Gold

| Platinum ← **gold** → Mercury
| Au
| ↓
| Rg

Gold in the periodic table

**Appearance**
metallic yellow

**General properties**

<table>
<thead>
<tr>
<th>Name, symbol, number</th>
<th>Gold, Au, 79</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pronunciation</td>
<td>/ˈɡoʊld/</td>
</tr>
<tr>
<td>Element category</td>
<td>transition metal</td>
</tr>
<tr>
<td>Group, period, block</td>
<td>11, 6, d</td>
</tr>
<tr>
<td>Standard atomic weight</td>
<td>196.966566(5)</td>
</tr>
</tbody>
</table>
### Electron configuration

\[ \text{[Xe]} 4f^{14} 5d^{10} 6s^1 \]

2, 8, 18, 32, 18, 1

### History

**Naming**

*aurum* in Latin, meaning glow of sunrise

**Discovery**

Middle Easterns (before 6000 BC)

### Physical properties

**Phase**

solid

**Density (near r.t.)**

19.30 g·cm\(^{-3}\)

**Liquid density at m.p.**

17.31 g·cm\(^{-3}\)

**Melting point**

1337.33 K, 1064.18 °C, 1947.52 °F

**Boiling point**

3129 K, 2856 °C, 5173 °F

**Heat of fusion**

12.55 kJ·mol\(^{-1}\)

**Heat of vaporization**

324 kJ·mol\(^{-1}\)

**Molar heat capacity**

25.418 J·mol\(^{-1}\)·K\(^{-1}\)

### Vapor pressure

<table>
<thead>
<tr>
<th>P (Pa)</th>
<th>1</th>
<th>10</th>
<th>100</th>
<th>1 k</th>
<th>10 k</th>
<th>100 k</th>
</tr>
</thead>
<tbody>
<tr>
<td>at T (K)</td>
<td>1646</td>
<td>1814</td>
<td>2021</td>
<td>2281</td>
<td>2620</td>
<td>3078</td>
</tr>
</tbody>
</table>

### Atomic properties

**Oxidation states**

5, 4, 3, 2, 1, –1

(amphoteric oxide)

**Electronegativity**

2.54 (Pauling scale)

**Ionization energies**

1st: 890.1 kJ·mol\(^{-1}\)

2nd: 1980 kJ·mol\(^{-1}\)

**Atomic radius**

144 pm

**Covalent radius**

13626 pm

**Van der Waals radius**

166 pm

### Miscellanea

**Crystal structure**

face centered cubic
Gold is a chemical element with the symbol Au and atomic number 79. It is a dense, soft, malleable, and ductile metal with an attractive, bright yellow color and luster that is maintained without tarnishing in air or water. Chemically, gold is a transition metal and a group 11 element. It is one of the least reactive chemical elements, solid under standard conditions. The metal therefore occurs often in free elemental (native) form, as nuggets or grains in rocks, in veins and in alluvial deposits. Less commonly, it occurs in minerals as gold compounds, such as with tellurium as calaverite, sylvanite and krennerite.

Gold resists attacks by individual acids, but it can be dissolved by aqua regia (nitro-hydrochloric acid), so named because it dissolves gold. Gold also dissolves in alkaline solutions of cyanide, which have been used in mining. It dissolves in mercury, forming amalgam alloys; is insoluble in nitric acid, which dissolves silver and base metals, a property that has long been used to confirm the presence of gold in items, giving rise to the term acid test.

This metal has been a valuable and highly sought-after precious metal for coinage, jewelry, and other arts since long before the beginning of recorded history. Gold standards have sometimes been monetary policies, but were widely supplanted by fiat currency starting in the 1930s. The last gold certificate and gold coin currencies were issued in the
U.S. in 1932. In Europe, most countries left the gold standard with the start of World War I in 1914 and, with huge war debts, did not return to gold as a medium of exchange.

A total of 174,100 tonnes of gold have been mined in human history, according to GFMS as of 2012. This is roughly equivalent to 5.6 billion troy ounces or, in terms of volume, about 9261 m³, or a cube 21.0 m on a side. The world consumption of new gold produced is about 50% in jewelry, 40% in investments, and 10% in industry.

Besides its widespread monetary and symbolic functions, gold has many practical uses in dentistry, electronics, and other fields. Its high malleability, ductility, resistance to corrosion and most other chemical reactions, and conductivity of electricity has led to many uses, including electric wiring, colored-glass production, and gold leafing.

Most of the Earth's gold probably lies at its core, the metal's high density having made it sink there in the planet's youth. Virtually all discovered gold is considered to have been deposited later by meteorites that contained the element, with the asteroid that formed Vredefort crater having been implicated in the formation of the largest gold mining region on earth, Witwatersrand basin.

**Etymology**

"Gold" is cognate with similar words in many Germanic languages, deriving via Proto-Germanic *gulþą from Proto-Indo-European *gʰel- ("yellow/green").

The symbol Au is from the Latin: *aurum*, according to some sources meaning "shining dawn", from Sabine *ausum* "glowing dawn" although according to definitions within Latin dictionaries the meaning of the word *aurum* is the same as today's use of *gold* in reference to the metal. The disagreement between definitions is possibly due to the accumulation of evidence from archaeology of the original anciency of the metal in civilization; in reference to "the dawn of civilization" and in this respect has become the adopted modern meaning, disassociated from the original etymological Latin.

**Characteristics**

Gold is the most malleable of all metals; a single gram can be beaten into a sheet of 1 square meter, or an ounce into 300 square feet. Gold leaf can be beaten thin enough to become transparent. The transmitted light appears greenish blue, because gold strongly reflects yellow and red. Such semi-transparent sheets also strongly reflect infrared light, making them useful as infrared (radiant heat) shields in visors of heat-resistant suits, and in sun-visors for spacesuits.

Gold readily dissolves in mercury at room temperature to form an amalgam, and forms alloys with many other metals at higher temperatures. These alloys can be produced to modify the hardness and other metallurgical properties, to control melting point or to create exotic colors. Gold is a good conductor of heat and electricity and reflects infrared radiation strongly. Chemically, it is unaffected by air, moisture and most corrosive reagents, and is therefore well suited for use in coins and jewelry and as a protective coating on other, more reactive metals. However, it is not chemically inert. Gold is almost insoluble, but can be dissolved in aqua regia or solutions of sodium or potassium cyanide, for example.

