# Silver

| Silver | |
|---|---|
| **Appearance** | |
| lustrous white metal  Electrolytically refined silver | |
| **General properties** | |
| **Name, symbol, number** | silver, Ag, 47 |
| **Pronunciation** | /ˈsɪlvər/ |
| **Element category** | transition metal |
| **Group, period, block** | 11, 5, d |
| **Standard atomic weight** | 107.8682 g·mol$^{-1}$ |
| **Electron configuration** | [Kr] 4d$^{10}$ 5s$^{1}$ |
| **Electrons per shell** | 2, 8, 18, 18, 1 (Image) |
| **Physical properties** | |
| **Phase** | solid |
| **Density (near r.t.)** | 10.49 g·cm$^{-3}$ |
| **Liquid density at m.p.** | 9.320 g·cm$^{-3}$ |
| **Melting point** | 1234.93 K,961.78 °C,1763.2 °F |
| **Boiling point** | 2435 K,2162 °C,3924 °F |
| **Heat of fusion** | 11.28 kJ·mol$^{-1}$ |
| **Heat of vaporization** | 250.58 kJ·mol$^{-1}$ |
| **Specific heat capacity** | (25 °C) 25.350 J·mol$^{-1}$·K$^{-1}$ |
| **Vapor pressure** | |

| *P*/Pa | 1 | 10 | 100 | 1 k | 10 k | 100 k |
|---|---|---|---|---|---|---|
| at *T*/K | 1283 | 1413 | 1575 | 1782 | 2055 | 2433 |

| | |
|---|---|
| **Atomic properties** | |
| **Oxidation states** | **1**, 2, 3 (amphoteric oxide) |
| **Electronegativity** | 1.93 (Pauling scale) |

| | |
|---|---|
| **Ionization energies** | 1st: 731.0 kJ·mol$^{-1}$ |
| | 2nd: 2070 kJ·mol$^{-1}$ |
| | 3rd: 3361 kJ·mol$^{-1}$ |
| **Atomic radius** | 144 pm |
| **Covalent radius** | 145±5 pm |
| **Van der Waals radius** | 172 pm |
| **Miscellanea** | |
| **Crystal structure** | face-centered cubic |
| **Magnetic ordering** | diamagnetic[1] |
| **Electrical resistivity** | (20 °C) 15.87 nΩ·m |
| **Thermal conductivity** | (300 K) 429 W·m$^{-1}$·K$^{-1}$ |
| **Thermal diffusivity** | (300 K) 174 mm²/s |
| **Thermal expansion** | (25 °C) 18.9 µm·m$^{-1}$·K$^{-1}$ |
| **Speed of sound (thin rod)** | (r.t.) 2680 m·s$^{-1}$ |
| **Young's modulus** | 83 GPa |
| **Shear modulus** | 30 GPa |
| **Bulk modulus** | 100 GPa |
| **Poisson ratio** | 0.37 |
| **Mohs hardness** | 2.5 |
| **Vickers hardness** | 251 MPa |
| **Brinell hardness** | 206 MPa |
| **CAS registry number** | 7440-22-4 |
| **Most stable isotopes** | |

| iso | NA | half-life | DM | DE (MeV) | DP |
|---|---|---|---|---|---|
| $^{105}$Ag | syn | 41.2 d | ε | - | $^{105}$Pd |
| | | | γ | 0.344, 0.280, 0.644, 0.443 | - |
| $^{106m}$Ag | syn | 8.28 d | ε | - | $^{106}$Pd |
| | | | γ | 0.511, 0.717, 1.045, 0.450 | - |
| $^{107}$Ag | 51.839% | $^{107}$Ag is stable with 60 neutron | | | |
| $^{108m}$Ag | syn | 418 y | ε | - | $^{108}$Pd |
| | | | IT | 0.109 | $^{108}$Ag |
| | | | γ | 0.433, 0.614, 0.722 | - |
| $^{109}$Ag | 48.161% | $^{109}$Ag is stable with 62 neutron | | | |
| $^{111}$Ag | syn | 7.45 d | $\beta^-$ | 1.036, 0.694 | $^{111}$Cd |
| | | | γ | 0.342 | - |

**Silver** is a metallic chemical element with the chemical symbol **Ag** (Greek: άργυρος <*árgyros*>, Latin: *argentum*, both from the Indo-European root **arg-* for "grey" or "shining") and atomic number 47. A soft, white, lustrous transition metal, it has the highest electrical conductivity of any element and the highest thermal conductivity of any metal. The metal occurs naturally in its pure, free form (native silver), as an alloy with gold and other metals, and in minerals such as argentite and chlorargyrite. Most silver is produced as a byproduct of copper, gold, lead, and zinc refining.

