= Bismuth =

Bismuth is a chemical element with the symbol Bi and the atomic number 83 . Bismuth , a pentavalent post @-@ transition metal , chemically resembles arsenic and antimony . Elemental bismuth may occur naturally , although its sulfide and oxide form important commercial ores . The free element is 86 % as dense as lead . It is a brittle metal with a silvery white color when freshly produced , but is often seen in air with a pink tinge owing to surface oxidation . Bismuth is the most naturally diamagnetic element , and has one of the lowest values of thermal conductivity among metals .

Bismuth metal has been known since ancient times , although it was often confused with lead and tin , which share some physical properties . The etymology is uncertain , but possibly comes from Arabic bi ismid , meaning having the properties of antimony or German words weiße Masse or Wismuth (" white mass ") , translated in the mid @-@ sixteenth century to New Latin bisemutum .

Bismuth has long been considered the element with the highest atomic mass that is stable . However , in 2003 it was discovered to be weakly radioactive : its only primordial isotope , bismuth @-@ 209 , decays via alpha decay with a half life more than a billion times the estimated age of the universe .

Bismuth compounds account for about half the production of bismuth . They are used in cosmetics , pigments , and a few pharmaceuticals , notably bismuth subsalicylate , used to treat diarrhea . Bismuth 's unusual propensity to expand upon freezing is responsible for some of its uses , such as in casting of printing type . Bismuth has unusually low toxicity for a heavy metal . As the toxicity of lead has become more apparent in recent years , there is an increasing use of bismuth alloys (presently about a third of bismuth production) as a replacement for lead .

= = History = =

The name bismuth is from ca . 1660s , and is of uncertain etymology . It is one of the first 10 metals to have been discovered . Bismuth appears in the 1660s , from obsolete German Bismuth , Wismut , Wissmuth (early 16th century) ; perhaps related to Old High German hwiz (" white ") . The New Latin bisemutum (due to Georgius Agricola , who Latinized many German mining and technical words) is from the German Wismuth , perhaps from weiße Masse , " white mass " . The element was confused in early times with tin and lead because of its resemblance to those elements . Bismuth has been known since ancient times , so no one person is credited with its discovery . Agricola , in De Natura Fossilium (ca . 1546) states that bismuth is a distinct metal in a family of metals including tin and lead . This was based on observation of the metals and their physical properties . Miners in the age of alchemy also gave bismuth the name tectum argenti , or " silver being made , " in the sense of silver still in the process of being formed within the Earth .

Beginning with Johann Heinrich Pott in 1738 , Carl Wilhelm Scheele and Torbern Olof Bergman , the distinctness of lead and bismuth became clear , and Claude François Geoffroy demonstrated in 1753 that this metal is distinct from lead and tin . Bismuth was also known to the Incas and used (along with the usual copper and tin) in a special bronze alloy for knives .

= = Characteristics = =

= = = Physical characteristics = = =

Bismuth is a brittle metal with a white , silver @-@ pink hue , often occurring in its native form , with an iridescent oxide tarnish showing many colors from yellow to blue . The spiral , stair @-@ stepped structure of bismuth crystals is the result of a higher growth rate around the outside edges than on the inside edges . The variations in the thickness of the oxide layer that forms on the surface of the crystal causes different wavelengths of light to interfere upon reflection , thus displaying a rainbow of colors . When burned in oxygen , bismuth burns with a blue flame and its oxide forms yellow fumes .

Its toxicity is much lower than that of its neighbors in the periodic table , such as lead , antimony , and polonium .

No other metal is verified to be more naturally diamagnetic than bismuth . (Superdiamagnetism is a different physical phenomenon .) Of any metal , it has one of the lowest values of thermal conductivity (after manganese , and maybe neptunium and plutonium) and the highest Hall coefficient . It has a high electrical resistance . When deposited in sufficiently thin layers on a substrate , bismuth is a semiconductor , despite being a post @-@ transition metal .

