological character ?????? , Cadmus , the founder of Thebes) was discovered simultaneously in 1817 by Friedrich Stromeyer and Karl Samuel Leberecht Hermann , both in Germany , as an impurity in zinc carbonate . Stromeyer found the new element as an impurity in zinc carbonate (calamine) , and , for 100 years , Germany remained the only important producer of the metal . The metal was named after the Latin word for calamine , because it was found in this zinc compound . Stromeyer noted that some impure samples of calamine changed color when heated but pure calamine did not . He was persistent in studying these results and eventually isolated cadmium metal by roasting and reducing the sulfide . The potential for cadmium yellow as pigment was recognized in the 1840s , but the lack of cadmium limited this application .

Even though cadmium and its compounds are toxic in certain forms and concentrations , the British Pharmaceutical Codex from 1907 states that cadmium iodide was used as a medication to treat " enlarged joints , scrofulous glands , and chilblains " .

In 1907 , the International Astronomical Union defined the international ångström in terms of a red cadmium spectral line (1 wavelength = $6438 @. @ 46963 \text{ Å}$) . This was adopted by the 7th General Conference on Weights and Measures in 1927 . In 1960 , the definitions of both the metre and ångström were changed to use krypton .

After the industrial scale production of cadmium started in the 1930s and 1940s , the major application of cadmium was the coating of iron and steel to prevent corrosion ; in 1944 , 62 % and in 1956 , 59 % of the cadmium in the United States was used for plating . In 1956 , 24 % of the cadmium in the United States was used for a second application in red , orange and yellow pigments from sulfides and selenides of cadmium .

The stabilizing effect of cadmium chemicals like the carboxylates cadmium laurate and cadmium stearate on PVC led to an increased use of those compounds in the 1970s and 1980s . The demand for cadmium in pigments , coatings , stabilizers , and alloys declined as a result of environmental and health regulations in the 1980s and 1990s ; in 2006 , only 7 % of total cadmium consumption was used for plating , and only 10 % was used for pigments . At the same time , these decreases in consumption were compensated by a growing demand for cadmium for nickel @-@ cadmium batteries , which accounted for 81 % of the cadmium consumption in the United States in 2006 .

= = Occurrence = =

Cadmium makes up about 0 @. @ 1 mg kg $\times 10^{-1}$ (ppm) of Earth 's crust . Typical background concentrations in other environmental media are : atmosphere < 5 ng m $\times 10^{-3}$; soil < 2 mg kg $\times 10^{-1}$; vegetation < 0 @. @ 5 mg kg $\times 10^{-1}$; freshwater < 1 ug L $\times 10^{-1}$; seawater < 50 ng L $\times 10^{-1}$; sediment < 2 mg kg $\times 10^{-1}$. Compared with the more abundant 65 ppm zinc , cadmium is rare . No significant

deposits of cadmium @-@ containing ores are known . Greenockite (CdS) , the only cadmium mineral of importance , is nearly always associated with sphalerite (ZnS) . This association is caused by geochemical similarity between zinc and cadmium , with no geological process likely to separate them . Thus , cadmium is produced mainly as a byproduct from mining , smelting , and refining sulfidic ores of zinc , and , to a lesser degree , lead and copper . Small amounts of cadmium , about 10 % of consumption , are produced from secondary sources , mainly from dust generated by recycling iron and steel scrap . Production in the United States began in 1907 , but not until after World War I did cadmium come into wide use .

Metallic cadmium can be found is the Vilyuy River basin in Siberia .

Rocks mined for phosphate fertilizers contain varying amounts of cadmium , resulting in a cadmium concentration of as much as 300 mg / kg in the fertilizers and a high cadmium content in agricultural soils . Coal can contain significant amounts of cadmium , which ends up mostly in flue dust .

= = Production = =

The British Geological Survey reports that in 2001 , China was the top producer of cadmium with almost one @-@ sixth of the world 's production , closely followed by South Korea and Japan .