Silver has long been valued as a precious metal, and is used as an investment, to make ornaments, jewelry, high-value tableware, utensils (hence the term silverware), and currency coins. Today, silver metal is also used in electrical contacts and conductors, in mirrors and in catalysis of chemical reactions. Its compounds are used in photographic film, and dilute silver nitrate solutions and other silver compounds are used as disinfectants and microbiocides (oligodynamic effect). While many medical antimicrobial uses of silver have been supplanted by antibiotics, further research into clinical potential continues.

## Characteristics

Silver 1000 oz t (~31 kg) bullion bar

Silver is a very ductile, malleable (slightly harder than gold), monovalent coinage metal, with a brilliant white metallic luster that can take a high degree of polish. It has the highest electrical conductivity of all metals, even higher than copper, but its greater cost has prevented it from being widely used in place of copper for electrical purposes. An exception to this is in radio-frequency engineering, particularly at VHF and higher frequencies, where silver plating to improve electrical conductivity of parts, including wires, is widely employed. During World War II in the US, 13,540 tons were used in the electromagnets used for enriching uranium, mainly because of the wartime shortage of copper.[2][3][4]

Among metals, pure silver has the highest thermal conductivity (the nonmetal carbon in the form of diamond and superfluid helium II are higher) and one of the highest optical reflectivities.[5] (Aluminium slightly outdoes silver in parts of the visible spectrum, and silver is a poor reflector of ultraviolet). Silver also has the lowest contact resistance of any metal. Silver halides are photosensitive and are remarkable for their ability to record a latent image that can later be developed chemically. Silver is stable in pure air and water, but tarnishes when it is exposed to air or water containing ozone or hydrogen sulfide, the latter forming a black layer of silver sulfide which can be cleaned off with dilute hydrochloric acid.[6] The most common oxidation state of silver is +1 (for example, silver nitrate, $AgNO_3$); the less common +2 compounds (for example, silver(II) fluoride, $AgF_2$), and the even less common +3 (for example, potassium tetrafluoroargentate(III), $KAgF_4$) and even +4 compounds (for example, potassium hexafluoroargentate(IV), $K_2AgF_6$)[7] are also known.

## Isotopes

Naturally occurring silver is composed of two stable isotopes, $^{107}Ag$ and $^{109}Ag$, with $^{107}Ag$ being slightly more abundant (51.839% natural abundance). Silver's isotopes are almost equal in abundance, something which is rare in the periodic table. Silver's atomic weight is 107.8682(2) g/mol.[8][9] Twenty-eight radioisotopes have been characterized, the most stable being $^{105}Ag$ with a half-life of 41.29 days, $^{111}Ag$ with a half-life of 7.45 days, and $^{112}Ag$ with a half-life of 3.13 hours. This element has numerous meta states, the most stable being $^{108m}Ag$ ($t_{1/2}$ = 418 years), $^{110m}Ag$ ($t_{1/2}$ = 249.79 days) and $^{106m}Ag$ ($t_{1/2}$ = 8.28 days). All of the remaining radioactive isotopes have half-lives of less than an hour, and the majority of these have half-lives of less than three minutes.

Isotopes of silver range in relative atomic mass from 93.943 ($^{94}Ag$) to 126.936 ($^{127}Ag$);[10] the primary decay mode before the most abundant stable isotope, $^{107}Ag$, is electron capture and the primary mode after is beta decay. The primary decay products before $^{107}Ag$ are palladium (element 46) isotopes, and the primary products after are cadmium (element 48) isotopes.

The palladium isotope $^{107}Pd$ decays by beta emission to $^{107}Ag$ with a half-life of 6.5 million years. Iron meteorites are the only objects with a high-enough palladium-to-silver ratio to yield measurable variations in $^{107}Ag$ abundance. Radiogenic $^{107}Ag$ was first discovered in the Santa Clara meteorite in 1978.[11] The discoverers suggest the coalescence and differentiation of iron-cored small planets may have occurred 10 million years after a nucleosynthetic event. $^{107}Pd$–$^{107}Ag$ correlations observed in bodies that have clearly been melted since the accretion of the solar system must reflect the presence of unstable nuclides in the early solar system.[12]

## Compounds

Silver metal dissolves readily in nitric acid ($HNO_3$) to produce silver nitrate ($AgNO_3$), a transparent crystalline solid that is photosensitive and readily soluble in water. Silver nitrate is used as the starting point for the synthesis of many other silver compounds, as an antiseptic, and as a yellow stain for glass in stained glass. Silver metal does not react with sulfuric acid, which is used in jewelry-making to clean and remove copper oxide firescale from silver articles after silver soldering or annealing. Silver reacts readily with sulfur or hydrogen sulfide $H_2S$ to produce silver sulfide, a dark-colored compound familiar as the tarnish on silver coins and other objects. Silver sulfide also forms silver whiskers when silver electrical contacts are used in an atmosphere rich in hydrogen sulfide.

$$4\ Ag + O_2 + 2\ H_2S \rightarrow 2\ Ag_2S + 2\ H_2O$$

Cessna 210 equipped with a silver iodide generator for cloud seeding

Silver chloride (AgCl) is precipitated from solutions of silver nitrate in the presence of chloride ions, and the other silver halides used in the manufacture of photographic emulsions are made in the same way, using bromide or iodide salts. Silver chloride is used in glass electrodes for pH testing and potentiometric measurement, and as a transparent cement for glass. Silver iodide has been used in attempts to seed clouds to produce rain.[6] Silver halides are highly insoluble in aqueous solutions and are used in gravimetric analytical methods.