Elemental bismuth is denser in the liquid phase than the solid , a characteristic it shares with antimony , germanium , silicon and gallium . Bismuth expands 3 @.@ 32 % on solidification ; therefore , it was long a component of low @-@ melting typesetting alloys , where it compensated for the contraction of the other alloying components , to form almost isostatic bismuth @-@ lead eutectic alloys .

Though virtually unseen in nature , high @-@ purity bismuth can form distinctive , colorful hopper crystals . It is relatively nontoxic and has a low melting point just above 271 ° C , so crystals may be grown using a household stove , although the resulting crystals will tend to be lower quality than lab @-@ grown crystals .

At ambient conditions bismuth shares the same layered structure as the metallic forms of arsenic and antimony , crystallizing in the rhombohedral lattice (Pearson symbol hR6 , space group R3m No. 166) , which is often classed into trigonal or hexagonal crystal systems . When compressed at room temperature , this Bi @-@ I structure changes first to the monoclinic Bi @-@ II at 2 @.@ 55 GPa , then to the tetragonal Bi @-@ III at 2 @.@ 7 GPa , and finally to the body @-@ centered cubic Bi @-@ IV at 7 @.@ 7 GPa . The corresponding transitions can be monitored via changes in electrical conductivity ; they are rather reproducible and abrupt , and are therefore used for calibration of high @-@ pressure equipment .

= = = Chemical characteristics = = =

Bismuth is stable to both dry and moist air at ordinary temperatures . When red @-@ hot , it reacts with water to make bismuth (III) oxide .

2 Bi + 3 H2O ? Bi2O3 + 3 H2

It reacts with fluorine to make bismuth (V) fluoride at 500 ° C or bismuth (III) fluoride at lower temperatures (typically from Bi melts) ; with other halogens it yields only bismuth (III) halides . The trihalides are corrosive and easily react with moisture , forming oxyhalides with the formula BiOX .

2 Bi + 3 X2 ? 2 BiX3 (X = F , Cl , Br , I)

Bismuth dissolves in concentrated sulfuric acid to make bismuth (III) sulfate and sulfur dioxide .

6 H2SO4 + 2 Bi ? 6 H2O + Bi2 (SO4) 3 + 3 SO2

It reacts with nitric acid to make bismuth (III) nitrate .

Bi + 6 HNO3 ? 3 H2O + 3 NO2 + Bi (NO3) 3

It also dissolves in hydrochloric acid , but only with oxygen present .

4 Bi + 3 O2 + 12 HCl ? 4 BiCl3 + 6 H2O

It is used as a transmetalating agent in the synthesis of alkaline @-@ earth metal complexes :

3 Ba + 2 BiPh3 ? 3 BaPh2 + 2 Bi

= = = Isotopes = = =

The only primordial isotope of bismuth , bismuth @-@ 209 , was traditionally regarded as the heaviest stable isotope , but it had long been suspected to be unstable on theoretical grounds . This was finally demonstrated in 2003 , when researchers at the Institut d 'Astrophysique Spatiale in Orsay , France , measured the alpha emission half @-@ life of 209Bi to be 1 @.@ 9 × 1019 years , over a billion times longer than the current estimated age of the universe . Owing to its extraordinarily long half @-@ life , for all presently known medical and industrial applications , bismuth can be treated as if it is stable and nonradioactive . The radioactivity is of academic interest because bismuth is one of few elements whose radioactivity was suspected and theoretically

predicted before being detected in the laboratory . Bismuth has the longest known alpha decay half @-@ life , although tellurium @-@ 128 has a double beta decay half @-@ life of over 2 @.@ 2 × 1024 years .

Several isotopes of bismuth with short half @-@ lives occur within the radioactive disintegration chains of actinium , radium , and thorium , and more have been synthesized experimentally . Bismuth @-@ 213 is also found on the decay chain of uranium @-@ 233 .