Common oxidation states of gold include +1 (gold(I) or aurous compounds) and +3 (gold(III) or auric compounds). Gold ions in solution are readily reduced and precipitated as metal by adding any other metal as the reducing agent. The added metal is oxidized and dissolves, allowing the gold to be displaced from solution and be recovered as a solid precipitate.

In addition, gold is very dense, a cubic meter weighing 19300 kg. By comparison, the density of lead is 11,340 kg/m³, and that of the densest element, osmium, is 22,588 ± 15 kg/m³.
Gold

Color

Whereas most other pure metals are gray or silvery white, gold is yellow. This color is determined by the density of loosely bound (valence) electrons; those electrons oscillate as a collective "plasma" medium described in terms of a quasiparticle called plasmon. The frequency of these oscillations lies in the ultraviolet range for most metals, but it falls into the visible range for gold due to subtle relativistic effects that affect the orbitals around gold atoms. Similar effects impart a golden hue to metallic caesium.

Common colored gold alloys such as rose gold can be created by the addition of various amounts of copper and silver, as indicated in the triangular diagram to the left. Alloys containing palladium or nickel are also important in commercial jewelry as these produce white gold alloys. Less commonly, addition of manganese, aluminium, iron, indium and other elements can produce more unusual colors of gold for various applications.

Isotopes

Gold has only one stable isotope, $^{197}$Au, which is also its only naturally occurring isotope. Thirty-six radioisotopes have been synthesized ranging in atomic mass from 169 to 205. The most stable of these is $^{195}$Au with a half-life of 186.1 days. The least stable is $^{171}$Au, which decays by proton emission with a half-life of 30 µs. Most of gold's radioisotopes with atomic masses below 197 decay by some combination of proton emission, $\alpha$ decay, and $\beta^+$ decay. The exceptions are $^{195}$Au, which decays by electron capture, and $^{196}$Au, which decays most often by electron capture (93%) with a minor $\beta^-$ decay path (7%). All of gold's radioisotopes with atomic masses above 197 decay by $\beta^-$ decay.

At least 32 nuclear isomers have also been characterized, ranging in atomic mass from 170 to 200. Within that range, only $^{178}$Au, $^{180}$Au, $^{181}$Au, $^{182}$Au, and $^{188}$Au do not have isomers. Gold's most stable isomer is $^{198m2}$Au with a half-life of 2.27 days. Gold's least stable isomer is $^{177m2}$Au with a half-life of only 7 ns. $^{184m1}$Au has three decay paths: $\beta^+$ decay, isomeric transition, and alpha decay. No other isomer or isotope of gold has three decay paths.

Applications

Monetary exchange

Gold has been widely used throughout the world as money, for efficient indirect exchange (versus barter), and to store wealth in hoards. For exchange purposes, mints produce standardized gold bullion coins, bars and other units of fixed weight and purity.

The first coins containing gold were struck in Lydia, Asia Minor, around 600 BC. The talent coin of gold in use during the periods of Grecian history both before and during the time of the life of Homer weighed between 8.42 and 8.75 grams. From an earlier preference in using silver, European economies re-established the minting of gold as coinage during the thirteenth and fourteenth centuries.

Bills (that mature into gold coin) and gold certificates (convertible into gold coin at the issuing bank) added to the circulating stock of gold standard money in most 19th century industrial economies. In preparation for World War I
the warring nations moved to fractional gold standards, inflating their currencies to finance the war effort. Post-war, the victorious countries, most notably Britain, gradually restored gold-convertibility, but international flows of gold via bills of exchange remained embargoed; international shipments were made exclusively for bilateral trades or to pay war reparations.

After World War II gold was replaced by a system of nominally convertible currencies related by fixed exchange rates following the Bretton Woods system. Gold standards and the direct convertibility of currencies to gold have been abandoned by world governments, led in 1971 by the United States' refusal to redeem its dollars in gold. Fiat currency now fills most monetary roles. Switzerland was the last country to tie its currency to gold; it backed 40% of its value until the Swiss joined the International Monetary Fund in 1999.

Central banks continue to keep a portion of their liquid reserves as gold in some form, and metals exchanges such as the London Bullion Market Association still clear transactions denominated in gold, including future delivery contracts. Today, gold mining output is declining. With the sharp growth of economies in the 20th century, and increasing foreign exchange, the world's gold reserves and their trading market have become a small fraction of all markets and fixed exchange rates of currencies to gold have been replaced by floating prices for gold and gold future contract. Though the gold stock grows by only 1 or 2% per year, very little metal is irrevocably consumed. Inventory above ground would satisfy many decades of industrial and even artisan uses at current prices.

The gold content of alloys is measured in carats (k). Pure gold is designated as 24k. English gold coins intended for circulation from 1526 into the 1930s were typically a standard 22k alloy called crown gold, for hardness (American gold coins for circulation after 1837 contained the slightly lower amount of 0.900 fine gold, or 21.6 kt).

Although the prices of some platinum group metals can be much higher, gold has long been considered the most desirable of precious metals, and its value has been used as the standard for many currencies. Gold has been used as a symbol for purity, value, royalty, and particularly roles that combine these properties. Gold as a sign of wealth and prestige was ridiculed by Thomas More in his treatise \textit{Utopia}. On that imaginary island, gold is so abundant that it is used to make chains for slaves, tableware, and lavatory seats. When ambassadors from other countries arrive, dressed in ostentatious gold jewels and badges, the Utopians mistake them for menial servants, paying homage instead to the most modestly dressed of their party.

\section*{Investment}

Many holders of gold store it in form of bullion coins or bars as a hedge against inflation or other economic disruptions. However, economist Martin Feldstein does not believe gold serves as a hedge against inflation or currency depreciation.

The ISO 4217 currency code of gold is XAU.