Silver oxide ($Ag_2O$), produced when silver nitrate solutions are treated with a base, is used as a positive electrode (anode) in watch batteries. Silver carbonate ($Ag_2CO_3$) is precipitated when silver nitrate is treated with sodium carbonate ($Na_2CO_3$).[13]

$$2\ AgNO_3 + 2\ OH^- \rightarrow Ag_2O + H_2O + 2\ NO_3^-$$

$$2\ AgNO_3 + Na_2CO_3 \rightarrow Ag_2CO_3 + 2\ NaNO_3$$

Silver fulminate (AgONC), a powerful, touch-sensitive explosive used in percussion caps, is made by reaction of silver metal with nitric acid in the presence of ethanol ($C_2H_5OH$). Other dangerously explosive silver compounds are silver azide ($AgN_3$), formed by reaction of silver nitrate with sodium azide ($NaN_3$),[14] and silver acetylide, formed when silver reacts with acetylene gas.

Latent images formed in silver halide crystals are developed by treatment with alkaline solutions of reducing agents such as hydroquinone, metol (4-(methylamino)phenol sulfate) or ascorbate, which reduce the exposed halide to silver metal. Alkaline solutions of silver nitrate can be reduced to silver metal by reducing sugars such as glucose, and this reaction is used to silver glass mirrors and the interior of glass Christmas ornaments. Silver halides are soluble in solutions of sodium thiosulfate ($Na_2S_2O_3$) which is used as a photographic fixer, to remove excess silver halide from photographic emulsions after image development.[13]

Silver metal is attacked by strong oxidizers such as potassium permanganate ($KMnO_4$) and potassium dichromate ($K_2Cr_2O_7$), and in the presence of potassium bromide (KBr); these compounds are used in photography to bleach silver images, converting them to silver halides that can either be fixed with thiosulfate or redeveloped to intensify the original image. Silver forms cyanide complexes (silver cyanide) that are soluble in water in the presence of an excess of cyanide ions. Silver cyanide solutions are used in electroplating of silver.[13]

## Applications

Many well-known uses of silver involve its precious metal properties, including currency, decorative items, and mirrors. The contrast between its bright white color and other media makes it very useful to the visual arts. It has also long been used to confer high monetary value as objects (such as silver coins and investment bars) or make objects symbolic of high social or political rank.

### Currency

Silver, in the form of electrum (a gold–silver alloy), was coined to produce money around 700 BC by the Lydians. Later, silver was refined and coined in its pure form. Many nations used silver as the basic unit of monetary value. In the modern world, silver bullion has the ISO currency code XAG. The name of the pound sterling (£) reflects the fact it originally represented the value of one pound Tower weight of sterling silver; other historical currencies, such as the French livre, have similar etymologies. During the 19th century, the bimetallism that prevailed in most countries was undermined by the discovery of large deposits of silver in the Americas; fearing a sharp decrease in the value of silver and thus the currency, most states switched to a gold standard by 1900. In some languages, such as Spanish and Hebrew, the same word means both silver and money.

The 20th century saw a gradual movement to fiat currency, with most of the world monetary system losing its link to precious metals after Richard Nixon took the United States dollar off the gold standard in 1971; the last currency backed by gold was the Swiss franc, which became a pure fiat currency on 1 May 2000. During this same period, silver gradually ceased to be used in circulating coins; the United States minted its last circulating silver coin in 1970 in its 40% half-dollar.

The Royal Canadian Mint still makes many silver coins with various dollar denominations. Silver is used as a currency by many individuals, and is legal tender in the state of Utah. Silver coins and bullion are also used as an investment to guard against inflation and dollar devaluation.

## Jewelry and silverware

Jewelry and silverware are traditionally made from sterling silver (standard silver), an alloy of 92.5% silver with 7.5% copper. In the US, only an alloy consisting of at least 90.0% fine silver can be marketed as "silver" (thus frequently stamped 900). Sterling silver (stamped 925) is harder than pure silver, and has a lower melting point (893°C) than either pure silver or pure copper.[6] Britannia silver is an alternative, hallmark-quality standard containing 95.8% silver, often used to make silver tableware and wrought plate. With the addition of germanium, the patented modified alloy Argentium Sterling silver is formed, with improved properties, including resistance to firescale.