Commercially , the radioactive isotope bismuth @-@ 213 can be produced by bombarding radium with bremsstrahlung photons from a linear particle accelerator . In 1997 , an antibody conjugate with bismuth @-@ 213 , which has a 45 @-@ minute half @-@ life and decays with the emission of an alpha particle , was used to treat patients with leukemia . This isotope has also been tried in cancer treatment , for example , in the targeted alpha therapy (TAT) program .

= = Chemical compounds = =

Bismuth forms trivalent and pentavalent compounds , the trivalent ones being more common . Many of its chemical properties are similar to those of arsenic and antimony , although they are less toxic than derivatives of those lighter elements .

= = = Oxides and sulfides = = =

At elevated temperatures , the vapors of the metal combine rapidly with oxygen , forming the yellow trioxide , Bi
2O
3 . When molten , at temperatures above 710 ° C , this oxide corrodes any metal oxide , and even platinum . On reaction with base , it forms two series of oxyanions : BiO ?
2 , which is polymeric and forms linear chains , and BiO3 ?
3 . The anion in Li
3BiO
3 is actually a cubic octameric anion , Bi
8O24 ?
24 , whereas the anion in Na
3BiO
3 is tetrameric .
The dark red bismuth (V) oxide , Bi
2O
5 , is unstable , liberating O
2 gas upon heating . The compound NaBiO3 is a strong oxidising agent .
Bismuth sulfide , Bi
2S
3 , occurs naturally in bismuth ores . It is also produced by the combination of molten bismuth and sulfur .

Bismuth oxychloride (BiOCl , see figure at right) and bismuth oxynitrate (BiONO3) stoichiometrically appear as simple anionic salts of the bismuthyl (III) cation (BiO +) which commonly occurs in aqueous bismuth compounds . However , in the case of BiOCl , the salt crystal forms in a structure of alternating plates of Bi , O , and Cl atoms , with each oxygen coordinating with four bismuth atoms in the adjacent plane . This mineral compound is used as a pigment and cosmetic (see below) .

= = = Bismuthine and bismuthides = = =

Unlike earlier members of group 15 elements such as nitrogen , phosphorus , and arsenic , and similar to the previous group 15 element antimony , bismuth does not form a stable hydride . Bismuth hydride , bismuthine (BiH

3) , is an endothermic compound that spontaneously decomposes at room temperature . It is stable only below ? 60 ° C. Bismuthides are intermetallic compounds between bismuth and other metals .

In 2014 researchers discovered that sodium bismuthide can exist as a form of matter called a ? three @-@ dimensional topological Dirac semi @-@ metal ? (3DTDS) that possess 3D Dirac fermions in bulk . It is a natural , three @-@ dimensional counterpart to graphene with similar electron mobility and velocity . Graphene and topological insulators (such as those in 3DTDS) are both crystalline materials that are electrically insulating inside but conducting on the surface , allowing them to function as transistors and other electronic devices . While sodium bismuthide (Na

3Bi) is too unstable to be used in devices without packaging , it can demonstrate potential applications of 3DTDS systems , which offer distinct efficiency and fabrication advantages over planar graphene in semiconductor and spintronics applications .

= = = Halides = = =

The halides of bismuth in low oxidation states have been shown to adopt unusual structures . What was originally thought to be bismuth (I) chloride , BiCl , turns out to be a complex compound consisting of Bi5 +

9 cations and BiCl2 ?

5 and Bi

2Cl2 ?

8 anions . The Bi5 +

9 cation has a distorted tricapped trigonal prismatic molecular geometry , and is also found in Bi

10Hf

3Cl

18 , which is prepared by reducing a mixture of hafnium (IV) chloride and bismuth chloride with elemental bismuth , having the structure [Bi +] [Bi5 +

9] [HfCl2 ?

