

= Selenium =

Selenium is a chemical element with symbol Se and atomic number 34 . It is a nonmetal with properties that are intermediate between the elements above and below in the periodic table , sulfur and tellurium . It rarely occurs in its elemental state or as pure ore compounds in the Earth 's crust . Selenium ( Greek ?????? selene meaning " Moon " ) was discovered in 1817 by Jöns Jacob Berzelius , who noted the similarity of the new element to the previously discovered tellurium ( named for the Earth ) .

Selenium is found in metal sulfide ores , where it partially replaces the sulfur . Commercially , selenium is produced as a byproduct in the refining of these ores , most often during production . Minerals that are pure selenide or selenate compounds are known but rare . The chief commercial uses for selenium today are glassmaking and pigments . Selenium is a semiconductor and is used in photocells . Applications in electronics , once important , have been mostly supplanted by silicon semiconductor devices . Selenium is still used in a few types of DC power surge protectors and one type of fluorescent quantum dot .

Selenium salts are toxic in large amounts , but trace amounts are necessary for cellular function in many organisms , including all animals . Selenium is an ingredient in many multivitamins and other dietary supplements , including infant formula . It is a component of the antioxidant enzymes glutathione peroxidase and thioredoxin reductase ( which indirectly reduce certain oxidized molecules in animals and some plants ) . It is also found in three deiodinase enzymes , which convert one thyroid hormone to another . Selenium requirements in plants differ by species , with some plants requiring relatively large amounts and others apparently requiring none .

= = Characteristics = =

= = = Physical properties = = =

Selenium forms several allotropes that interconvert with temperature changes , depending somewhat on the rate of temperature change . When prepared in chemical reactions , selenium is usually an amorphous , brick @-@ red powder . When rapidly melted , it forms the black , vitreous form , usually sold commercially as beads . The structure of black selenium is irregular and complex and consists of polymeric rings with up to 1000 atoms per ring . Black Se is a brittle , lustrous solid that is slightly soluble in CS<sub>2</sub> . Upon heating , it softens at 50 ° C and converts to gray selenium at 180 ° C ; the transformation temperature is reduced by presence of halogens and amines .

The red ? , ? , and ? forms are produced from solutions of black selenium by varying the evaporation rate of the solvent ( usually CS<sub>2</sub> ) . They all have relatively low , monoclinic crystal symmetries and contain nearly identical puckered Se<sub>8</sub> rings with different arrangements , as in sulfur . The packing is most dense in the ? form . In the Se<sub>8</sub> rings , the Se @-@ Se distance is 233 @.@ 5 pm and Se @-@ Se @-@ Se angle is 105 @.@ 7 ° . Other selenium allotropes may contain Se<sub>6</sub> or Se<sub>7</sub> rings .

The most stable and dense form of selenium is gray and has a hexagonal crystal lattice consisting of helical polymeric chains , where the Se @-@ Se distance is 237 @.@ 3 pm and Se @-@ Se @-@ Se angle is 130 @.@ 1 ° . The minimum distance between chains is 343 @.@ 6 pm . Gray Se is formed by mild heating of other allotropes , by slow cooling of molten Se , or by condensing Se vapor just below the melting point . Whereas other Se forms are insulators , gray Se is a semiconductor showing appreciable photoconductivity . Unlike the other allotropes , it is insoluble in CS<sub>2</sub> . It resists oxidation by air and is not attacked by nonoxidizing acids . With strong reducing agents , it forms polyselenides . Selenium does not exhibit the changes in viscosity that sulfur undergoes when gradually heated .

= = = Isotopes = = =

Selenium has six naturally occurring isotopes . Synthetic isotope  $^{79}\text{Se}$  and 23 others have been identified :

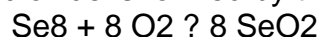
$^{82}\text{Se}$  is stable , for all practical purposes . See also Selenium @-@ 79 for recent changes in the measured half @-@ life of  $^{79}\text{Se}$  , which are important for the dose calculations in the geological disposal of long @-@ lived radioactive waste .

= = Chemical compounds = =

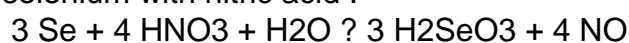
Selenium compounds commonly exist in the oxidation states  $-2$  ,  $+2$  ,  $+4$  , and  $+6$  .