Silver plate with goddess Minerva from the Hildesheim Treasure, 1st century BC

Sterling silver jewelry is often plated with a thin coat of .999 fine silver to give the item a shiny finish. This process is called "flashing". Silver jewelry can also be plated with rhodium (for a bright, shiny look) or gold.

Silver is a constituent of almost all colored carat gold alloys and carat gold solders, giving the alloys paler color and greater hardness.[15] White 9 carat gold contains 62.5% silver and 37.5% gold, while 22 carat gold contains up to 91.7% gold and 8.4% silver or copper or a mixture of both.[15]

Historically, the training and guild organization of goldsmiths included silversmiths, as well, and the two crafts remain largely overlapping. Unlike blacksmiths, silversmiths do not shape the metal while it is red-hot, but instead, work it at room temperature with gentle and carefully placed hammer blows. The essence of silversmithing is to take a flat piece of metal and to transform it into a useful object using different hammers, stakes and other simple tools.[16]

While silversmiths specialize in, and principally work silver, they also work with other metals, such as gold, copper, steel, and brass. They make jewelry, silverware, armor, vases, and other artistic items. Because silver is such a malleable metal, silversmiths have a large range of choices with how they prefer to work the metal. Historically, silversmiths are mostly referred to as goldsmiths, which was usually the same guild. In the western Canadian silversmith tradition, guilds do not exist; however, mentoring through colleagues becomes a method of professional learning within a community of craftspeople.[17]

Silver is much cheaper than gold, though still valuable, so is very popular with jewelers who are just starting out and cannot afford to make pieces in gold, or as a practicing material for goldsmith apprentices. Silver has also become very fashionable, and is used frequently in more artistic jewelry pieces.

Traditionally, silversmiths mostly made "silverware" (cutlery, tableware, bowls, candlesticks and such). Only in more recent times has silversmithing become mainly work in jewelry, as much less solid silver tableware is now handmade.

## Dentistry

Silver can be alloyed with mercury, tin and other metals at room temperature to make amalgams that are widely used for dental fillings. To make dental amalgam, a mixture of powdered silver and other metals is mixed with mercury to make a stiff paste that can be adapted to the shape of a cavity. The dental amalgam achieves initial hardness within minutes, and sets hard in a few hours.

## Photography and electronics

Photography used 30.98% of the silver consumed in 1998 in the form of silver nitrate and silver halides. In 2001, 23.47% was used for photography, while 20.03% was used in jewelry, 38.51% for industrial uses, and only 3.5% for coins and medals. The use of silver in photography has rapidly declined, due to the lower demand for consumer color film from the advent of digital technology; since 2007, of the 907 million ounces of silver in supply, just 117.6 million ounces (13%) were consumed by the photographic sector, about 50% of the amount used in photography in 1998. By 2010, the supply had increased by about 10% to 1056.8 million ounces, of which 72.7 million ounces were used in the photographic sector, a decline of 38% compared with 2007.[18]

Some electrical and electronic products use silver for its superior conductivity, even when tarnished. The primary example of this is in high quality RF connectors. The increase in conductivity is also taken advantage of in RF engineering at VHF and higher frequencies, where conductors often cannot be scaled by 6%, due to tuning requirements, e.g. cavity filters. As an additional example, printed circuits and RFID antennas can be made using silver paints,[6][19] and computer keyboards use silver electrical contacts. Silver cadmium oxide is used in high-voltage contacts because it can withstand arcing.

Some manufacturers produce audio connector cables, speaker wires, and power cables using silver conductors, which have a 6% higher conductivity than ordinary copper ones of identical dimensions, but cost very much more. Though debatable, many hi-fi enthusiasts believe silver wires improve sound quality.

Small devices, such as hearing aids and watches, commonly use silver oxide batteries due to their long life and high energy-to-weight ratio. Another usage is high-capacity silver-zinc and silver-cadmium batteries.

## Mirrors and optics

Mirrors which need superior reflectivity for visible light are commonly made with silver as the reflecting material in a process called silvering, though common mirrors are backed with aluminium. Using a process called sputtering, silver, along with other optically transparent layers, is applied to glass, creating low emissivity coatings used in high-performance insulated glazing. The amount of silver used per window is small because the silver layer is only 10–15 nanometers thick.[20] However, the amount of silver-coated glass worldwide is hundreds of millions of square meters per year, leading to silver consumption on the order of 10 cubic meters or 100 metric tons/year. Silver color seen in architectural glass and tinted windows on vehicles is produced by sputtered chrome, stainless steel or other alloys. Silver is seldom used as the reflector in telescope mirrors, where aluminum is generally preferred because it is cheaper and less susceptible to tarnishing and corrosion.[21] Silver is the reflective coating of choice for solar reflectors.[22]