Cadmium is a common impurity in zinc ores , and it is most often isolated during the production of zinc . Some zinc ores concentrates from sulfidic zinc ores contain up to 1 @. @ 4 % of cadmium . In the 1970s , the output of cadmium was 6 @. @ 5 pounds per ton of zinc . Zinc sulfide ores are roasted in the presence of oxygen , converting the zinc sulfide to the oxide . Zinc metal is produced either by smelting the oxide with carbon or by electrolysis in sulfuric acid . Cadmium is isolated from the zinc metal by vacuum distillation if the zinc is smelted , or cadmium sulfate is precipitated from the electrolysis solution .

= = Applications = =

Cadmium is a common component of electric batteries , pigments , coatings , and electroplating .

= = = Batteries = = =

In 2009 , 86 % of cadmium was used in batteries , predominantly in rechargeable nickel @-@ cadmium batteries . Nickel @-@ cadmium cells have a nominal cell potential of 1 @. @ 2 V. The cell consists of a positive nickel hydroxide electrode and a negative cadmium electrode plate separated by an alkaline electrolyte (potassium hydroxide) . The European Union put a limit on cadmium in electronics in 2004 of 0 @. @ 01 % , with some exceptions , and reduced the limit on cadmium content to 0 @. @ 002 % .

= = = Electroplating = = =

Cadmium electroplating , consuming 6 % of the global production , is used in the aircraft industry reduce corrosion of steel components . This coating is passivated by chromate salts . A limitation of cadmium plating is hydrogen embrittlement of high @-@ strength steels from the electroplating process . Therefore , steel parts heat @-@ treated to tensile strength above 1300 MPa (200 ksi) should be coated by an alternative method (such as special low @-@ embrittlement cadmium electroplating processes or physical vapor deposition) .

Titanium embrittlement from cadmium @-@ plated tool residues resulted in banishment of those tools (and the implementation of routine tool testing to detect cadmium contamination) in the A @-@ 12 / SR @-@ 71 , U @-@ 2 , and subsequent aircraft programs that use titanium .

= = = Nuclear fission = = =

Cadmium is used in the control rods of nuclear reactors , acting as a very effective " neutron poison

" to control neutron flux in nuclear fission . When cadmium rods are inserted in the core of a nuclear reactor , cadmium absorbs neutrons preventing them from creating additional fission events , thus controlling the amount of reactivity . The pressurized water reactor designed by Westinghouse Electric Company uses an alloy consisting of 80 % silver , 15 % indium , and 5 % cadmium .

= = = Compounds = = =

Cadmium oxide was used in black and white television phosphors and in the blue and green phosphors of color television cathode ray tubes . Cadmium sulfide (CdS) is used as a photoconductive surface coating for photocopier drums .

Various cadmium salts are used in paint pigments , with CdS as a yellow pigment being the most common . Cadmium selenide is a red pigment , commonly called cadmium red . To painters who work with the pigment , cadmium provides the most brilliant and durable yellows , oranges , and reds ? so much so that during production , these colors are significantly toned down before they are ground with oils and binders or blended into watercolors , gouaches , acrylics , and other paint and pigment formulations . Because these pigments are potentially toxic , users should use a barrier cream on the hands to prevent absorption through the skin even though the amount of cadmium absorbed into the body through the skin is reported to be less than 1 % .

In PVC , cadmium was used as heat , light , and weathering stabilizers . Currently , cadmium stabilizers have been completely replaced with barium @-@ zinc , calcium @-@ zinc and organo @-@ tin stabilizers . Cadmium is used in many kinds of solder and bearing alloys , because a low coefficient of friction and fatigue resistance . It is also found in some of the lowest @-@ melting alloys , such as Wood 's metal .

= = = Laboratory uses = = =

Helium ? cadmium lasers are a common source of blue @-@ ultraviolet laser light . They operate at either 325 or 422 nm in fluorescence microscopes and various laboratory experiments . Cadmium selenide quantum dots emit bright luminescence under UV excitation (He @-@ Cd laser , for example) . The color of this luminescence can be green , yellow or red depending on the particle size . Colloidal solutions of those particles are used for imaging of biological tissues and solutions with a fluorescence microscope .