Modern bullion coins for investment or collector purposes do not require good mechanical wear properties; they are typically fine gold at 24k, although the American Gold Eagle and the British gold sovereign continue to be minted in 22k metal in historical tradition, and the South African Krugerand, first released in 1967, is also 22k. The \textit{special issue} Canadian Gold Maple Leaf coin contains the highest purity gold of any bullion coin, at 99.999% or 0.99999, while the \textit{popular issue} Canadian Gold Maple Leaf coin has a purity of

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{gold_prices.png}
\caption{Gold prices (US$ per troy ounce), in nominal US$ and inflation adjusted US$.}
\end{figure}
Several other 99.99% pure gold coins are available. In 2006, the United States Mint began producing the American Buffalo gold bullion coin with a purity of 99.99%. The Australian Gold Kangaroos were first coined in 1986 as the Australian Gold Nugget but changed the reverse design in 1989. Other modern coins include the Austrian Vienna Philharmonic bullion coin and the Chinese Gold Panda.

**Jewelry**

Because of the softness of pure (24k) gold, it is usually alloyed with base metals for use in jewelry, altering its hardness and ductility, melting point, color and other properties. Alloys with lower carat rating, typically 22k, 18k, 14k or 10k, contain higher percentages of copper or other base metals or silver or palladium in the alloy. Copper is the most commonly used base metal, yielding a redder color.[11]

Eighteen-carat gold containing 25% copper is found in antique and Russian jewelry and has a distinct, though not dominant, copper cast, creating rose gold. Fourteen-carat gold-copper alloy is nearly identical in color to certain bronze alloys, and both may be used to produce police and other badges. Blue gold can be made by alloying with iron and purple gold can be made by alloying with aluminium, although rarely done except in specialized jewelry. Blue gold is more brittle and therefore more difficult to work with when making jewelry.

Fourteen- and eighteen-carat gold alloys with silver alone appear greenish-yellow and are referred to as green gold. White gold alloys can be made with palladium or nickel. White 18-carat gold containing 17.3% nickel, 5.5% zinc and 2.2% copper is silvery in appearance. Nickel is toxic, however, and its release from nickel white gold is controlled by legislation in Europe.

Alternative white gold alloys are available based on palladium, silver and other white metals, but the palladium alloys are more expensive than those using nickel. High-carat white gold alloys are far more resistant to corrosion than are either pure silver or sterling silver. The Japanese craft of Mokume-gane exploits the color contrasts between laminated colored gold alloys to produce decorative wood-grain effects.

**Medicine**

Gold is perhaps the most anciently administered medicine (apparently by shamanic practitioners) and known to Dioscorides,[12] apparent paradoxes of the actual toxicology of the substance nevertheless suggests the possibility still of serious gaps in understanding of action on physiology.

In medieval times, gold was often seen as beneficial for the health, in the belief that something so rare and beautiful could not be anything but healthy. Even some modern esotericists and forms of alternative medicine assign metallic gold a healing power. Some gold salts do have anti-inflammatory properties and are used as pharmaceuticals in the treatment of arthritis and other similar conditions. Gold based injections have been explored as a means to help to reduce the pain and swelling of rheumatoid arthritis and tuberculosis. However, only salts and radioisotopes of gold are of pharmacological value, as elemental (metallic) gold is inert to all chemicals it encounters inside the body.

Gold alloys are used in restorative dentistry, especially in tooth restorations, such as crowns and permanent bridges. The gold alloys' slight malleability facilitates the creation of a superior molar mating surface with other teeth and produces results that are generally more satisfactory than those produced by the creation of porcelain crowns. The use of gold crowns in more prominent teeth such as incisors is favored in some cultures and discouraged in others.

Colloidal gold preparations (suspensions of gold nanoparticles) in water are intensely red-colored, and can be made with tightly controlled particle sizes up to a few tens of nanometers across by reduction of gold chloride with citrate...
Gold or ascorbate ions. Colloidal gold is used in research applications in medicine, biology and materials science. The technique of immunogold labeling exploits the ability of the gold particles to adsorb protein molecules onto their surfaces. Colloidal gold particles coated with specific antibodies can be used as probes for the presence and position of antigens on the surfaces of cells. In ultrathin sections of tissues viewed by electron microscopy, the immunogold labels appear as extremely dense round spots at the position of the antigen.

Gold, or alloys of gold and palladium, are applied as conductive coating to biological specimens and other non-conducting materials such as plastics and glass to be viewed in a scanning electron microscope. The coating, which is usually applied by sputtering with an argon plasma, has a triple role in this application. Gold's very high electrical conductivity drains electrical charge to earth, and its very high density provides stopping power for electrons in the electron beam, helping to limit the depth to which the electron beam penetrates the specimen. This improves definition of the position and topography of the specimen surface and increases the spatial resolution of the image. Gold also produces a high output of secondary electrons when irradiated by an electron beam, and these low-energy electrons are the most commonly used signal source used in the scanning electron microscope.

The isotope gold-198 (half-life 2.7 days) is used, in nuclear medicine, in some cancer treatments and for treating other diseases.

**Food and drink**

- Gold can be used in food and has the E number 175.
- Gold leaf, flake or dust is used on and in some gourmet foods, notably sweets and drinks as decorative ingredient. Gold flake was used by the nobility in medieval Europe as a decoration in food and drinks, in the form of leaf, flakes or dust, either to demonstrate the host's wealth or in the belief that something that valuable and rare must be beneficial for one's health.
- Danziger Goldwasser (German: Gold water of Danzig) or Goldwasser (English: Goldwater) is a traditional German herbal liqueur produced in what is today Gdańsk, Poland, and Schwabach, Germany, and contains flakes of gold leaf. There are also some expensive (~$1000) cocktails which contain flakes of gold leaf. However, since metallic gold is inert to all body chemistry, it has no taste, it provides no nutrition, and it leaves the body unaltered.

**Industry**

- Gold solder is used for joining the components of gold jewelry by high-temperature hard soldering or brazing. If the work is to be of hallmarking quality, gold solder must match the carat weight of the work, and alloy formulas are manufactured in most industry-standard carat weights to color match yellow and white gold. Gold solder is usually made in at least three melting-point ranges referred to as Easy, Medium and Hard. By using the hard, high-melting point solder first, followed by solders with progressively lower melting points, goldsmiths can assemble complex items with several separate soldered joints.
- Gold can be made into thread and used in embroidery.
- Gold produces a deep, intense red color when used as a coloring agent in cranberry glass.
- In photography, gold toners are used to shift the color of silver bromide black-and-white prints towards brown or blue tones, or to
increase their stability. Used on sepia-toned prints, gold toners produce red
tones. Kodak published formulas for several types of gold toners, which use
gold as the chloride.\textsuperscript{[14]}

- Gold is a good reflector of electromagnetic radiation such as infrared and
visible light as well as radio waves. It is used for the protective coatings on
many artificial satellites, in infrared protective faceplates in thermal protection
suits and astronauts' helmets and in electronic warfare planes like the EA-6B
Prowler.