6]

3 . Other polyatomic bismuth cations are also known , such as Bi2 +

8 , found in Bi

8 (AlCl

4)

2 . Bismuth also forms a low @-@ valence bromide with the same structure as " BiCl " . There is a true monoiodide , BiI , which contains chains of Bi

4I

4 units . BiI decomposes upon heating to the triiodide , BiI

3 , and elemental bismuth . A monobromide of the same structure also exists . In oxidation state + 3 , bismuth forms trihalides with all of the halogens : BiF

3 , BiCl

3 , BiBr

3 , and BiI

3 . All of these except BiF

3 are hydrolyzed by water .

Bismuth (III) chloride reacts with hydrogen chloride in ether solution to produce the acid HBiCl

4 .

The oxidation state + 5 is less frequently encountered . One such compound is BiF

5 , a powerful oxidizing and fluorinating agent . It is also a strong fluoride acceptor , reacting with xenon tetrafluoride to form the XeF +

3 cation :

BiF

5 + XeF

4 ? XeF +

3BiF ?
6

= = = Aqueous species = = =

In aqueous solution , in strong acid conditions the Bi3 + ion solvated to form the aqua ion Bi (H
2O) 3 +
8 . At pH > 0 polynuclear species exist , the most important of which is believed to be the octahedral complex [Bi
6O
4 (OH)
4] 6 + .

= = Occurrence and production = =

In the Earth 's crust , bismuth is about twice as abundant as gold . The most important ores of bismuth are bismuthinite and bismite . Native bismuth is known from Australia , Bolivia , and China .
According to the United States Geological Survey , the world mining production of bismuth in 2014 was 13 @,@ 600 tonnes , with the major contributions from China (7 @,@ 600 tonnes) , Vietnam (4 @,@ 950 tonnes) and Mexico (948 tonnes) . The refinery production in 2010 was 16 @,@ 000 tonnes , of which China produced 13 @,@ 000 , Mexico 850 and Belgium 800 tonnes . The difference reflects bismuth 's status as a byproduct of extraction of other metals such as lead , copper , tin , molybdenum and tungsten .
Bismuth travels in crude lead bullion (which can contain up to 10 % bismuth) through several stages of refining , until it is removed by the Kroll @-@ Betterton process which separates the impurities as slag , or the electrolytic Betts process . Bismuth will behave similarly with another of its major metals , copper . The raw bismuth metal from both processes contains still considerable amounts of other metals , foremost lead . By reacting the molten mixture with chlorine gas the metals are converted to their chlorides while bismuth remains unchanged . Impurities can also be removed by various other methods for example with fluxes and treatments yielding high @-@ purity bismuth metal (over 99 % Bi) . World bismuth production from refineries is a more complete and reliable statistic .

= = = Price = = =

The price for pure bismuth metal has been relatively stable through most of the 20th century , except for a spike in the 1970s . Bismuth has always been produced mainly as a byproduct of lead refining , and thus the price , usually reflected the cost of recovery and the balance between production and demand .
Demand for bismuth was small prior to World War II and was pharmaceutical ? bismuth compounds were used to treat such conditions as digestive disorders , sexually transmitted diseases and burns . Minor amounts of bismuth metal were consumed in fusible alloys for fire sprinkler systems and fuse wire . During World War II bismuth was considered a strategic material , used for solders , fusible alloys , medications and atomic research . To stabilize the market , the producers set the price at $ 1 @.@ 25 per pound (2 @.@ 75 $ / kg) during the war and at $ 2 @.@ 25 per pound (4 @.@ 96 $ / kg) from 1950 until 1964 .
In the early 1970s , the price rose rapidly as a result of increasing demand for bismuth as a metallurgical additive to aluminium , iron and steel . This was followed by a decline owing to increased world production , stabilized consumption , and the recessions of 1980 and 1981 ? 82 . In 1984 , the price began to climb as consumption increased worldwide , especially in the United States and Japan . In the early 1990s , research began on the evaluation of bismuth as a nontoxic replacement for lead in ceramic glazes , fishing sinkers , food @-@ processing equipment , free @-@ machining brasses for plumbing applications , lubricating greases , and shot for waterfowl

hunting . Growth in these areas remained slow during the middle 1990s , in spite of the backing of lead replacement by the US Government , but intensified around 2005 . This resulted in a rapid and continuing increase in price .