= = = Chalcogen compounds = = =

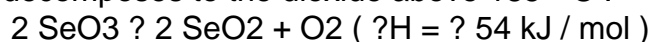
Selenium forms two oxides : selenium dioxide (  $\text{SeO}_2$  ) and selenium trioxide (  $\text{SeO}_3$  ) . Selenium dioxide is formed by the reaction of elemental selenium with oxygen :



It is a polymeric solid that forms monomeric  $\text{SeO}_2$  molecules in the gas phase . It dissolves in water to form selenous acid ,  $\text{H}_2\text{SeO}_3$  . Selenous acid can also be made directly by oxidizing elemental selenium with nitric acid :



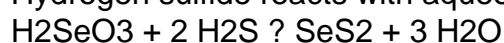
Unlike sulfur , which forms a stable trioxide , selenium trioxide is thermodynamically unstable and decomposes to the dioxide above  $185^\circ \text{C}$  :



Selenium trioxide is produced in the laboratory by the reaction of anhydrous potassium selenate (  $\text{K}_2\text{SeO}_4$  ) and sulfur trioxide (  $\text{SO}_3$  ) .

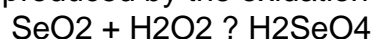
Salts of selenous acid are called selenites . These include silver selenite (  $\text{Ag}_2\text{SeO}_3$  ) and sodium selenite (  $\text{Na}_2\text{SeO}_3$  ) .

Hydrogen sulfide reacts with aqueous selenous acid to produce selenium disulfide :



Selenium disulfide consists of 8 @-@ membered rings . It has an approximate composition of  $\text{SeS}_2$  , with individual rings varying in composition , such as  $\text{Se}_4\text{S}_4$  and  $\text{Se}_2\text{S}_6$  . Selenium disulfide has been used in shampoo as an antidandruff agent , an inhibitor in polymer chemistry , a glass dye , and a reducing agent in fireworks .

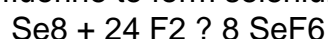
Selenium trioxide may be synthesized by dehydrating selenic acid ,  $\text{H}_2\text{SeO}_4$  , which is itself produced by the oxidation of selenium dioxide with hydrogen peroxide :



Hot , concentrated selenic acid can react with gold to form gold ( III ) selenate .

= = = Halogen compounds = = =

Iodides of selenium are not well known . The only stable chloride is selenium monochloride (  $\text{Se}_2\text{Cl}_2$  ) , which might be better known as selenium ( I ) chloride ; the corresponding bromide is also known . These species are structurally analogous to the corresponding disulfur dichloride . Selenium dichloride is an important reagent in the preparation of selenium compounds ( e.g. the preparation of  $\text{Se}_7$  ) . It is prepared by treating selenium with sulfuryl chloride (  $\text{SO}_2\text{Cl}_2$  ) . Selenium reacts with fluorine to form selenium hexafluoride :

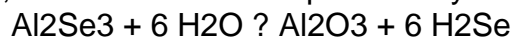


In comparison with its sulfur counterpart ( sulfur hexafluoride ) , selenium hexafluoride (  $\text{SeF}_6$  ) is more reactive and is a toxic pulmonary irritant . Some of the selenium oxyhalides , such as selenium oxyfluoride (  $\text{SeOF}_2$  ) and selenium oxychloride (  $\text{SeOCl}_2$  ) have been used as specialty solvents .

= = = Selenides = = =

Analogous to the behavior of other chalcogens , selenium forms hydrogen selenide ,  $\text{H}_2\text{Se}$  . It is a

strongly odiferous , toxic , and colorless gas . It is more acidic than  $\text{H}_2\text{S}$  . In solution it ionizes to  $\text{HSe}^-$  . The selenide dianion  $\text{Se}^{2-}$  forms a variety of compounds , including the minerals from which selenium is obtained commercially . Illustrative selenides include mercury selenide (  $\text{HgSe}$  ) , lead selenide (  $\text{PbSe}$  ) , zinc selenide (  $\text{ZnSe}$  ) , and copper indium gallium diselenide (  $\text{Cu}(\text{Ga}, \text{In})_2\text{Se}_2$  ) . These materials are semiconductors . With highly electropositive metals , such as aluminium , these selenides are prone to hydrolysis :

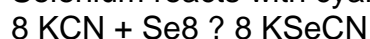


Alkali metal selenides react with selenium to form polyselenides ,  $\text{Se}_n^{2-}$  , which exist as chains .