- Gold is used as the reflective layer on some high-end CDs.
- Automobiles may use gold for heat shielding. McLaren uses gold foil in the
engine compartment of its F1 model.
- Gold can be manufactured so thin that it appears transparent. It is used in
some aircraft cockpit windows for de-icing or anti-icing by passing electricity
through it. The heat produced by the resistance of the gold is enough to deter
ice from forming.

**Electronics**

The concentration of free electrons in gold metal is $5.90 \times 10^{22} \text{ cm}^{-3}$. Gold is
highly conductive to electricity, and has been used for electrical wiring in some
high-energy applications (only silver and copper are more conductive per
volume, but gold has the advantage of corrosion resistance). For example, gold
electrical wires were used during some of the Manhattan Project's atomic
experiments, but large high current silver wires were used in the calutron isotope
separator magnets in the project.

Though gold is attacked by free chlorine, its good conductivity and general
resistance to oxidation and corrosion in other environments (including resistance
to non-chlorinated acids) has led to its widespread industrial use in the electronic
era as a thin layer coating electrical connectors, thereby ensuring good
connection. For example, gold is used in the connectors of the more expensive
electronics cables, such as audio, video and USB cables. The benefit of using
gold over other connector metals such as tin in these applications has been debated; gold connectors are often
criticized by audio-visual experts as unnecessary for most consumers and seen as simply a marketing ploy. However,
the use of gold in other applications in electronic sliding contacts in highly humid or corrosive atmospheres, and in
use for contacts with a very high failure cost (certain computers, communications equipment, spacecraft, jet aircraft
engines) remains very common.

Besides sliding electrical contacts, gold is also used in electrical contacts because of its resistance to corrosion,
electrical conductivity, ductility and lack of toxicity. Switch contacts are generally subjected to more intense
corrosion stress than are sliding contacts. Fine gold wires are used to connect semiconductor devices to their
packages through a process known as wire bonding.
Commercial chemistry

Gold is attacked by and dissolves in alkaline solutions of potassium or sodium cyanide, to form the salt gold cyanide—a technique that has been used in extracting metallic gold from ores in the cyanide process. Gold cyanide is the electrolyte used in commercial electroplating of gold onto base metals and electroforming.

Gold chloride (chloroauric acid) solutions are used to make colloidal gold by reduction with citrate or ascorbate ions. Gold chloride and gold oxide are used to make cranberry or red-colored glass, which, like colloidal gold suspensions, contains evenly sized spherical gold nanoparticles.

Cultural history

Gold artifacts found at the Nahal Kana cave cemetery dated during the 1980s, showed these to be from within the Chalcolithic, and considered the earliest find from the Levant (Gopher et al. 1990). Gold artifacts in the Balkans also appear from the 4th millennium BC, such as those found in the Varna Necropolis near Lake Varna in Bulgaria, thought by one source (La Niece 2009) to be the earliest "well-dated" find of gold artifacts. Gold artifacts such as the golden hats and the Nebra disk appeared in Central Europe from the 2nd millennium BC Bronze Age.

Egyptian hieroglyphs from as early as 2600 BC describe gold, which king Tushratta of the Mitanni claimed was "more plentiful than dirt" in Egypt. Egypt and especially Nubia had the resources to make them major gold-producing areas for much of history. The earliest known map is known as the Turin Papyrus Map and shows the plan of a gold mine in Nubia together with indications of the local geology. The primitive working methods are described by both Strabo and Diodorus Siculus, and included fire-setting. Large mines were also present across the Red Sea in what is now Saudi Arabia.

The legend of the golden fleece may refer to the use of fleeces to trap gold dust from placer deposits in the ancient world. Gold is mentioned frequently in the Old Testament, starting with Genesis 2:11 (at Havilah), the story of The Golden Calf and many parts of the temple including the Menorah and the golden altar. In the New Testament, it is included with the gifts of the magi in the first chapters of Matthew. The Book of Revelation 21:21 describes the city of New Jerusalem as having streets "made of pure gold, clear as crystal". Exploitation of gold in the south-east corner of the Black Sea is said to date from the time of Midas, and this gold was important in the establishment of what is probably the world's earliest coinage in Lydia around 610 BC. From the 6th or 5th century BC, the Chu (state) circulated the Ying Yuan, one kind of square gold coin.

In Roman metallurgy, new methods for extracting gold on a large scale were developed by introducing hydraulic mining methods, especially in Hispania from 25 BC onwards and in Dacia from 106 AD onwards. One of their largest mines was at Las Medulas in León (Spain), where
seven long aqueducts enabled them to sluice most of a large alluvial deposit. The mines at Roşia Montană in Transylvania were also very large, and until very recently, still mined by opencast methods. They also exploited smaller deposits in Britain, such as placer and hard-rock deposits at Dolaucothi. The various methods they used are well described by Pliny the Elder in his encyclopedia Naturalis Historia written towards the end of the first century AD.

During Mansa Musa's (ruler of the Mali Empire from 1312 to 1337) hajj to Mecca in 1324, he passed through Cairo in July 1324, and was reportedly accompanied by a camel train that included thousands of people and nearly a hundred camels where he gave away so much gold that it depressed the price in Egypt for over a decade. A contemporary Arab historian remarked:

Gold was at a high price in Egypt until they came in that year. The mithqal did not go below 25 dirhams and was generally above, but from that time its value fell and it cheapened in price and has remained cheap till now. The mithqal does not exceed 22 dirhams or less. This has been the state of affairs for about twelve years until this day by reason of the large amount of gold which they brought into Egypt and spent there […]

—Chihab Al-Umari,

The Portuguese overseas expansion started in 1415 with the taking of Ceuta, to control the gold trade coming across the desert. Although the caravan trade routes were then diverted, the Portuguese continued expanding southwards along the coast and eventually buying the gold directly (or less indirectly) from the Africans in the Gulf of Guinea.