= = = Recycling = = =

Whereas bismuth is most available today as a byproduct , its sustainability is more dependent on recycling . Bismuth is mostly a byproduct of lead smelting , along with silver , zinc , antimony , and other metals , and also of tungsten production , along with molybdenum and tin , and also of copper production . Recycling bismuth is difficult in many of its end uses , primarily because of scattering .

Probably the easiest to recycle would be bismuth @-@ containing fusible alloys in the form of larger objects , then larger soldered objects . Half of the world 's solder consumption is in electronics (i.e. , circuit boards) . As the soldered objects get smaller or contain little solder or little bismuth , the recovery gets progressively more difficult and less economic , although solder with a higher silver content will be more worthwhile recovering . Next in recycling feasibility would be sizeable catalysts with a fair bismuth content , perhaps as bismuth phosphomolybdate , and then bismuth used in galvanizing and as a free @-@ machining metallurgical additive .

Bismuth in uses where it is dispersed most widely include stomach medicines (bismuth subsalicylate) , paints (bismuth vanadate) on a dry surface , pearlescent cosmetics (bismuth oxychloride) , and bismuth @-@ containing bullets that have been fired . The bismuth scattered in these uses is unrecoverable with present technology .

The most important sustainability fact about bismuth is its byproduct status , which can either improve sustainability (i.e. , vanadium or manganese nodules) or , for bismuth from lead ore , constrain it ; bismuth is constrained . The extent that the constraint on bismuth can be ameliorated or not is going to be tested by the future of the lead storage battery , since 90 % of the world market for lead is in storage batteries for gasoline or diesel @-@ powered motor vehicles .

The life @-@ cycle assessment of bismuth will focus on solders , one of the major uses of bismuth , and the one with the most complete information . The average primary energy use for solders is around 200 MJ per kg , with the high @-@ bismuth solder (58 % Bi) only 20 % of that value , and three low @-@ bismuth solders (2 % to 5 % Bi) running very close to the average . The global warming potential averaged 10 to 14 kg carbon dioxide , with the high @-@ bismuth solder about two @-@ thirds of that and the low @-@ bismuth solders about average . The acidification potential for the solders is around 0 @.@ 9 to 1 @.@ 1 kg sulfur dioxide equivalent , with the high @-@ bismuth solder and one low @-@ bismuth solder only one @-@ tenth of the average and the other low @-@ bismuth solders about average . There is very little life @-@ cycle information on other bismuth alloys or compounds .

= = Applications = =

Bismuth has few commercial applications , none of which is particularly large . Taking the US as an example , 884 tonnes of bismuth were consumed in 2010 , of which 63 % went into chemicals (including pharmaceuticals , pigments , and cosmetics) , 26 % into metallurgical additives for casting and galvanizing , 7 % into bismuth alloys , solders and ammunition , and 4 % into research and other uses .

Some manufacturers use bismuth as a substitute in equipment for potable water systems such as valves to meet " lead @-@ free " mandates in the U.S. (starts in 2014) . This is a fairly large application since it covers all residential and commercial building construction .

In the early 1990s , researchers began to evaluate bismuth as a nontoxic replacement for lead in various applications .