== Other compounds ==

Tetraselenium tetranitride ,  $\text{Se}_4\text{N}_4$  , is an explosive orange compound analogous to tetrasulfur tetranitride (  $\text{S}_4\text{N}_4$  ) . It can be synthesized by the reaction of selenium tetrachloride (  $\text{SeCl}_4$  ) with [ (  $\text{CH}_3$  )<sub>3</sub>Si ]<sub>2</sub>N<sub>2</sub> .

Selenium reacts with cyanides to yield selenocyanates :



== Organoselenium compounds ==

Selenium , especially in the II oxidation state , forms stable bonds to carbon , which are structurally analogous to the corresponding organosulfur compounds . Especially common are selenides (  $\text{R}_2\text{Se}$  , analogues of thioethers ) , diselenides (  $\text{R}_2\text{Se}_2$  , analogues of disulfides ) , and selenols (  $\text{RSeH}$  , analogues of thiols ) . Representatives of selenides , diselenides , and selenols include respectively selenomethionine , diphenyldiselenide , and benzeneselenol . The sulfoxide in sulfur chemistry is represented in selenium chemistry by the selenoxides ( formula  $\text{RSe}(\text{O})\text{R}$  ) , which are intermediates in organic synthesis , as illustrated by the selenoxide elimination reaction . Consistent with trends indicated by the double bond rule , selenoketones ,  $\text{R}(\text{C}=\text{Se})\text{R}$  , and selenaldehydes ,  $\text{R}(\text{C}=\text{Se})\text{H}$  , are rarely observed .

== History ==

Selenium ( Greek ?????? selene meaning " Moon " ) was discovered in 1817 by Jöns Jakob Berzelius and Johan Gottlieb Gahn . Both chemists owned a chemistry plant near Gripsholm , Sweden , producing sulfuric acid by the lead chamber process . The pyrite from the Falun mine created a red precipitate in the lead chambers which was presumed to be an arsenic compound , so the pyrite 's use to make acid was discontinued . Berzelius and Gahn wanted to use the pyrite and they also observed that the red precipitate gave off a smell like horseradish when burned . This smell was not typical of arsenic , but a similar odor was known from tellurium compounds . Hence , Berzelius 's first letter to Alexander Marcet stated that this was a tellurium compound . However , the lack of tellurium compounds in the Falun mine minerals eventually led Berzelius to reanalyze the red precipitate , and in 1818 he wrote a second letter to Marcet describing a newly found element similar to sulfur and tellurium . Because of its similarity to tellurium , named for the Earth , Berzelius named the new element after the Moon .

In 1873 , Willoughby Smith found that the electrical resistance of grey selenium was dependent on the ambient light . This led to its use as a cell for sensing light . The first commercial products using selenium were developed by Werner Siemens in the mid @-@ 1870s . The selenium cell was used in the photophone developed by Alexander Graham Bell in 1879 . Selenium transmits an electric current proportional to the amount of light falling on its surface . This phenomenon was used in the

design of light meters and similar devices . Selenium 's semiconductor properties found numerous other applications in electronics . The development of selenium rectifiers began during the early 1930s , and these replaced copper oxide rectifiers because they were more efficient . These lasted in commercial applications until the 1970s , following which they were replaced with less expensive and even more efficient silicon rectifiers .

Selenium came to medical notice later because of its toxicity to human beings working in industries . Selenium was also recognized as an important veterinary toxin , which is seen in animals that have eaten high @-@ selenium plants . In 1954 , the first hints of specific biological functions of selenium were discovered in microorganisms . It was discovered to be essential for mammalian life 1957 . In the 1970s , it was shown to be present in two independent sets of enzymes . This was followed by the discovery of selenocysteine in proteins . During the 1980s , selenocysteine was shown to be encoded by the codon UGA . The recoding mechanism was worked out first in bacteria and then in mammals ( see SECIS element ) .

= = Occurrence = =

Native ( i.e. , elemental ) selenium is a rare mineral , which does not usually form good crystals , but , when it does , they are steep rhombohedra or tiny acicular ( hair @-@ like ) crystals . Isolation of selenium is often complicated by the presence of other compounds and elements .

Selenium occurs naturally in a number of inorganic forms , including selenide , selenate , and selenite , but these minerals are rare . The common mineral selenite is not a selenium mineral , and contains no selenite ion , but is rather a type of gypsum ( calcium sulfate hydrate ) named like selenium for the moon well before the discovery of selenium . Selenium is most commonly found as an impurity , replacing a small part of the sulfur in sulfide ores of many metals .