The European exploration of the Americas was fueled in no small part by reports of the gold ornaments displayed in great profusion by Native American peoples, especially in Central America, Peru, Ecuador and Colombia. The Aztecs regarded gold as literally the product of the gods, calling it "god excrement" (teocuitlatl in Nahuatl), and after Montezuma was killed, most of this gold was shipped to Spain. However, for the indigenous peoples of North America gold was considered useless and they saw much greater value in other minerals which were directly related to their utility, such as obsidian, flint, and slate.

Gold played a role in western culture, as a cause for desire and of corruption, as told in children's fables like Rumplestiltskin, where the peasant's daughter turns hay into gold, in return for giving up her child when she becomes a princess, and stealing the hen that lays golden eggs in Jack and the beanstalk.

The top prize at the Olympic games is the gold medal.

There is an age-old tradition of biting gold to test its authenticity. Although this is certainly not a professional way of examining gold, the bite test was not to check if the coin was gold (90% gold coins are fairly strong) but to see if the coin was gold plated lead. A lead coin would be very soft and thus teeth marks would result. Fake gold coins were a common problem before 1932 so weighing a coin and also sliding a coin through a "counterfeit detector" slot was common (making a lead coin thicker would add weight thus why slide it through a measured slot).
establishments (especially US Western saloons) would never accept a gold (or silver) coin of high value before weighing such an item.\[citation needed\]

75% of all gold ever produced has been extracted since 1910. It has been estimated that all gold ever refined would form a single cube 20 m (66 ft) on a side (equivalent to 8,000 m$^3$).

One main goal of the alchemists was to produce gold from other substances, such as lead — presumably by the interaction with a mythical substance called the philosopher's stone. Although they never succeeded in this attempt, the alchemists promoted an interest in what can be done with substances, and this laid a foundation for today's chemistry. Their symbol for gold was the circle with a point at its center (☉), which was also the astrological symbol and the ancient Chinese character for the Sun.

Golden treasures have been rumored to be found at various locations, following tragedies such as the Jewish temple treasures in the Vatican, following the temple's destruction in 70 AD, a gold stash on the Titanic, the Nazi gold train – following World War II.

The Dome of the Rock on the Jerusalem temple site is covered with an ultra-thin golden glasureWikipedia:Please clarify. The Sikh Golden temple, the Harmandir Sahib, is a building covered with gold. Similarly the Wat Phra Kaew emerald Budha temple in Thailand has ornamental gold statues walls and roofs. Some European king and queen's crowns were made of gold, and gold was used for the bridal crown since antiquity. An ancient Talmudic text circa 100 AD describes Rachel, Rabbi Akiba's wife asking for a "Jerusalem of Gold" (crown). A Greek burial crown made of gold was found in a grave circa 370 BC.

### Occurrence

Gold's atomic number of 79 makes it one of the higher atomic number elements which occur naturally. Like all elements with atomic numbers larger than iron, gold is thought to have been formed from a supernova nucleosynthesis process,\[citation needed\] although a newer theory suggests they are made by the collision of neutron stars instead. Either way, satellites should be able to detect the resulting gold, "but we have no spectroscopic evidence that [such] elements have truly been produced." \[17\] These theories hold that the resulting explosions scattered metal-containing dusts (including heavy elements like gold) into the region of space in which they later condensed into our solar system and the Earth. Because the Earth was molten when it was just formed, almost all of the gold present on Earth sank into the core. Most of the gold that is present today in the Earth's crust and mantle was delivered to Earth by asteroid impacts during the late heavy bombardment.

On Earth, gold is found in ores in rock formed from the Precambrian time onward. It most often occurs as a native metal, typically in a metal solid solution with silver (i.e. as a gold silver alloy). Such alloys usually have a silver content of 8–10%. Electrum is elemental gold with more than 20% silver. Electrum's color runs from golden-silvery to silvery, dependent upon the silver content. The more silver, the lower the specific gravity.

Native gold occurs as very small to microscopic particles embedded in rock, often together with quartz or sulfide minerals such as "Fool's Gold", which is a pyrite. These are called lode deposits. The metal in a native state is also found in the form of free flakes, grains or larger nuggets that have been eroded from rocks and end up in alluvial deposits called placer deposits. Such free gold is always richer at the surface of gold-bearing veinsWikipedia:Please clarify owing to the oxidation of accompanying minerals followed by weathering, and washing of the dust into streams and rivers, where it collects and can be welded by water action to form nuggets.
Gold sometimes occurs combined with tellurium as the minerals calaverite, krennerite, nagyagite, petzite and sylvanite (see telluride minerals), and as the rare bismuthide maldonite (Au₂Bi) and antimonide aurostibite (AuSb₂). Gold also occurs in rare alloys with copper, lead, and mercury: the minerals auricupride (Cu₃Au), novodneprite (AuPb₃) and weishanite ((Au, Ag)₃Hg₂).

Recent research suggests that microbes can sometimes play an important role in forming gold deposits, transporting and precipitating gold to form grains and nuggets that collect in alluvial deposits.[18]

Another recent study has claimed water in faults vaporizes during an earthquake, depositing gold. When an earthquake strikes, it moves along a fault. Water often lubricates faults, filling in fractures and jogs. About 6 miles (10 kilometers) below the surface, under incredible temperatures and pressures, the water carries high concentrations of carbon dioxide, silica, and gold. During an earthquake, the fault jog suddenly opens wider. The water inside the void instantly vaporizes, flashing to steam and forcing silica, which forms the mineral quartz, and gold out of the fluids and onto nearby surfaces.

**Seawater**

The world's oceans contain gold. Measured concentrations of gold in the Atlantic and Northeast Pacific are 50–150 fmol/L or 10–30 parts per 1,000,000,000,000,000 quadrillion (about 10–30 g/km³). In general, gold concentrations for south Atlantic and central Pacific samples are the same (~50 fmol/L) but less certain. Mediterranean deep waters contain slightly higher concentrations of gold (100–150 fmol/L) attributed to wind-blown dust and/or rivers. At 10 parts per quadrillion the Earth's oceans would hold 15,000 tonnes of gold. These figures are three orders of magnitude less than reported in the literature prior to 1988, indicating contamination problems with the earlier data.

