Gold

From Wikipedia, the free encyclopedia

Gold is a chemical element with the symbol **Au** (from Latin: *aurum*) and the atomic number 79. In its purest form, it is a bright, slightly reddish yellow, dense, soft, malleable and ductile metal. Chemically, gold is a transition metal and a group 11 element. It is one of the least reactive chemical elements, and is 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. It occurs in a solid solution series with the native element silver (as electrum) and also naturally alloyed with copper and palladium. Less commonly, it occurs in minerals as gold compounds, often with tellurium (gold tellurides).

Gold's atomic number of 79 makes it one of the higher atomic number elements that occur naturally in the universe. It is thought to have been produced in supernova nucleosynthesis and from the collision of neutron stars[4] and to have been present in the dust from which the Solar System formed. Because the Earth was molten when it was just formed, almost all of the gold present in the early Earth probably sank into the planetary core. Therefore, most of the gold that is present today in the Earth's crust and mantle is thought to have been delivered to Earth later, by asteroid impacts during the Late Heavy Bombardment, about 4 billion years ago.[5][6]

Gold resists attack by individual acids, but aqua regia (literally "royal water", a mixture of nitric acid and hydrochloric acid) can dissolve it. The acid mixture causes the formation of a soluble tetrachloroaurate anion. It is insoluble in nitric acid, which dissolves silver and base metals, a property that has long been used to refine gold and to confirm the presence of gold in metallic objects, giving rise to the term *acid test*. Gold also dissolves in alkaline solutions of cyanide, which are used in mining and electroplating. Gold dissolves in mercury, forming amalgam alloys, but this is not a chemical reaction.

Gold is a precious metal used for coinage, jewelry, and other arts throughout recorded history. In the past, a gold standard was often implemented as a monetary policy within and between nations, but gold coins ceased to be minted as a circulating currency in the 1930s, and the world gold standard was abandoned for a fiat currency

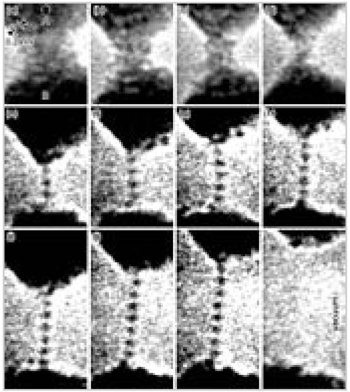
Gold, $_{79}$Au

General properties	
Name, symbol	gold, Au
Appearance	metallic yellow
Gold in the periodic table	
Atomic number (*Z*)	79
Group, block	group 11, d-block
Period	period 6
Element category	transition metal
Standard atomic weight (±) (A_r)	196.966569(5)[1]
Electron configuration	[Xe] $4f^{14}$ $5d^{10}$ $6s^1$
per shell	2, 8, 18, 32, 18, 1
Physical properties	
Phase	solid
Melting point	1337.33 K (1064.18 °C, 1947.52 °F)
Boiling point	3243 K (2970 °C,

system after 1976. The historical value of gold was rooted in its relative rarity, easy handling and minting, easy smelting and fabrication, resistance to corrosion and other chemical reactions (nobility), and distinctive color.

A total of 183,600 tonnes of gold is in existence above ground, as of 2014.[7] This is equivalent to 9513 m^3 of gold. The world consumption of new gold produced is about 50% in jewelry, 40% in investments, and 10% in industry.[8] Gold's high malleability, ductility, resistance to corrosion and most other chemical reactions, and conductivity of electricity have led to its continued use in corrosion resistant electrical connectors in all types of computerized devices (its chief industrial use). Gold is also used in infrared shielding, colored-glass production, gold leafing, and tooth restoration. Certain gold salts are still used as anti-inflammatories in medicine.

Characteristics



Gold is extremely ductile. It can be drawn into a monoatomic wire, and then stretched about twice before it breaks.[14]

Gold is the most malleable of all metals; a single gram can be beaten into a sheet of 1 square meter, and an avoirdupois ounce into 300 square feet. Gold leaf can be beaten thin enough to become semi-transparent. The transmitted light appears greenish blue, because gold strongly reflects yellow and red.[15] 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.[16] Gold is a good conductor of heat and electricity and reflects infrared radiation strongly.

Gold has a density of 19.3 g/cm^3, almost identical to that of tungsten at 19.25 g/cm^3; as such, tungsten has been used in counterfeiting of gold bars, such as by plating a tungsten bar with gold,[17][18][19][20] or taking an existing gold bar, drilling holes, and replacing the removed gold with tungsten rods.[21] By comparison, the density of lead is 11.34 g/cm^3, and that of the densest element, osmium, is 22.588 ± 0.015 g/cm^3.[22]

	5378 °F)
Density near r.t.	19.30 g/cm^3
when liquid, at m.p.	17.31 g/cm^3
Heat of fusion	12.55 kJ/mol
Heat of vaporization	342 kJ/mol
Molar heat capacity	25.418 J/(mol·K)

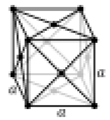
Vapor pressure

P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	1646	1814	2021	2281	2620	3078

Atomic properties

Oxidation states	5, **3**, 2, **1**, −1, −2, −3 (an amphoteric oxide)
Electronegativity	Pauling scale: 2.54
Ionization energies	1st: 890.1 kJ/mol 2nd: 1980 kJ/mol
Atomic radius	empirical: 144 pm
Covalent radius	136±6 pm
Van der Waals radius	166 pm

Miscellanea

Crystal structure	face-centered cubic (fcc) 
Speed of sound thin rod	2030 m/s (at r.t.)
Thermal expansion	14.2 µm/(m·K) (at 25 °C)
Thermal conductivity	318 W/(m·K)

Chemistry

Although gold is the most noble of the noble metals,[23][24] 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(I) compounds are typically linear. A good example is $Au(CN)_2^-$, which is the soluble form of gold encountered in mining. 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.[25]

Au(III) (auric) is a common oxidation state, and is illustrated by gold(III) chloride, Au_2Cl_6. The gold atom centers in Au(III) complexes, like other d^8 compounds, are typically square planar, with chemical bonds that have both covalent and ionic character.