In living systems , selenium is found in the amino acids selenomethionine , selenocysteine , and methylselenocysteine . In these compounds , selenium plays a role analogous to that of sulfur . Another naturally occurring organoselenium compound is dimethyl selenide .

Certain solids are selenium @-@ rich , and selenium can be bioconcentrated by some plants . In soils , selenium most often occurs in soluble forms such as selenate ( analogous to sulfate ) , which are leached into rivers very easily by runoff . Ocean water contains significant amounts of selenium .

Anthropogenic sources of selenium include coal burning , and the mining and smelting of sulfide ores .

= = Production = =

Selenium is most commonly produced from selenide in many sulfide ores , such as those of copper , nickel , or lead . Electrolytic metal refining is particularly productive of selenium as a byproduct , obtained from the anode mud of copper refineries . Another source was the mud from the lead chambers of sulfuric acid plants , a process that is no longer used . Selenium can be refined from these muds by a number of methods . However , most elemental selenium comes as a byproduct of refining copper or producing sulfuric acid . Since its invention , solvent extraction and electrowinning ( SX / EW ) production of copper produces an increasing share of the worldwide copper supply . This changes the availability of selenium because only a comparably small part of the selenium in the ore is leached with the copper .

Industrial production of selenium usually involves the extraction of selenium dioxide from residues obtained during the purification of copper . Common production from the residue then begins by oxidation with sodium carbonate to produce selenium dioxide , which is mixed with water and acidified to form selenous acid ( oxidation step ) . Selenous acid is bubbled with sulfur dioxide ( reduction step ) to give elemental selenium .

About 2 @, @ 000 tonnes of selenium were produced in 2011 worldwide , mostly in Germany ( 650 t ) , Japan ( 630 t ) , Belgium ( 200 t ) , and Russia ( 140 t ) , and the total reserves were estimated at 93 @, @ 000 tonnes . These data exclude two major producers , the United States and China . A

previous sharp increase was observed in 2004 from 4 ? 5 to \$ 27 / lb . The price was relatively stable during 2004 ? 2010 at about US \$ 30 per pound ( in 100 @-@ pound lots ) but increased to \$ 65 / lb in 2011 . The consumption in 2010 was divided as follows : metallurgy ? 30 % , glass manufacturing ? 30 % , agriculture ? 10 % , chemicals and pigments ? 10 % , and electronics ? 10 % . China is the dominant consumer of selenium at 1 @,@ 500 ? 2 @,@ 000 tonnes / year .

= = Applications = =

= = = Manganese electrolysis = = =

During the electro winning of manganese , the addition of selenium dioxide decreases the power necessary to operate the electrolysis cells . China is the largest consumer of selenium dioxide for this purpose . For every tonne of manganese , an average 2 kg selenium oxide is used .

= = = Glass production = = =

The largest commercial use of Se , accounting for about 50 % of consumption , is for the production of glass . Se compounds confer a red color to glass . This color cancels out the green or yellow tints that arise from iron impurities typical for most glass . For this purpose , various selenite and selenate salts are added . For other applications , a red color may be desired , produced by mixtures of CdSe and CdS .

= = = Alloys = = =

Selenium is used with bismuth in brasses to replace more toxic lead . The regulation of lead in drinking water applications with the Safe Drinking Water Act of 1974 made a reduction of lead in brass necessary . The new brass is marketed under the name EnviroBrass . Like lead and sulfur , selenium improves the machinability of steel at concentrations around 0 @.@ 15 % . Selenium produces the same machinability improvement in copper alloys .

= = = = Solar cells = = = =

Copper indium gallium selenide is a material used in solar cells .

= = = Other uses = = =

Small amounts of organoselenium compounds are used to modify the vulcanization catalysts for the production of rubber .

The demand for selenium by the electronics industry is declining , despite a number of continuing applications . Its photovoltaic and photoconductive properties are still useful in photocopying , photocells , light meters and solar cells . Its use as a photoconductor in plain @-@ paper copiers once was a leading application , but in the 1980s , the photoconductor application declined ( although it was still a large end @-@ use ) as more and more copiers switched to organic photoconductors . Though once widely used , selenium rectifiers have mostly been replaced ( or are being replaced ) by silicon @-@ based devices . The most notable exception is in power DC surge protection , where the superior energy capabilities of selenium suppressors make them more desirable than metal oxide varistors .