A number of people have claimed to be able to economically recover gold from sea water, but so far they have all been either mistaken or acted in an intentional deception. Prescott Jernegan ran a gold-from-seawater swindle in the United States in the 1890s. A British fraudster ran the same scam in England in the early 1900s.[19] Fritz Haber (the German inventor of the Haber process) did research on the extraction of gold from sea water in an effort to help pay Germany's reparations following World War I. Based on the published values of 2 to 64 ppb of gold in seawater a commercially successful extraction seemed possible. After analysis of 4,000 water samples yielding an average of 0.004 ppb it became clear that the extraction would not be possible and he stopped the project. No commercially viable mechanism for performing gold extraction from sea water has yet been identified. Gold synthesis is not economically viable and is unlikely to become so in the foreseeable future.
Specimens of crystalline native gold

Native gold nuggets

"Rope gold" from Lena River, Sakha Republic, Russia. Size: 2.5×1.2×0.7 cm.

Crystalline gold from Mina Zapata, Santa Elena de Uairen, Venezuela. Size: 3.7×1.1×0.4 cm.

Gold leaf from Harvard Mine, Jamestown, California, USA. Size: 9.3×3.2× >0.1 cm.

Production

At the end of 2009, it was estimated that all the gold ever mined totaled 165,000 tonnes. This can be represented by a cube with an edge length of about 20.28 meters. At $1,600 per troy ounce, 165,000 metric tonnes of gold would have a value of $8.5 trillion.

World production for 2011 was at 2,700 tonnes, compared to 2,260 tonnes for 2008.

Since the 1880s, South Africa has been the source for a large proportion of the world's gold supply, with about 50% of all gold ever produced having come from South Africa. Production in 1970 accounted for 79% of the world supply, producing about 1,480 tonnes. In 2007 China (with 276 tonnes) overtook South Africa as the world's largest gold producer, the first time since 1905 that South Africa has not been the largest.

Mining

The city of Johannesburg located in South Africa was founded as a result of the Witwatersrand Gold Rush which resulted in the discovery of some of the largest gold deposits the world has ever seen. Gold fields located within the basin in the Free State and Gauteng provinces are extensive in strike and dip requiring some of the world's deepest mines, with the Savuka and TauTona mines being currently the world's deepest gold mine at 3,777 m. The Second Boer War of 1899–1901 between the British Empire and the Afrikaner Boers was at least partly over the rights of miners and possession of the gold wealth in South Africa.
Other major producers are the United States, Australia, Russia, and Peru, as well as, Ghana, Burkina Faso, Mali, Indonesia and Uzbekistan. Mines in South Dakota and Nevada supply two-thirds of gold used in the United States. In South America, the controversial project Pascua Lama aims at exploitation of rich fields in the high mountains of Atacama Desert, at the border between Chile and Argentina. Today about one-quarter of the world gold output is estimated to originate from artisanal or small scale mining.

Prospecting

During the 19th century, gold rushes occurred whenever large gold deposits were discovered. The first documented discovery of gold in the United States was at the Reed Gold Mine near Georgeville, North Carolina in 1803. The first major gold strike in the United States occurred in a small north Georgia town called Dahlonega. Further gold rushes occurred in California, Colorado, the Black Hills, Otago in New Zealand, Australia, Witwatersrand in South Africa, and the Klondike in Canada.

Extraction

Gold extraction is most economical in large, easily mined deposits. Ore grades as little as 0.5 mg/kg (0.5 parts per million, ppm) can be economical. Typical ore grades in open-pit mines are 1–5 mg/kg (1–5 ppm); ore grades in underground or hard rock mines are usually at least 3 mg/kg (3 ppm). Because ore grades of 30 mg/kg (30 ppm) are usually needed before gold is visible to the naked eye, in most gold mines the gold is invisible.

The average gold mining and extraction costs were about US$317/oz in 2007, but these can vary widely depending on mining type and ore quality; global mine production amounted to 2,471.1 tonnes.

Refining

After initial production, gold is often subsequently refined industrially by the Wohlwill process which is based on electrolysis or by the Miller process, that is chlorination in the melt. The Wohlwill process results in higher purity, but is more complex and is only applied in small-scale installations. Other methods of assaying and purifying smaller amounts of gold include parting and inquartation as well as cupellation, or refining methods based on the dissolution of gold in aqua regia.

Synthesis from other elements

Gold was synthesized from mercury by neutron bombardment in 1941, but the isotopes of gold produced were all radioactive. In 1924, a Japanese physicist, Hantaro Nagaoka, accomplished the same feat.

Gold can currently be manufactured in a nuclear reactor by irradiation either of platinum or mercury.

Only the mercury isotope 196Hg, which occurs with a frequency of 0.15% in natural mercury, can be converted to gold by neutron capture, and following electron capture-decay into 197Au with slow neutrons. Other mercury isotopes are converted when irradiated with slow neutrons into one another, or formed mercury isotopes which beta decay into thallium.

Using fast neutrons, the mercury isotope 198Hg, which composes 9.97% of natural mercury, can be converted by splitting off a neutron and becoming 197Hg, which then disintegrates to stable gold. This reaction, however, possesses a smaller activation cross-section and is feasible only with un-moderated reactors.

It is also possible to eject several neutrons with very high energy into the other mercury isotopes in order to form 197Hg. However such high-energy neutrons can be produced only by particle accelerators.
Consumption
The consumption of gold produced in the world is about 50% in jewelry, 40% in investments, and 10% in industry.\[citation needed\]

India is the world's largest single consumer of gold, as Indians buy about 25% of the world's gold, purchasing approximately 800 tonnes of gold every year, mostly for jewelry. India is also the largest importer of gold; in 2008, India imported around 400 tonnes of gold. Indian households hold 18,000 tonnes of gold which represents 11% of the global stock and worth more than $950 billion.