Gold does not react with oxygen at any temperature;[26] similarly, it does not react with ozone.

Some free halogens react with gold.[27] Gold is strongly attacked by fluorine at dull-red heat[28] to form gold(III) fluoride. Powdered gold reacts with chlorine at 180 °C to form $AuCl_3$.[29] Gold reacts with bromine at 140 °C to form gold(III) bromide, but reacts only very slowly with iodine to form the monoiodide.

Gold does not react with sulfur directly,[30] but gold(III) sulfide can be made by passing hydrogen sulfide through a dilute solution of gold(III) chloride or chlorauric acid.

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.[31]

Electrical resistivity	22.14 nΩ·m (at 20 °C)
Magnetic ordering	diamagnetic[2]
Tensile strength	120 MPa
Young's modulus	79 GPa
Shear modulus	27 GPa
Bulk modulus	180 GPa[3]
Poisson ratio	0.4
Mohs hardness	2.5
Vickers hardness	188–216 MPa
Brinell hardness	188–245 MPa
CAS Number	7440-57-5
History	
Naming	from Latin *aurum*, meaning gold
Discovery	In the Middle East (before 6000 BCE)

Most stable isotopes of gold

iso	NA	half-life	DM	DE (MeV)	DP
^{195}**Au**	syn	186.10 d	ε	0.227	^{195}Pt
^{196}**Au**	syn	6.183 d	ε	1.506	^{196}Pt
			β−	0.686	^{196}Hg
^{197}**Au**	100%	is stable with 118 neutrons			
^{198}**Au**	syn	2.69517 d	β−	1.372	^{198}Hg
^{199}**Au**	syn	3.169 d	β−	0.453	^{199}Hg

Gold reacts with potassium, rubidium, caesium, or tetramethylammonium, to form the respective auride salts, containing the Au^- ion. Caesium auride is perhaps the most famous.


Gold(III) chloride solution in water

Gold is unaffected by most acids. It does not react with hydrofluoric, hydrochloric, hydrobromic, hydriodic, sulfuric, or nitric acid. It does react with aqua regia, a mixture of nitric and hydrochloric acids, and with selenic acid. 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 $AuCl_4^-$ ions, or chloroauric acid, thereby enabling further oxidation.

Gold is similarly unaffected by most bases. It does not react with aqueous, solid, or molten sodium or potassium hydroxide. It does however, react with sodium or potassium cyanide under alkaline conditions when oxygen is present to form soluble complexes.[30]

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.

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.[32] Other aurides include those of Rb^+, K^+, and tetramethylammonium $(CH_3)_4N^+$.[33] 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 $[Au(CH_2)_2P(C_6H_5)_2]_2Cl_2$. The evaporation of a solution of $Au(OH)_3$ in concentrated H_2SO_4 produces red crystals of gold(II) sulfate, $Au_2(SO_4)_2$. Originally thought to be a mixed-valence compound, it has been shown to contain Au_2^{4+} cations, analogous to the better-known mercury(I) ion, Hg_2^{2+} .[34][35] A gold(II) complex, the tetraxenonogold(II) cation, which contains xenon as a ligand, occurs in $[AuXe_4](Sb_2F_{11})_2$.[36]

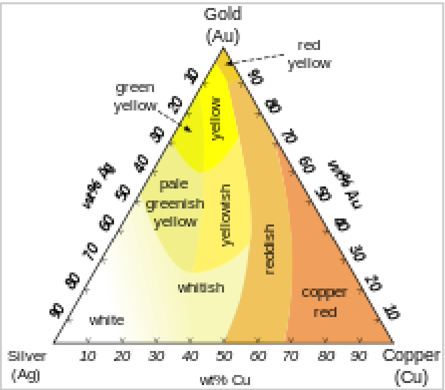
Gold pentafluoride, along with its derivative anion, AuF_6^-, and its difluorine complex, gold heptafluoride, is the sole example of gold(V), the highest verified oxidation state.[37]

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.[33] In such cases, gold has a fractional oxidation state. A representative example is the octahedral species $\{Au(P(C_6H_5)_3)\}_6^{2+}$. Gold chalcogenides, such as gold sulfide, feature equal amounts of Au(I) and Au(III).

Color



Different colors of Ag-Au-Cu alloys

Whereas most other pure metals are gray or silvery white, gold is slightly reddish yellow.[38] 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 a 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.[39][40] 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.[31]

Isotopes

Gold has only one stable isotope, ^{197}Au, which is also its only naturally occurring isotope, so gold is both a mononuclidic and monoisotopic element. 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, α decay, and β^+ 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 β^- decay path (7%).[41] All of gold's radioisotopes with atomic masses above 197 decay by β^- decay.[42]

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: β^+ decay, isomeric transition, and alpha decay. No other isomer or isotope of gold has three decay paths.[42]

Source

- Wikipedia: Gold (https://en.wikipedia.org/wiki/Gold)