## Other industrial and commercial applications

Silver and silver alloys are used in the construction of high-quality musical wind instruments of many types.[23] Flutes, in particular, are commonly constructed of silver alloy or silver plated, both for appearance and for the frictional surface properties of silver.[24]

Silver's catalytic properties make it ideal for use as a catalyst in oxidation reactions, for example, the production of formaldehyde from methanol and air by means of silver screens or crystallites containing a minimum 99.95 weight-percent silver. Silver (upon some suitable support) is probably the only catalyst available today to convert ethylene to ethylene oxide (later hydrolyzed to ethylene glycol, used for making polyesters)— an important industrial reaction. It is also used in the Oddy test to detect reduced sulfur compounds and carbonyl sulfides.

This Yanagisawa A9932J alto saxophone has a solid silver bell and neck with a solid phosphor bronze body. The bell, neck, and key-cups are extensively engraved. It was manufactured in 2008.

Because silver readily absorbs free neutrons, it is commonly used to make control rods to regulate the fission chain reaction in pressurized water nuclear reactors, generally in the form of an alloy containing 80% silver, 15% indium, and 5% cadmium.

Silver is used to make solder and brazing alloys, and as a thin layer on bearing surfaces can provide a significant increase in galling resistance and reduce wear under heavy load, particularly against steel.

## Medical

Silver ions and silver compounds show a toxic effect on some bacteria, viruses, algae and fungi, typical for heavy metals such as lead or mercury, but without the high toxicity to humans normally associated with these other metals. Its germicidal effects kill many microbial organisms *in vitro*, but testing and standardization of silver products is difficult.[25]

Hippocrates, the "father of Western medicine",[26] wrote that silver had beneficial healing and antidisease properties, and the Phoenicians stored water, wine, and vinegar in silver bottles to prevent spoiling. Its germicidal effects increased its value in utensils and as jewelry. The exact process of silver's germicidal effect is still not entirely understood, although theories exist. One of these is the oligodynamic effect, which explains the effect on microorganisms, but would not explain antiviral effects.

Silver is widely used in topical gels and impregnated into bandages because of its wide-spectrum antimicrobial activity. The antimicrobial properties of silver stem from the chemical properties of its ionized form, $Ag^+$. This ion forms strong molecular bonds with other substances used by bacteria to respire, such as molecules containing sulfur, nitrogen, and oxygen.[27] When the $Ag^+$ ion forms a complex with these molecules, they are rendered unusable by the bacteria, depriving them of necessary compounds and eventually leading to their deaths.

Silver compounds were used to prevent infection in World War I before the advent of antibiotics. Silver nitrate solution use continued, then was largely replaced by silver sulfadiazine (SSD) cream,[28] which generally became the "standard of care" for the antibacterial and antibiotic treatment of serious burns until the late 1990s.[29] Now, other options, such as silver-coated dressings (activated silver dressings), are used in addition to SSD cream. However, the evidence for the effectiveness of such silver-treated dressings is mixed; although the evidence is promising, it is marred by the poor quality of the trials used to assess these products. Consequently, a systematic review by the Cochrane Collaboration (published in 2008) found insufficient evidence to recommend the use of silver-treated dressings to treat infected wounds.[30]

Interest in silver has renewed as a broad-spectrum antimicrobial agent. One application has silver being used with alginate, a naturally occurring biopolymer derived from seaweed, in a range of products designed to prevent

infections as part of wound management procedures, particularly applicable to burn victims.[31] In 2007, a company introduced a glass product they claimed had antibacterial properties by coating the glass with a thin layer of silver.[32] In addition, in 2007 the U.S. Food and Drug Administration approved an endotracheal breathing tube with a fine coat of silver for use in mechanical ventilation, after studies found it reduced the risk of ventilator-associated pneumonia.[33]

Another example uses the known enhanced antibacterial action of silver by applying an electric field. In 2009, the antibacterial action of silver electrodes was found to be greatly improved if the electrodes were covered with silver nanorods.[34] The University of Missouri has found silver nanoparticles threaten benign bacteria which extract ammonia from sewage treatment systems. A serious concern is the eventual spread of the toxin into rivers, streams, lakes, and ultimately the oceans.[35] A note of caution is sounded by Martin A. Philbert, professor of toxicology at the University of Michigan, Ann Arbor, "In the context of environmental health, the scientific community will have to pay close attention to those physicochemical properties of engineered nanomaterials that defeat or circumvent normal cellular processes and lend themselves to indiscriminate penetration of biological barriers, tissues, and cellular systems."[36]