<table>
<thead>
<tr>
<th>Country</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
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</thead>
<tbody>
<tr>
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<td>442.37</td>
<td>745.70</td>
<td>986.3</td>
<td>864.0</td>
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<td>428.00</td>
<td>921.5</td>
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<td>74.07</td>
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<td>72.95</td>
<td>69.1</td>
<td>58.5</td>
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<tr>
<td>Russia</td>
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<td>67.50</td>
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</tr>
<tr>
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<td>58.1</td>
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<td>56.68</td>
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<td>55.0</td>
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</tr>
<tr>
<td>United Kingdom</td>
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<td>27.35</td>
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<td>22</td>
<td>19.9</td>
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<td>15.5</td>
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<td>Total</td>
<td>1508.70</td>
<td>1805.60</td>
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<td>Other Countries</td>
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<td>390.4</td>
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<td>1760.3</td>
<td>2059.6</td>
<td>3487.5</td>
<td>3163.6</td>
</tr>
</tbody>
</table>

Pollution
Gold production is associated with contribution to hazardous pollution.\[20\] The ore, generally containing less than one ppm gold metal, is ground and mixed with sodium cyanide or mercury to react with gold in the ore for gold separation. Cyanide is a highly poisonous chemical, which can kill living creatures when exposed in minute quantities. Many cyanide spills\[21\] from gold mines have occurred in both developed and developing countries which killed marine life in long stretches of affected rivers. Environmentalists consider these events major environmental disasters.\[22\][23] When mercury is used in gold production, minute quantity of mercury compounds reach water bodies, causing heavy metal contamination. Mercury can then enter into the human food chain in the form of methyl mercury. Mercury poisoning in humans causes incurable brain function damage and severe retardation.

Thirty tonnes of used ore is dumped as waste for producing one 1 ounce (28 g) of gold.\[24\] Gold ore dumps are the source of many heavy elements such as cadmium, lead, zinc, copper, arsenic, selenium and mercury. When sulfide bearing minerals in these ore dumps are exposed to air and water, the sulfide transforms into sulfuric acid which in
turn dissolves these heavy metals facilitating their passage into surface water and ground water. This process is called acid mine drainage. These gold ore dumps are long term, highly hazardous wastes second only to nuclear waste dumps.

Gold extraction is also a highly energy intensive industry, extracting ore from deep mines and grinding the large quantity of ore for further chemical extraction requires with 25 kW·h of electricity required per gram of gold produced.

**Chemistry**

Although gold is the most noble of the noble metals, it still forms many diverse compounds. The oxidation state of gold in its compounds ranges from −1 to +5, but Au(I) and Au(III) dominate its chemistry. Au(I), referred to as the aurous ion, is the most common oxidation state with soft ligands such as thioethers, thiolates, and tertiary phosphines. Au(III) compounds are typically linear. A good example is Au(CN)₂⁻, which is the soluble form of gold encountered in mining. Curiously, aurous complexes of water are rare. The binary gold halides, such as AuCl, form zigzag polymeric chains, again featuring linear coordination at Au. Most drugs based on gold are Au(I) derivatives.

Au(III) (auric) is a common oxidation state, and is illustrated by gold(III) chloride, AuCl₆³⁻. The gold atom centers in Au(III) complexes, like other d⁸ compounds, are typically square planar, with chemical bonds that have both covalent and ionic character.

Aqua regia, a 1:3 mixture of nitric acid and hydrochloric acid, dissolves gold. Nitric acid oxidizes the metal to +3 ions, but only in minute amounts, typically undetectable in the pure acid because of the chemical equilibrium of the reaction. However, the ions are removed from the equilibrium by hydrochloric acid, forming AuCl₄⁻ ions, or chloroauric acid, thereby enabling further oxidation.

Some free halogens react with gold. Gold also reacts in alkaline solutions of potassium cyanide. With mercury, it forms an amalgam.

**Less common oxidation states**

Less common oxidation states of gold include −1, +2, and +5.

The −1 oxidation state occurs in compounds containing the Au⁻ anion, called aurides. Caesium auride (CsAu), for example, crystallizes in the caesium chloride motif. Other aurides include those of Rb⁺, K⁺, and tetramethylammonium (CH₃)₄N⁺. Gold has the highest Pauling electronegativity of any metal, with a value of 2.54, making the auride anion relatively stable.

Gold(II) compounds are usually diamagnetic with Au–Au bonds such as [Au(CH₃)₂P(C₆H₅)₂]₂Cl₂. The evaporation of a solution of Au(OH)₃ in concentrated H₂SO₄ produces red crystals of gold(II) sulfate, Au₂(SO₄)₂. Originally thought to be a mixed-valence compound, it has been shown to contain Au⁴⁺ cations. A noteworthy, legitimate gold(II) complex is the tetraxenonogold(II) cation, which contains xenon as a ligand, found in [AuXe₄⁺(Sb₂F₁₁)₂]⁻.

Gold pentafluoride, along with its derivative anion, AuF⁻₆, and its difluorine complex, gold heptafluoride, is the sole example of gold(V), the highest verified oxidation state.
Some gold compounds exhibit aurophilic bonding, which describes the tendency of gold ions to interact at distances that are too long to be a conventional Au–Au bond but shorter than van der Waals bonding. The interaction is estimated to be comparable in strength to that of a hydrogen bond.

**Mixed valence compounds**

Well-defined cluster compounds are numerous. In such cases, gold has a fractional oxidation state. A representative example is the octahedral species \( \{\text{Au}(\text{P(C}_6\text{H}_5)_3)^{2+}\}_6 \). Gold chalcogenides, such as gold sulfide, feature equal amounts of Au(I) and Au(III).

**Toxicity**

Pure metallic (elemental) gold is non-toxic and non-irritating when ingested and is sometimes used as a food decoration in the form of gold leaf. Metallic gold is also a component of the alcoholic drinks Goldschläger, Gold Strike, and Goldwasser. Metallic gold is approved as a food additive in the EU (E175 in the Codex Alimentarius). Although the gold ion is toxic, the acceptance of metallic gold as a food additive is due to its relative chemical inertness, and resistance to being corroded or transformed into soluble salts (gold compounds) by any known chemical process which would be encountered in the human body.

Soluble compounds (gold salts) such as gold chloride are toxic to the liver and kidneys. Common cyanide salts of gold such as potassium gold cyanide, used in gold electroplating, are toxic by virtue of both their cyanide and gold content. There are rare cases of lethal gold poisoning from potassium gold cyanide. Gold toxicity can be ameliorated with chelation therapy with an agent such as dimercaprol.

