Learn About ...

SILVER

Element 47: the element that makes up parts of the jewelry we wear, the mirrors we look into, and perhaps on special occasions, the utensils we eat with. This element is silver. Silver is a soft, white metal that has been known since 4000 BC, the antiquity. Its chemical symbol is Ag, which comes from its Latin name, *argentum*, which was derived from its Greek name, ἀργός (*argos*), which means bright. Unlike most metals, silver is sometimes found as the elemental metallic form in nature. It is also found combined with sulfur in the mineral argentite. The simple process of heating (called roasting) argentite will free the silver from sulfur and produce the free metal (although this is not how we produce it now). The ease of this process accounts for why silver is one of the seven metals of antiquity (along with gold, copper, lead, tin, mercury, and iron – metals whose chemical symbols are also based on Latin and therefore do not correspond to their English names).

ARGENTITE
Photo credit: Krystalle.com

Silver has long been valued as a precious metal and is used to make coins in some monetary systems. The United States used silver in its 10-cent, 25-cent, 50-cent, and dollar coins for many years. However, in 1964 the value of silver in these coins rose to above their face value, and the silver coins were replaced with coins made from other metals, including nickel and copper. Often, a copper middle piece is sandwiched between a 75% copper and 25% nickel alloy.

Jewelry and silverware however, continue to contain silver, and we usually call this “sterling silver.” Sterling silver is an alloy of 92.5% silver and 4.5% copper that is harder than either silver or copper, both of which are rather soft and malleable. Gold jewelry also contains silver as a minor component, again forming an alloy that is harder than either metal. When we talk about this alloy, we refer to it as karat gold. In naming karat gold, 24 karat refers to pure gold, 22-karat gold is 91.7% (22/24) gold and 8.3% silver, and 18-karat gold is 75% (18/24) gold and 25% silver.

If you’ve ever seen aged silver jewelry or silverware, it has likely lost its luster and has developed a rather dull black coating. This is called tarnish and is the result of silver interacting with sulfur-containing compounds in the atmosphere. The black color that appears is Ag_2S. It can be removed using a commercial silver polish which relies on mechanical action (a person scrubbing) and a fine polishing compound to gently strip the layer of tarnish. There are also chemical cleaners which work in a variety of ways.

There is a way to clean up silver at home without relying on a silver polish or cleaner; instead, it relies on something already in your kitchen – aluminum foil. The directions for this home experiment can be found on our website. Instead of mechanically removing the silver compound, this method removes the sulfur by a reaction which forms Al2S3. The reaction is represented by this equation:

$$3\ Ag_2S + 2\ Al \rightarrow 6\ Ag + Al_2S_3$$

Photo credit: Mom4Real.com

This process relies on having an electric current in the solution as well as the preference for Al_2S_3 to form, compared to Ag_2S. Silver is an excellent conductor of both electricity and heat. If you've ever stirred sugar into a cup of hot coffee using a silver spoon, you will have noticed that the handle of the spoon becomes quite warm. It becomes much warmer than the handle of a spoon made from stainless steel, which is a much poorer conductor of heat than silver. It is this property of silver that makes it so valuable in solar cells. In solar cells, a silver paste is used to coat silicon wafers. When the wafers are exposed to sunlight, electrons are released from the silicon and can freely travel because of silver's excellent conductivity. These electrons can be stored for later use or used immediately.

Many mirrors are made by depositing a thin film of metallic silver on glass. Mirrors can also be made with other metals, such as aluminum. However, silver is the preferred metal for cosmetic mirrors because it is slightly more reflective to red light than to green and blue light, so it gives a pleasing, warm "glow" to its reflected image. Faces reflected from an aluminum mirror have a relatively green complexion, which is somewhat unattractive. The silver in a mirror is on the back side of the glass, to protect the coating from scratches.

There are two general ways silver mirrors are made. Commercially, silver mirrors are made in a two-step, reduction-oxidation (or redox) process. A rigorously cleaned piece of glass is first coated with a tin compound (tin chloride, $SnCl_2$ is quite common). This acts as a bonding agent also, as metallic silver won't stick to plain glass alone. A silver solution (usually $AgNO_3$) is then applied to the glass. Overall, this is the equation for the reaction that takes place:

$$SnCl_2 + 2Ag^+ + 2NO_3^- \rightarrow Sn^{4+} + 2Ag^0 + 2Cl^- + 2NO_3^-$$

In this reaction, the tin has lost two electrons (oxidized), and each silver has gained one electron (reduced). The Ag^0 is what we see deposited on the piece of glass as a shiny, mirrored surface. This surface is then coated with a copper backing and several coats of paint to protect it from the air.

VIDEO

Silver Mirrors Can Be Formed Other Ways,
As in This Video from the Lab of Shakhashiri!

In a medical setting, silver is sometimes used in wound dressings, creams, or as an antibiotic coating on some medical devices. Silver was even used in some antibiotics until the 1930s, when penicillin was introduced. Silver nitrate is often used to clean wounds of extra skin as well as to cauterize bleeding. In 1999 the Food and Drug Administration banned its use for ingestion as it leads to a condition known as argyria. Simply put, it turns the skin blue! Some people continue to take colloidal silver, although there are no studies to support any health claims. Over time, silver accumulates irreversibly in the body. With chronic ingestion and exposure to sunlight, people who consume large volumes of silver turn blue.

It is silver's interactions with light that made it popular in photography until the development of digital photography. When silver halide compounds are exposed to light, they undergo a change which forms tiny particles of metallic silver. These particles can be made larger through chemical development, which causes the compound to turn dark. Thus, the areas of the photographs that were exposed to light become dark, forming a negative image. The negative can be reversed by shining light through it onto a second sheet, which forms a positive image when developed.

When we think of silver we may think of coins, jewelry, or photography. Today, aside from jewelry, uses in coinage and photography are dwindling. However, newer technologies including solar cells and electronics now use silver and rely on its properties, first explored during the antiquity. Silver remains a valuable and precious metal whose versatile chemistry will continue to make it applicable to the new technologies that arise.

Two demonstrations of chemical transformations involving silver compounds can be found in Volume 1 of *Chemical Demonstrations: A Handbook for Teachers of Chemistry* by Bassam Z. Shakhashiri. These are *4.6: Precipitates and Complexes of Silver(I)*, and *4.4: Iodo and Silver(I) Complexes of Silver Iodide*.

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