Silver is commonly used in catheters. Silver alloy catheters are more effective than standard catheters for reducing bacteriuria in adults having short-term catheterization in hospitals. This meta-analysis clarifies discrepant results among trials of silver-coated urinary catheters by revealing silver alloy catheters are significantly more effective in preventing urinary tract infections than are silver oxide catheters. Though silver alloy urinary catheters cost about $6 more than standard urinary catheters, they may be worth the extra cost, since catheter-related infection is a common cause of nosocomial infection and bacteremia.[37]

Various silver compounds, devices to make homeopathic solutions, and colloidal silver suspensions are sold as remedies for numerous conditions. Although most colloidal silver preparations are harmless, cases where excessive consumption led to argyria over a period of months or years have been reported.[38] High consumption doses of colloidal silver can result in coma, pleural edema, and hemolysis.[39]

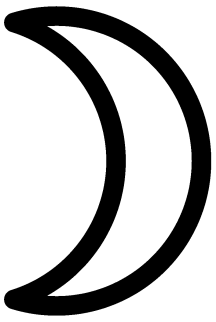
## Investing

Silver coins and bullion are used for investing. Mints sell a wide variety of silver products for investors and collectors. Various institutions provide safe storage for large physical silver investments, and various types of silver investments can be made on the stock markets, including mining stocks. Silver bullion bars are sold in a wide range of ounces, provided by various mints and mines around the world. Silver coins and bullion bars are generally 99.9% pure. Canadian Silver Maple Leafs are also popular, with a purity of 99.99% silver.

### Clothing

Silver inhibits the growth of bacteria and fungi on clothing, such as socks, so is added to reduce odors and the risk of bacterial and fungal infections. It is incorporated into clothing or shoes either by integrating silver nanoparticles into the polymer from which yarns are made or by coating yarns with silver.[40][41] The loss of silver during washing varies between textile technologies, and the resultant effect on the environment is not yet fully known.[42][43]

## History



The crescent moon has been used since ancient times to represent silver.

Silver has been used for thousands of years for ornaments and utensils, for trade, and as the basis for many monetary systems. Its value as a precious metal was long considered second only to gold. The word "silver" appears in Anglo-Saxon in various spellings, such as *seolfor* and *siolfor*. A similar form is seen throughout the Germanic languages (compare Old High German *silabar* and *silbir*). The chemical symbol Ag is from the Latin for "silver", *argentum* (compare Greek ἄργυρος, *árgyros*), from the Indo-European root **arg-*, meaning "white" or "shining". Silver has been known since ancient times. Mentioned in the Book of Genesis, slag heaps found in Asia Minor and on the islands of the Aegean Sea indicate silver was being separated from lead as early as the 4th millennium BC using surface mining.[6]

The stability of the Roman currency relied to a high degree on the supply of silver bullion, which Roman miners produced on a scale unparalleled before the discovery of the New World. Reaching a peak production of 200 t per year, an estimated silver stock of 10,000 t circulated in the Roman economy in the middle of the second century AD, five to ten times larger than the combined amount of silver available to medieval Europe and the Caliphate around 800 AD.[44][45] Financial officials of the Roman Empire worried about the loss of silver to pay for the greatly in demand silk from Sinica (China).

Mines were made in Laureion during 483 BC. [46]

In the Gospels, Jesus' disciple Judas Iscariot is infamous for having taken a bribe of 30 coins of silver from religious leaders in Jerusalem to turn Jesus of Nazareth over to soldiers of the High Priest Caiaphas.[47]

The Chinese Empire during most of its history primarily used silver as a means of exchange. In the 19th century, the threat to the balance of payments of the United Kingdom from Chinese merchants demanding payment in silver in exchange for tea, silk, and porcelain led to the Opium War because Britain had to find a way to address the imbalance in the balance of payments, and they decided to do so by selling opium produced in their colony of British India to China.[48]

Recorded use of silver to prevent infection dates to ancient Greece and Rome; it was rediscovered in the Middle Ages, when it was used for several purposes, such as to disinfect water and food during storage, and also for the treatment of burns and wounds as wound dressing. In the 19th century, sailors on long ocean voyages would put silver coins in barrels of water and wine to keep the liquid potable. Pioneers in America used the same idea as they made their journey from coast to coast. Silver solutions were approved in the 1920s by the US Food and Drug Administration for use as antibacterial agents.

In certain circumstances, Islam permits Muslim men to wear silver jewelry. Muhammad himself wore a silver signet ring.[49]

## Folklore

In European folklore, silver was considered a mystical element, and much like Cold Iron, was considered something of an anathema towards aspects of the supernatural. The myth of silver's mystical properties goes deep into human history. Silver is believed to have purifying effects, a belief that likely arose from the observation that water kept in a silver pitcher took longer to go scummy; in real-life, silver has been shown to have antibacterial properties.