Gold metal was voted Allergen of the Year in 2001 by the American Contact Dermatitis Society. Gold contact allergies affect mostly women.\(^{[26]}\) Despite this, gold is a relatively non-potent contact allergen, in comparison with metals like nickel.

**Price**

Gold is currently valued at around US$62,000 per kilogram.

Like other precious metals, gold is measured by troy weight and by grams. When it is alloyed with other metals the term carat or karat is used to indicate the purity of gold present, with 24 carats being pure gold and lower ratings proportionally less. The purity of a gold bar or coin can also be expressed as a decimal figure ranging from 0 to 1, known as the millesimal fineness, such as 0.995 being very pure.

**History**

The price of gold is determined through trading in the gold and derivatives markets, but a procedure known as the Gold Fixing in London, originating in September 1919, provides a daily benchmark price to the industry. The afternoon fixing was introduced in 1968 to provide a price when US markets are open.

Historically gold coinage was widely used as currency; when paper money was introduced, it typically was a receipt redeemable for gold coin or bullion. In a monetary system known as the gold standard, a certain weight of gold was
given the name of a unit of currency. For a long period, the United States government set the value of the US dollar so that one troy ounce was equal to $20.67 ($664.56/kg), but in 1934 the dollar was devalued to $35.00 per troy ounce ($1125.27/kg). By 1961, it was becoming hard to maintain this price, and a pool of US and European banks agreed to manipulate the market to prevent further currency devaluation against increased gold demand.

On 17 March 1968, economic circumstances caused the collapse of the gold pool, and a two-tiered pricing scheme was established whereby gold was still used to settle international accounts at the old $35.00 per troy ounce ($1.13/g) but the price of gold on the private market was allowed to fluctuate; this two-tiered pricing system was abandoned in 1975 when the price of gold was left to find its free-market level. Central banks still hold historical gold reserves as a store of value although the level has generally been declining. The largest gold depository in the world is that of the U.S. Federal Reserve Bank in New York, which holds about 3% of the gold ever mined, as does the similarly laden U.S. Bullion Depository at Fort Knox. In 2005 the World Gold Council estimated total global gold supply to be 3,859 tonnes and demand to be 3,754 tonnes, giving a surplus of 105 tonnes.

Sometime around 1970 the price began in trend to greatly increase, and since 1968 the price of gold has ranged widely, from a high of $850/oz ($27,300/kg) on 21 January 1980, to a low of $252.90/oz ($8,131/kg) on 21 June 1999 (London Gold Fixing). The period from 1999 to 2001 marked the "Brown Bottom" after a 20-year bear market. Prices increased rapidly from 2001, but the 1980 high was not exceeded until 3 January 2008 when a new maximum of $865.35 per troy ounce was set. Another record price was set on 17 March 2008 at $1023.50/oz ($32,900/kg).

In late 2009, gold markets experienced renewed momentum upwards due to increased demand and a weakening US dollar. On 2 December 2009, Gold reached a new high closing at $1,217.23. Gold further rallied hitting new highs in May 2010 after the European Union debt crisis prompted further purchase of gold as a safe asset. On 1 March 2011, gold hit a new all-time high of $1432.57, based on investor concerns regarding ongoing unrest in North Africa as well as in the Middle East.

Since April 2001 the gold price has more than quintupled in value against the US dollar, hitting a new all-time high of $1,913.50 on 23 August 2011, prompting speculation that this long secular bear market has ended and a bull market has returned.

**Symbolism**

Great human achievements are frequently rewarded with gold, in the form of gold medals, golden trophies and other decorations. Winners of athletic events and other graded competitions are usually awarded a gold medal. Many awards such as the Nobel Prize are made from gold as well. Other award statues and prizes are depicted in gold or are gold plated (such as the Academy Awards, the Golden Globe Awards, the Emmy Awards, the Palme d'Or, and the British Academy Film Awards).

Aristotle in his ethics used gold symbolism when referring to what is now commonly known as the golden mean. Similarly, gold is associated with perfect or divine principles, such as in the case of the golden ratio and the golden rule.
Gold is further associated with the wisdom of aging and fruition. The fiftieth wedding anniversary is golden. Our precious latter years are sometimes considered "golden years". The height of a civilization is referred to as a "golden age".

In some forms of Christianity and Judaism, gold has been associated both with holiness and evil. In the Book of Exodus, the Golden Calf is a symbol of idolatry, while in the Book of Genesis, Abraham was said to be rich in gold and silver, and Moses was instructed to cover the Mercy Seat of the Ark of the Covenant with pure gold. In Byzantine iconography the halos of Christ, Mary and the Christian saints are often golden.

Medieval kings were inaugurated under the signs of sacred oil and a golden crown, the latter symbolizing the eternal shining light of heaven and thus a Christian king's divinely inspired authority[citation needed].

According to Christopher Columbus, Those who had something of gold, were in possession of something of great value on Earth and a substance to even help souls to paradise.

Wedding rings have long been made of gold. It is long lasting and unaffected by the passage of time and may aid in the ring symbolism of eternal vows before God and/or the sun and moon and the perfection the marriage signifies. In Orthodox Christian wedding ceremonies, the wedded couple is adorned with a golden crown (though some opt for wreaths, instead) during the ceremony, an amalgamation of symbolic rites.

In popular culture gold holds many connotations but is most generally connected to terms such as good or great, such as in the phrases: "has a heart of gold", "that's golden!", "golden moment", "then you're golden!" and "golden boy". Gold also still holds its place as a symbol of wealth and through that, in many societies, success.

State emblem

In 1965, the California Legislature designated gold "the State Mineral and mineralogical emblem".[28]
In 1968, the Alaska Legislature named gold "the official state mineral".[29]

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External links

- Gold (http://www.periodicvideos.com/videos/079.htm) at The Periodic Table of Videos (University of Nottingham)
- Getting Gold 1898 book (http://www.lateralscience.co.uk/gold/auriferous.html), www.lateralscience.co.uk
- Picture in the Element collection from Heinrich Pniok (http://www.pniok.de/au.htm), www.pniok.de
- The Art of Precolumbian Gold: The Jan Mitchell Collection (http://librarycontentdm.oclc.org/cdm/compoundobject/collection/p15324coll10/id/119785/rec/1), an exhibition catalog from The Metropolitan Museum of Art (fully available online as PDF)

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