= = = Medicines = = =

Bismuth is an ingredient in some pharmaceuticals , although the use of some of these substances

is declining .
Bismuth subsalicylate is used as an antidiarrheal ; it is the active ingredient in such " Pink Bismuth " preparations as Pepto @-@ Bismol , as well as the 2004 reformulation of Kaopectate . It is also used to treat some other gastro @-@ intestinal diseases . The mechanism of action of this substance is still not well documented , although an oligodynamic effect (toxic effect of small doses of heavy metal ions on microbes) may be involved in at least some cases . Salicylic acid from hydrolysis of the compound is antimicrobial for toxogenic E. coli , an important pathogen in traveler 's diarrhea .
a combination of bismuth subsalicylate and bismuth subcitrate is used to treat the bacteria causing peptic ulcers .
Bibrocathol is an organic bismuth @-@ containing compound used to treat eye infections .
Bismuth subgallate , the active ingredient in Devrom , is used as an internal deodorant to treat malodor from flatulence (" gas ") and feces .
Bismuth compounds (including sodium bismuth tartrate) were formerly used to treat syphilis
" Milk of bismuth " (an aqueous solution of bismuth hydroxide and bismuth subcarbonate) was marketed as an alimentary cureall in the early 20th century
Bismuth subnitrate (Bi5O (OH) 9 (NO3) 4) and bismuth subcarbonate (Bi2O2 (CO3)) are also used in medicine .

= = = Cosmetics and pigments = = =

Bismuth oxychloride (BiOCl) is sometimes used in cosmetics , as a pigment in paint for eye shadows , hair sprays and nail polishes . This compound is found as the mineral bismoclite and in crystal form contains layers of atoms (see figure above) that refract light chromatically , resulting in an iridescent appearance similar to nacre of pearl . It was used as a cosmetic in ancient Egypt and in many places since . Bismuth white (also " Spanish white ") can refer to either bismuth oxychloride or bismuth oxynitrate (BiONO3) , when used as a white pigment .

= = = Metal and alloys = = =

Bismuth is used in metal alloys with other metals such as iron , to create alloys to go into automatic sprinkler systems for fires . Also used to make bismuth bronze which was used in the Bronze Age .

= = = = Lead replacement = = = =

The density difference between lead (density 11 @.@ 32 g · cm ? 3) and bismuth (density 9 @.@ 78 g · cm ? 3) is small enough that for many ballistics and weighting applications , bismuth can substitute for lead . For example , it can replace lead as a dense material in fishing sinkers . It has been used as a replacement for lead in shot , bullets and less @-@ lethal riot gun ammunition . The Netherlands , Denmark , England , Wales , the US , and many other countries now prohibit the use of lead shot for the hunting of wetland birds , as many birds are prone to lead poisoning owing to mistaken ingestion of lead (instead of small stones and grit) to aid digestion , or even prohibit the use of lead for all hunting , such as in the Netherlands . Bismuth @-@ tin alloy shot is one alternative that provides similar ballistic performance to lead . (Another less expensive but also more poorly performing alternative is " steel " shot , which is actually soft iron .) Bismuth 's lack of malleability does , however , make it unsuitable for use in expanding hunting bullets .
Bismuth , as a dense element of high atomic weight , is used in bismuth @-@ impregnated latex shields to shield from X @-@ ray in medical examinations , such as CTs , mostly as it is considered non @-@ toxic .
The European Union 's Restriction of Hazardous Substances Directive (RoHS) for reduction of lead has broadened bismuth 's use in electronics as a component of low @-@ melting point solders , as a replacement for traditional tin @-@ lead solders . Its low toxicity will be especially important for solders to be used in food processing equipment and copper water pipes , although it can also

be used in other applications including those in the automobile industry , in the EU for example .
Bismuth has been evaluated as a replacement for lead in free @-@ machining brasses for plumbing applications , although it does not equal the performance of leaded steels .