Zinc selenide was the first material for blue LEDs , but gallium nitride is dominating the market now . Cadmium selenide was an important component in quantum dots . Sheets of amorphous selenium convert X @-@ ray images to patterns of charge in xeroradiography and in solid @-@ state , flat @-@ panel X @-@ ray cameras .

Selenium is a catalyst in some chemical reactions , but it is not widely used because of issues with

toxicity . In X-ray crystallography , incorporation of one or more selenium atoms in place of sulfur helps with multiple wavelength anomalous dispersion and single wavelength anomalous dispersion phasing .

Selenium is used in the toning of photographic prints , and it is sold as a toner by numerous photographic manufacturers . Selenium intensifies and extends the tonal range of black and white photographic images and improves the permanence of prints .

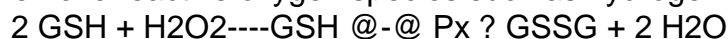
<sup>75</sup>Se is used as a gamma source in industrial radiography .

== Biological role ==

Although it is toxic in large doses , selenium is an essential micronutrient for animals . In plants , it occurs as a bystander mineral , sometimes in toxic proportions in forage ( some plants may accumulate selenium as a defense against being eaten by animals , but other plants , such as locoweed , require selenium , and their growth indicates the presence of selenium in soil ) . See more on plant nutrition below .

Selenium is a component of the unusual amino acids selenocysteine and selenomethionine . In humans , selenium is a trace element nutrient that functions as cofactor for reduction of antioxidant enzymes , such as glutathione peroxidases and certain forms of thioredoxin reductase found in animals and some plants ( this enzyme occurs in all living organisms , but not all forms of it in plants require selenium ) .

The glutathione peroxidase family of enzymes ( GSH-Px ) catalyze certain reactions that remove reactive oxygen species such as hydrogen peroxide and organic hydroperoxides :



The thyroid gland and every cell that uses thyroid hormone use selenium , which is a cofactor for the three of the four known types of thyroid hormone deiodinases , which activate and then deactivate various thyroid hormones and their metabolites ; the iodothyronine deiodinases are the subfamily of deiodinase enzymes that use selenium as the otherwise rare amino acid selenocysteine . ( Only the deiodinase , iodothyronine deiodinase , which works on the last breakdown products of thyroid hormone , does not use selenium . )

Selenium may inhibit Hashimoto 's disease , in which the body 's own thyroid cells are attacked as alien . A reduction of 21 % on TPO antibodies is reported with the dietary intake of 0.2 mg of selenium .

Increased dietary selenium reduces the effects of mercury toxicity , although it is effective only at low to modest doses of mercury . Evidence suggests that the molecular mechanisms of mercury toxicity includes the irreversible inhibition of selenoenzymes that are required to prevent and reverse oxidative damage in brain and endocrine tissues .

== Evolution in biology ==

From about three billion years ago , prokaryotic selenoprotein families drive the evolution of selenocysteine , an amino acid . Selenium is incorporated into several prokaryotic selenoprotein families in bacteria , archaea , and eukaryotes as selenocysteine , where selenoprotein peroxiredoxins protect bacterial and eukaryotic cells against oxidative damage . Selenoprotein families of GSH-Px and the deiodinases of eukaryotic cells seem to have a bacterial phylogenetic origin . The selenocysteine-containing form occurs in species as diverse as green algae , diatoms , sea urchin , fish , and chicken . Selenium enzymes are involved in the small reducing molecules glutathione and thioredoxin . One family of selenium-bearing molecules ( the glutathione peroxidases ) destroys peroxide and repairs damaged peroxidized cell membranes , using glutathione . Another selenium-bearing enzyme in some plants and in animals ( thioredoxin reductase ) generates reduced thioredoxin , a dithiol that serves as an electron source for peroxidases and also the important reducing enzyme ribonucleotide reductase that makes DNA precursors from RNA precursors .

Trace elements involved in GSH-Px and superoxide dismutase enzymes activities , i.e.

selenium , vanadium , magnesium , copper , and zinc , may have been lacking in some terrestrial mineral @-@ deficient areas . Marine organisms retained and sometimes expanded their selenoproteomes , whereas the selenoproteomes of some terrestrial organisms were reduced or completely lost . These findings suggest that , with the exception of vertebrates , aquatic life supports selenium use , whereas terrestrial habitats lead to reduced use of this trace element . Marine fishes and vertebrate thyroid glands have the highest concentration of selenium and iodine . From about 500 million years ago , freshwater and terrestrial plants slowly optimized the production of " new " endogenous antioxidants such as ascorbic acid ( vitamin C ) , polyphenols ( including flavonoids ) , tocopherols , etc . A few of these appeared more recently , in the last 50 ? 200 million years , in fruits and flowers of angiosperm plants . In fact , the angiosperms ( the dominant type of plant today ) and most of their antioxidant pigments evolved during the late Jurassic period .