As a noble metal akin to gold, this is often attributed to something along the lines of silver's "Incorruptible Pure Pureness". Due to the above, silver is almost always considered to be on the good end of magic (and items formed of it may also be "Made of Good"). In Neopaganism, silver is the metal associated with the powers of the Moon, symbolizes the light of the moon, representing the feminine energies of the Triple Goddess. In Francis Barret's *The Magus*, it is said to make the bearer "amiable, pleasent, cheerful and honoured, removing all malice and ill-will; it causes security in a journey, increases the riches, and health of body drives away enemies..." In rituals, silver is said to encourage a harmonious energy and a sense of peace.

In folklore, and now later in fiction, the metal is said to do many things, from channel magic, to stopping evil (including warding off or harming vampires and werewolves), making magic mirrors, to turning water into a "Healing Potion". Throughout mythology and subsequent fiction, silver has been a common ward against evil. Silver, especially if blessed, was thought to ward off or harm certain supernatural beings (including vampires) since the Middle Ages.

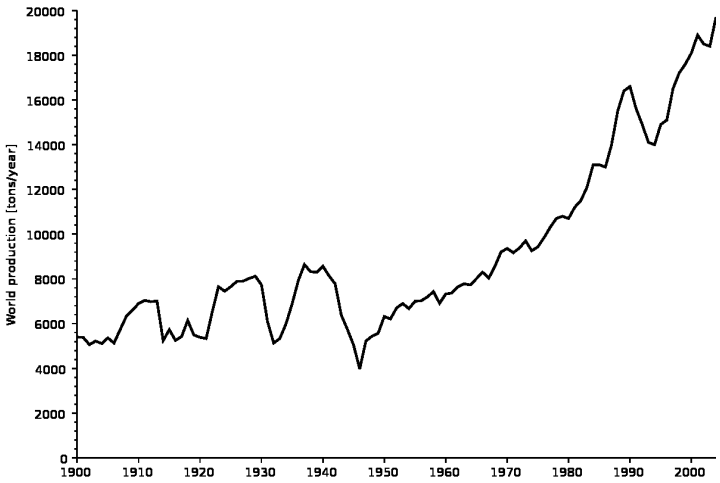
If a "Gold Silver Copper Standard" is involved, expect gold to be even more powerful, while silver still has its own powers.

## World War II

During World War II, the short supply of copper led to the substitution of silver in many industrial applications. The United States government loaned out silver from its massive reserve located in the West Point vaults to a wide range of industrial users. One very important use was for bus bars for new aluminum plants needed to make aircraft. During the war, many electrical connectors and switches were silver plated. Another use was aircraft master rod bearings and other types of bearings. Since silver can replace tin in solder at a lower volume, a large amount of tin was freed up for other uses by substituting government silver. Silver was also used as the reflector in searchlights and other types of lights. One high-tech use of silver was for conductors at Oak Ridge National Laboratory used in calutrons to isolate uranium as part of the Manhattan project. (After the war ended, the silver was returned to the vaults.)[50] Silver was used in nickels during the war to save that metal for use in steel alloys.[51]

## Occurrence and extraction

Silver is found in native form, as an alloy with gold (electrum), and in ores containing sulfur, arsenic, antimony or chlorine. Ores include argentite ($Ag_2S$), chlorargyrite (AgCl) which includes horn silver, and pyrargyrite ($Ag_3SbS_3$). The principal sources of silver are the ores of copper, copper-nickel, lead, and lead-zinc obtained from Peru, Bolivia, Mexico, China, Australia, Chile, Poland and Serbia.[6] Peru, Bolivia and Mexico have been mining silver since 1546, and are still major world producers. Top silver-producing mines are Cannington (Australia), Fresnillo (Mexico), San Cristobal (Bolivia), Antamina (Peru), Rudna (Poland), and Penasquito (Mexico).[52] Top near-term mine development projects through 2015 are Pascua Lama (Chile), Navidad (Argentina), Jaunicipio (Mexico), Malku Khota (Bolivia),[53] and Hackett River (Canada).[52]