Cadmium is a component of some compound semiconductors , such as cadmium sulfide , cadmium selenide , and cadmium telluride , used for light detection and solar cells . HgCdTe is sensitive to infrared light and can be used as an infrared detector , motion detector , or switch in remote control devices .

In molecular biology , cadmium is used to block voltage @-@ dependent calcium channels from fluxing calcium ions , as well as in hypoxia research to stimulate proteasome @-@ dependent degradation of Hif @-@ 1? .

= = = Cadmium @-@ selective sensors = = =

Cadmium @-@ selective sensors based on the fluorophore BODIPY have been developed for imaging and sensing of cadmium in cells .

= = Biological role = =

Cadmium has no known function in higher organisms , but a cadmium @-@ dependent carbonic anhydrase has been found in some marine diatoms . The diatoms live in environments with very low zinc concentrations and cadmium performs the function normally carried out by zinc in other anhydrases . This was discovered with X @-@ ray absorption fluorescence spectroscopy (XAFS) .

The highest concentration of cadmium is absorbed in the kidneys of humans , and up to about 30 mg of cadmium is commonly inhaled throughout human childhood and adolescence .

Cadmium can be used to block calcium channels in chicken neurons . Analytical methods for the determination of cadmium in biological samples have been reviewed .

= = Environment = =

The biogeochemistry of cadmium and its release to the environment has been the subject of review , as has the speciation of cadmium in the environment .

Environmental concentrations can exceed adverse @-@ effect @-@ thresholds in cadmium @-@ polluted ecosystems (e.g. in some parts of Europe) and pollutant cadmium can accumulate in invertebrates , earthworms , seabirds , marine mammals , plants , and some algal species ; effects in animals include kidney disorders , impairment of enzymes , disruption of calcium metabolism , and changes in cell membrane permeability ; excess Cd uptake in plants can affect growth and metabolic processes such as photosynthesis and transpiration .

= = Safety = =

The bioinorganic aspects of cadmium toxicity have been reviewed .

The most dangerous form of occupational exposure to cadmium is inhalation of fine dust and fumes , or ingestion of highly soluble cadmium compounds . Inhalation of cadmium fumes can result initially in metal fume fever but may progress to chemical pneumonitis , pulmonary edema , and death .

Cadmium is also an environmental hazard . Human exposure is primarily from fossil fuel combustion , phosphate fertilizers , natural sources , iron and steel production , cement production and related activities , nonferrous metals production , and municipal solid waste incineration . Bread , root crops , and vegetables also contribute to the cadmium in modern populations .

There have been a few instances of general population poisoning as the result of long @-@ term exposure to cadmium in contaminated food and water , and research into an estrogen mimicry that may induce breast cancer is ongoing . In the decades leading up to World War II , mining operations contaminated the Jinz? River in Japan with cadmium and traces of other toxic metals . As a consequence , cadmium accumulated in the rice crops along the riverbanks downstream of the mines . Some members of the local agricultural communities consumed the contaminated rice and developed itai @-@ itai disease and renal abnormalities , including proteinuria and glucosuria .

The victims of this poisoning were almost exclusively post @-@ menopausal women with low iron and other mineral body stores . Similar general population cadmium exposures in other parts of the world have not resulted in the same health problems because the populations maintained sufficient iron and other mineral levels . Thus , although cadmium is a major factor in the itai @-@ itai disease in Japan , most researchers have concluded that it was one of several factors . Cadmium is one of six substances banned by the European Union 's Restriction on Hazardous Substances (RoHS) directive , which regulates hazardous substances in electrical and electronic equipment but allows for certain exemptions and exclusions from the scope of the law . The International Agency for Research on Cancer has classified cadmium and cadmium compounds as carcinogenic to humans . Although occupational exposure to cadmium is linked to lung and prostate cancer , there is still a substantial controversy about the carcinogenicity of cadmium in low environmental exposure . Recent data from epidemiological studies suggest that intake of cadmium through diet associates to higher risk of endometrial , breast and prostate cancer as well as to osteoporosis in humans . A recent study has demonstrated that endometrial tissue is characterized by higher levels of cadmium in current and former smoking females .