The deiodinase isoenzymes constitute another family of eukaryotic selenoproteins with identified enzyme function . Deiodinases are able to extract electrons from iodides , and iodides from iodothyronines . They are , thus , involved in thyroid @-@ hormone regulation , participating in the protection of thyrocytes from damage by H<sub>2</sub>O<sub>2</sub> produced for thyroid @-@ hormone biosynthesis . About 200 million years ago , new selenoproteins were developed as mammalian GSH @-@ Px enzymes .

== Nutritional sources of selenium ==

Dietary selenium comes from nuts , cereals and mushrooms . Brazil nuts are the richest dietary source ( though this is soil @-@ dependent , since the Brazil nut does not require high levels of the element for its own needs ) .

Recommended Dietary Allowance ~ 55 µg / day . Selenium as a dietary supplement is available in many forms , including multi @-@ vitamins / mineral supplements - typically 20 µg / day . Selenium @-@ specific supplements may have -200 µg / day .

In June 2015 the U.S. Food and Drug Administration ( FDA ) published its final rule establishing the requirement of minimum and maximum levels of selenium in infant formula .

The selenium content in the human body is believed to be in the 13 ? 20 milligram range .

== Indicator plant species ==

Certain species of plants are considered indicators of high selenium content of the soil because they require high levels of selenium to thrive . The main selenium indicator plants are *Astragalus* species ( including some locoweeds ) , prince 's plume ( *Stanleya* sp . ) , woody asters ( *Xylorhiza* sp . ) , and false goldenweed ( *Oenopsis* sp . )

== Medical use ==

The substance loosely called selenium sulfide ( approximate formula , SeS<sub>2</sub> ) is the active ingredient in some anti @-@ dandruff shampoos . The selenium compound kills the scalp fungus *Malassezia* , which causes shedding of dry skin fragments . The ingredient is also used in body lotions to treat tinea versicolor due to infection by a different species of *Malassezia* fungus .

== Detection in biological fluids ==

Selenium may be measured in blood , plasma , serum , or urine to monitor excessive environmental or occupational exposure , to confirm a diagnosis of poisoning in hospitalized victims , or investigate a suspected case of fatal overdose . Some analytical techniques are capable of distinguishing organic from inorganic forms of the element . Both organic and inorganic forms of selenium are largely converted to monosaccharide conjugates ( selenosugars ) in the body prior elimination in the urine . Cancer patients receiving daily oral doses of selenothionine may achieve very high plasma and urine selenium concentrations .

### == Toxicity ==

Although selenium is an essential trace element , it is toxic if taken in excess . Exceeding the Tolerable Upper Intake Level of 400 micrograms per day can lead to selenosis . This 400 µg Tolerable Upper Intake Level is based primarily on a 1986 study of five Chinese patients who exhibited overt signs of selenosis and a follow up study on the same five people in 1992 . The 1992 study actually found the maximum safe dietary Se intake to be approximately 800 micrograms per day ( 15 micrograms per kilogram body weight ) , but suggested 400 micrograms per day to avoid creating an imbalance of nutrients in the diet and to accord with data from other countries . In China , people who ingested corn grown in extremely selenium @-@ rich stony coal ( carbonaceous shale ) have suffered from selenium toxicity . This coal was shown to have selenium content as high as 9 @. @ 1 % , the highest concentration in coal ever recorded .

Signs and symptoms of selenosis include a garlic odor on the breath , gastrointestinal disorders , hair loss , sloughing of nails , fatigue , irritability , and neurological damage . Extreme cases of selenosis can exhibit cirrhosis of the liver , pulmonary edema , or death . Elemental selenium and most metallic selenides have relatively low toxicities because of low bioavailability . By contrast , selenates and selenites have an oxidant mode of action similar to that of arsenic trioxide and are very toxic . The chronic toxic dose of selenite for humans is about 2400 to 3000 micrograms of selenium per day . Hydrogen selenide is an extremely toxic , corrosive gas . Selenium also occurs in organic compounds , such as dimethyl selenide , selenomethionine , selenocysteine and methylselenocysteine , all of which have high bioavailability and are toxic in large doses .