Time trend of silver production

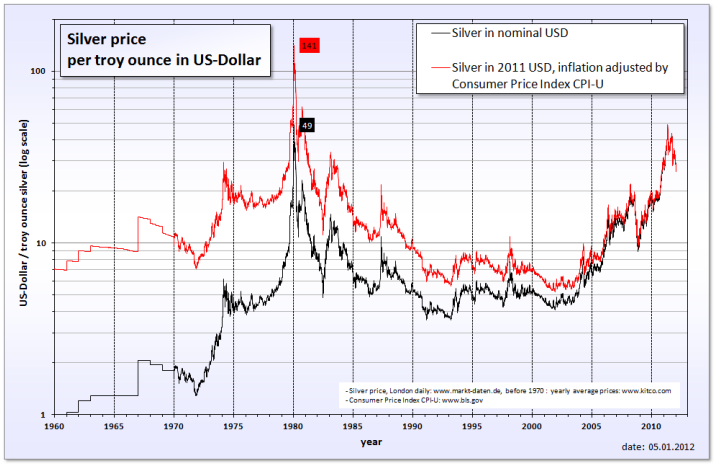

Native silver

The metal is primarily produced as a byproduct of electrolytic copper refining, gold, nickel, and zinc refining, and by application of the Parkes process on lead metal obtained from lead ores that contain small amounts of silver. Commercial-grade fine silver is at least 99.9% pure, and purities greater than 99.999% are available. In 2011, Mexico was the top producer of silver (4,500 tonnes or 19% of the world's total), closely followed by Peru (4,000 t) and China (4,000 t).[54]

## Price

At an August 1, 2012 price of about $27.50 USD per troy ounce,[55] silver is about 1/58th the price of gold. The ratio has varied from 1/15 to 1/100 in the past 100 years. Physical silver bullion prices are higher than the paper prices, with premiums increasing when demand is high and local shortages occur.[56]

In 1980, the silver price rose to a peak for modern times of US$49.45 per troy ounce (ozt) due to market manipulation of Nelson Bunker Hunt and Herbert Hunt. Inflation-adjusted to 2011, this is



Silver price history in 1960–2011

approximately US$150 per troy ounce. Some time after Silver Thursday, the price was back to $10/ozt.[57] From 2001 to 2010, the price moved from $4.37 to $20.19 (average London US$/oz).[58] According to the Silver Institute, silver's recent gains have greatly stemmed from a rise in investor interest and an increase in fabrication demand.[58] In late April 2011, silver reached an all-time high of $49.76/ozt.

In earlier times, silver has commanded much higher prices. In the early 15th century, the price of silver is estimated to have surpassed $1,200 per ounce, based on 2011 dollars.[59] The discovery of massive silver deposits in the New World during the succeeding centuries has been stated as a cause for its price to have diminished greatly.

The price of silver is important in Judaic law. The lowest fiscal amount a Jewish court, or Beth Din, can convene to adjudicate a case over is a *shova pruta* (value of a Babylonian *pruta* coin). This is fixed at 0.025 grams (0.00088 oz) of pure, unrefined silver, at market price. In a Jewish tradition, still continuing today, on the first birthday of a first-born son, the parents pay the price of five pure-silver coins to a *Kohen* (priest). Today, the Israel mint fixes the coins at 117 grams (4.1 oz) of silver. The *Kohen* will often give those silver coins back as a gift for the child to inherit.[60]

## Human exposure and consumption

Silver plays no known natural biological role in humans, and possible health effects of silver are a disputed subject. Silver itself is not toxic, but most silver salts are, and some may be carcinogenic. Silver and compounds containing it (such as colloidal silver) can be absorbed into the circulatory system and become deposited in various body tissues, leading to argyria, which results in a blue-grayish pigmentation of the skin, eyes, and mucous membranes. Although this condition does not otherwise harm a person's health, it is disfiguring and usually permanent. Argyria is rare, and mild forms are sometimes mistaken for cyanosis.[6]

### Monitoring exposure

Overexposure to silver can occur in workers in the metallurgical industry, persons taking silver-containing dietary supplements, patients who have received silver sulfadiazine treatment, and individuals who accidentally or intentionally ingest silver salts. Silver concentrations in whole blood, plasma, serum, or urine may be measured to monitor for safety in exposed workers, to confirm the diagnosis in potential poisoning victims, or to assist in the forensic investigation in a case of fatal overdosage.[61]

### Use in food

Silver is used in food coloring; it has the E174 designation and is approved in the European Union. The amount of silver in the coating of *dragée* or as in cookie decoration is minuscule.

The safety of silver for use in food is disputed.[62] Traditional Indian dishes sometimes include the use of decorative silver foil known as *vark*,[63] and in various cultures, silver *dragée* are used to decorate cakes, cookies, and other dessert items.[62] The use of silver as a food additive is not approved in the United States and Australia.

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- Society of American Silversmiths (http://www.silversmithing.com/)
- The Silver Institute (http://www.silverinstitute.org/) A silver industry website
- A collection of silver items (http://www.theodoregray.com/PeriodicTable/Elements/047/index.html) Samples of silver
- Transport, Fate and Effects of Silver in the Environment (http://digital.library.wisc.edu/1711.dl/EcoNatRes.Argentum)
- Picture in the Element collection from Heinrich Pniok (http://www.pniok.de/ag.htm)
- Chemistry in its element podcast (http://www.rsc.org/chemistryworld/podcast/element.asp) (MP3) from the Royal Society of Chemistry's Chemistry World: Silver (http://www.rsc.org/images/CIIE_silver_48kbps_tcm18-118748.mp3)

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