= = = = Other metal uses and specialty alloys = = = =

Many bismuth alloys have low melting points and are found in specialty applications such as solders . Many automatic sprinklers , electric fuses , and safety devices in fire detection and suppression systems contain the eutectic In19.1 @-@ Cd5.3 @-@ Pb22.6 @-@ Sn8.3 @-@ Bi44.7 alloy that melts at 47 ° C (117 ° F) This is a convenient temperature since it is unlikely to be exceeded in normal living conditions . Low @-@ melting alloys , such as Bi @-@ Cd @-@ Pb @-@ Sn alloy which melts at 70 ° C , are also used in automotive and aviation industries . Before deforming a thin @-@ walled metal part , it is filled with a melt or covered with a thin layer of the alloy to reduce the chance of breaking . Then the alloy is removed by submerging the part in boiling water .
Bismuth is used to make free @-@ machining steels and free @-@ machining aluminium alloys for precision machining properties . It has similar effect to lead and improves the chip breaking during machining . The shrinking on solidification in lead and the expansion of bismuth compensate each other and therefore lead and bismuth are often used in similar quantities . Similarly , alloys containing comparable parts of bismuth and exhibit a very small change (on the order 0 @.@ 01 %) upon melting , solidification or aging . Such alloys are used in high @-@ precision casting , e.g. in dentistry , to create models and molds . Bismuth is also used as an alloying agent in production of malleable irons and as a thermocouple material .
Bismuth is also used in Aluminum @-@ Silicon cast alloys in order to refine Si morphology . However , it indicated a poisoning effect on modification of strontium (Sr) . Some bismuth alloys , such as Bi35 @-@ Pb37 @-@ Sn25 , are combined with non @-@ sticking materials such as mica , glass and enamels because they easily wet them allowing to make joints to other parts . Addition of bismuth to caesium enhances the quantum yield of Cs cathodes . Sintering of bismuth and manganese powders at 300 ° C produces a permanent magnet and magnetostrictive material , which is used in ultrasonic generators and receivers working in the 10 ? 100 kHz range and in magnetic memory devices .

= = = Other uses as compounds = = =

Bismuth is included in BSCCO (bismuth strontium calcium copper oxide) which is a group of similar superconducting compounds discovered in 1988 that exhibit the highest superconducting transition temperatures .
Bismuth subnitrate is a component of glazes that produces an iridescence and is used as a pigment in paint .
Bismuth telluride is a semiconductor and an excellent thermoelectric material . Bi2Te3 diodes are used in mobile refrigerators , CPU coolers , and as detectors in infrared spectrophotometers .
Bismuth oxide , in its delta form , is a solid electrolyte for oxygen . This form normally breaks down below a high @-@ temperature threshold , but can be electrodeposited well below this temperature in a highly alkaline solution .
Bismuth vanadate is an opaque yellow pigment in artists ' oil and acrylic paint . This compound is a non @-@ toxic lightfast substitute for lemon yellow pigments such as the cadmium sulfides and the lead / strontium / barium chromates . Unlike lead chromate + lead sulfate lemon , bismuth vanadate does not readily blacken with UV exposure .
A catalyst for making acrylic fibers .
As an electrocatalyst in the conversion of CO2 to CO .
Ingredient in lubricating greases .
In crackling microstars (dragon 's eggs) in pyrotechnics , as the oxide , subcarbonate or subnitrate .

= = Toxicology and ecotoxicology = =

Scientific literature concurs that bismuth and most of its compounds are less toxic compared to other heavy metals (lead , antimony , etc .) and that it is not bioaccumulative . They have low solubilities in the blood , are easily removed with urine , and showed no carcinogenic , mutagenic or teratogenic effects in long @-@ term tests on animals (up to 2 years) . Its biological half @-@ life for whole @-@ body retention is 5 days but it can remain in the kidney for years in patients treated with bismuth compounds .

Bismuth poisoning exists and mostly affects the kidney , liver , and bladder . Skin and respiratory irritation can also follow exposure to respective organs . As with lead , overexposure to bismuth can result in the formation of a black deposit on the gingiva , known as a bismuth line .

Bismuth 's environmental impacts are not very well known . It is considered that its environmental impact is small , due in part to the low solubility of its compounds . Limited information however means that a close eye should be kept on its impact .

= = Bioremediation = =

The fungus Marasmius oreades can be used for the biological remediation of bismuth in polluted soils .