On 19 April 2009 , 21 polo ponies died shortly before a match in the United States Polo Open . Three days later , a pharmacy released a statement explaining that the horses had received an incorrect dose of one of the ingredients used in a vitamin / mineral supplement compound that had been incorrectly compounded by a compounding pharmacy . Analysis of blood levels of inorganic compounds in the supplement indicated the selenium concentrations were ten to fifteen times higher than normal in the blood samples , and 15 to 20 times higher than normal in the liver samples . Selenium was later confirmed to be the toxic factor .

Selenium poisoning of water systems may result whenever new agricultural runoff courses through normally dry , undeveloped lands . This process leaches natural soluble selenium compounds ( such as selenates ) into the water , which may then be concentrated in new " wetlands " as the water evaporates . Selenium pollution of waterways also occurs when selenium is leached from coal flue ash , mining and metal smelting , crude oil processing , and landfill . The resultant high selenium levels in waterways were found to cause congenital disorders in oviparous species , including wetland birds and fish . Elevated dietary methylmercury levels can amplify the harm of selenium toxicity in oviparous species .

In fish and other wildlife , selenium is necessary for life , but toxic in high doses . For salmon , the optimal concentration of selenium is about 1 microgram selenium per gram of whole body weight . Much below that level , young salmon die from deficiency ; much above , they die from toxic excess .

The Occupational Safety and Health Administration ( OSHA ) has set the legal limit ( Permissible exposure limit ) for selenium in the workplace at 0 @. @ 2 mg / m<sup>3</sup> over an 8 @-@ hour workday . The National Institute for Occupational Safety and Health ( NIOSH ) has set a Recommended exposure limit ( REL ) of 0 @. @ 2 mg / m<sup>3</sup> over an 8 @-@ hour workday . At levels of 1 mg / m<sup>3</sup> , selenium is immediately dangerous to life and health .

### == Deficiency ==

Selenium deficiency is rare in otherwise healthy , well @-@ nourished individuals . It can occur in patients with severely compromised intestinal function , those undergoing total parenteral nutrition , and in those of advanced age ( over 90 ) . Also , people dependent on food grown from selenium @-@ deficient soil are at risk . Although New Zealand soil has low levels of selenium , adverse



health effects have not been detected in the residents .

Selenium deficiency , defined by low ( < 60 % of normal ) selenoenzyme activity levels in brain and endocrine tissues , occurs only when a low selenium level is linked with an additional stress , such as high exposures to mercury or increased oxidant stress from vitamin E deficiency .

Selenium interacts with other nutrients , such as iodine and vitamin E. The effect of selenium deficiency on health remains uncertain , particularly in relation to Kashin @-@ Beck disease . Also , selenium interacts with other minerals , such as zinc and copper . High doses of Se supplements in pregnant animals might disturb the Zn : Cu ratio and lead to Zn reduction ; in such treatment cases , Zn levels should be monitored . Further studies are needed to con?rm these interactions .

In the regions ( e.g. various regions within North America ) where low selenium soil levels lead to low concentrations in the plants , some animal species may be deficient unless selenium is supplemented with diet or injection . Ruminants are particularly susceptible . In general , absorption of dietary selenium is lower in ruminants than other animals , and is lower from forages than from grain . Ruminants grazing certain forages , e.g. , some white clover varieties containing cyanogenic glycosides , may have higher selenium requirements , presumably because cyanide is released from the aglycone by glucosidase activity in the rumen and glutathione peroxidases is deactivated by the cyanide acting on the glutathione moiety . Neonate ruminants at risk of WMD ( white muscle disease ) may be administered both selenium and vitamin E by injection ; some of the WMD myopathies respond only to selenium , some only to vitamin E , and some to either .

= = = Controversial health effects = = =

A number of correlative epidemiological studies have implicated selenium deficiency ( measured by blood levels ) in a number of serious or chronic diseases , such as cancer , diabetes , HIV / AIDS , and tuberculosis . In addition , selenium supplementation has been found to be a chemopreventive for some types of cancer in some types of rodents . However , in randomized , blinded , controlled prospective trials in humans , selenium supplementation has not succeeded in reducing the incidence of any disease , nor has a meta @-@ analysis of such selenium supplementation studies detected a decrease in overall mortality .