Cadmium exposure is a risk factor associated with a large number of illnesses including kidney disease , early atherosclerosis , hypertension , and cardiovascular diseases . Although studies show a significant correlation between cadmium exposure and occurrence of disease in human populations , a necessary molecular mechanism has not been identified . One hypothesis holds that cadmium is an endocrine disruptor and some experimental studies have shown that it can interact with different hormonal signaling pathways . For example , cadmium can bind to the estrogen

receptor alpha , and affect signal transduction along the estrogen and MAPK signaling pathways at low doses .

Tobacco smoking is the most important single source of cadmium exposure in the general population . An estimated 10 % of the cadmium content of a cigarette is inhaled through smoking . Absorption of cadmium through the lungs is more effective than through the gut , and as much as 50 % of the cadmium inhaled in cigarette smoke may be absorbed . On average , cadmium concentrations in the blood of smokers is 4 times 5 times greater and in the kidney , 2 ? 3 times greater than non @-@ smokers . Despite the high cadmium content in cigarette smoke , there seems to be little exposure to cadmium from passive smoking .

In a non @-@ smoking population , food is the greatest source of exposure . High quantities of cadmium can be found in crustaceans , mollusks , offal , and algae products . However , grains , vegetables , and starchy roots and tubers are consumed in much greater quantity in the US , and are the source of the greatest dietary exposure . Most plants bio @-@ accumulate metal toxins like Cd , and when composted to form organic fertilizers yield a product which can often contain high amounts (e.g. , over 0 @. @ 5 mg) of metal toxins for every kilo of fertilizer . Fertilizers made from animal dung (e.g. , cow dung) or urban waste can contain similar amounts of Cd . The Cd added to the soil from fertilizers (rock phosphates or organic fertilizers) become bio @-@ available and toxic only if the soil pH is low (i.e. , acidic soils) . Zinc is chemically similar to cadmium and some evidence indicates the presence of Zn ions reduces cadmium toxicity .

Zinc , Cu , Ca , and Fe ions , and selenium with vitamin C are used to treat Cd intoxication , though it is not easily reversed .

= = = Regulations = = =

Because of the adverse effects of cadmium on the environment and human health , the supply and use of cadmium is restricted in Europe under the REACH Regulation .

The EFSA Panel on Contaminants in the Food Chain specifies that 2 @. @ 5 ?g / kg body weight is a tolerable weekly intake for humans . The Joint FAO / WHO Expert Committee on Food Additives has declared 7 ?g / kg bw to be the provisional tolerable weekly intake level .

The US Occupational Safety and Health Administration (OSHA) has set the permissible exposure limit (PEL) for cadmium at a time @-@ weighted average (TWA) of 0 @. @ 005 ppm . The National Institute for Occupational Safety and Health (NIOSH) has not set a recommended exposure limit (REL) and has designated cadmium as a known human carcinogen . The IDLH (immediately dangerous to life and health) level for cadmium is 9 mg / m³ .

= = = Product recalls = = =

In May 2006 , a sale of the seats from Arsenal F.C. ' s old stadium , Highbury in London , England was cancelled when the seats were discovered to contain trace amounts of cadmium . Reports of high levels of cadmium use in children 's jewelry in 2010 led to a US Consumer Product Safety Commission investigation . The U.S. CPSC issued specific recall notices for cadmium content in jewelry sold by Claire 's and Wal @-@ Mart stores .

In June 2010 , McDonald 's voluntarily recalled more than 12 million promotional " Shrek Forever After 3D " Collectable Drinking Glasses because of the cadmium levels in paint pigments on the glassware . The glasses were manufactured by Arc International , of Millville , NJ , USA .