

Palladium

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Palladium is a chemical element with symbol **Pd** and atomic number 46. It is a rare and lustrous silvery-white metal discovered in 1803 by William Hyde Wollaston. He named it after the asteroid Pallas, which was itself named after the epithet of the Greek goddess Athena, acquired by her when she slew Pallas. Palladium, platinum, rhodium, ruthenium, iridium and osmium form a group of elements referred to as the platinum group metals (PGMs). These have similar chemical properties, but palladium has the lowest melting point and is the least dense of them.

More than half the supply of palladium and its congener platinum is used in catalytic converters, which convert as much as 90% of the harmful gases in automobile exhaust (hydrocarbons, carbon monoxide, and nitrogen dioxide) into less noxious substances (nitrogen, carbon dioxide and water vapor). Palladium is also used in electronics, dentistry, medicine, hydrogen purification, chemical applications, groundwater treatment, and jewelry. Palladium is a key component of fuel cells, which react hydrogen with oxygen to produce electricity, heat, and water.

Ore deposits of palladium and other PGMs are rare. The most extensive deposits have been found in the norite belt of the Bushveld Igneous Complex covering the Transvaal Basin in South Africa, the Stillwater Complex in Montana, United States, the Sudbury Basin and Thunder Bay District of Ontario, Canada, and the Norilsk Complex in Russia. Recycling is also a source, mostly from scrapped catalytic converters. The numerous applications and limited supply sources result in considerable investment interest.

Characteristics

Palladium belongs to group 10 in the periodic table, but the configuration in the outermost electron shells is atypical for group 10 (see also niobium (41), ruthenium (44), and rhodium (45)). Fewer electron shells are filled than the

Palladium, $_{46}\text{Pd}$



General properties

Name, symbol	palladium, Pd
Appearance	silvery white

Palladium in the periodic table

Atomic number (<i>Z</i>)	46
Group, block	group 10, d-block
Period	period 5
Element category	□ transition metal
Standard atomic weight (\pm) (<i>A</i> _r)	106.42(1) ^[1]
Electron configuration	[Kr] 4d ¹⁰
per shell	2, 8, 18, 18

Physical properties

Phase	solid
Melting point	

elements directly preceding it (a phenomenon unique to palladium). The valence shell has eighteen electrons – ten more than the eight found in the valence shells of the noble gases from neon onward.

Palladium is a soft silver-white metal that resembles platinum. It is the least dense and has the lowest melting point of the platinum group metals. It is soft and ductile when annealed and is greatly increased in strength and hardness when cold-worked. Palladium dissolves slowly in concentrated nitric acid, in hot, concentrated sulfuric acid, and when finely ground, in hydrochloric acid.^[3] It dissolves readily at room temperature in aqua regia.

Common oxidation states of palladium are 0, +1, +2 and +4. Relatively few compounds are known with palladium unambiguously in the +3 oxidation state, though such compounds have been proposed as intermediates in many palladium-catalyzed cross-coupling reactions.^[4] Palladium(VI) was first observed in 2002.^{[5][6]}

Palladium films with defects produced by alpha particle bombardment at low temperature exhibit superconductivity having $T_c=3.2$ K.^[7]

Isotopes

Naturally occurring palladium is composed of seven isotopes, six of which are stable. The most stable radioisotopes are ¹⁰⁷Pd with a half-life of 6.5 million years (found in nature), ¹⁰³Pd with 17 days, and ¹⁰⁰Pd with 3.63 days. Eighteen other radioisotopes have been characterized with atomic weights ranging from 90.94948(64) u (⁹¹Pd) to 122.93426(64) u (¹²³Pd).^[8] These have half-lives of less than thirty minutes, except ¹⁰¹Pd (half-life: 8.47 hours), ¹⁰⁹Pd (half-life: 13.7 hours), and ¹¹²Pd (half-life: 21 hours).^[9]

For isotopes with atomic mass unit values less than that of the most abundant stable isotope, ¹⁰⁶Pd, the primary decay mode is electron capture with the primary decay product being rhodium. The primary mode of decay for those isotopes of Pd with atomic mass greater than 106 is beta decay with the primary product of this decay being silver.^[9]

1828.05 K (1554.9 °C, 2830.82 °F)

Boiling point 3236 K (2963 °C, 5365 °F)

Density near r.t. 12.023 g/cm³

when liquid, at m.p. 10.38 g/cm³

Heat of fusion 16.74 kJ/mol

Heat of vaporization 358 kJ/mol

Molar heat capacity 25.98 J/(mol·K)

Vapor pressure

P (Pa)	1	10	100	1 k	10 k	100 k
at T (K)	1721	1897	2117	2395	2753	3234

Atomic properties

Oxidation states 0, +1, +2, +3, +4, +5, +6 (a mildly basic oxide)

Electronegativity Pauling scale: 2.20

Ionization energies
1st: 804.4 kJ/mol
2nd: 1870 kJ/mol
3rd: 3177 kJ/mol

Atomic radius empirical: 137 pm

Covalent radius 139±6 pm

Van der Waals radius 163 pm

Miscellanea

Crystal structure face-centered cubic (fcc)



Speed of sound 3070 m/s (at 20 °C)
thin rod

Thermal 11.8 μm/(m·K) (at 25 °C)

Radiogenic ^{107}Ag is a decay product of ^{107}Pd and was first discovered in 1978^[10] in the Santa Clara^[11] meteorite of 1976. The discoverers suggest that the coalescence and differentiation of iron-cored small planets may have occurred 10 million years after a nucleosynthetic event. ^{107}Pd versus Ag correlations observed in bodies, which have been melted since accretion of the solar system, must reflect the presence of short-lived nuclides in the early solar system.^[12]

Source

- Wikipedia: Palladium (<https://en.wikipedia.org/wiki/Palladium>)

expansion	
Thermal conductivity	71.8 W/(m·K)
Electrical resistivity	105.4 nΩ·m (at 20 °C)
Magnetic ordering	paramagnetic ^[2]
Young's modulus	121 GPa
Shear modulus	44 GPa
Bulk modulus	180 GPa
Poisson ratio	0.39
Mohs hardness	4.75
Vickers hardness	400–600 MPa
Brinell hardness	320–610 MPa
CAS Number	7440-05-3

History

Naming	after asteroid Pallas, itself named after Pallas Athena
Discovery and first isolation	William Hyde Wollaston (1803)

Most stable isotopes of palladium

iso	NA	half-life	DM	DE (MeV)	DP
100Pd	syn	3.63 d	ε	-	¹⁰⁰ Rh
			γ	0.084, 0.074, 0.126	-
102Pd	1.02%	is stable with 56 neutrons			
103Pd	syn	16.991 d	ε	-	¹⁰³ Rh
104Pd	11.14%	is stable with 58 neutrons			
105Pd	22.33%	is stable with 59 neutrons			
106Pd	27.33%	is stable with 60 neutrons			
107Pd	trace	6.5×10 ⁶ y	β ⁻	0.033	¹⁰⁷ Ag
108Pd	26.46%	is stable with 62 neutrons			
110Pd	11.72%	is stable with 64 neutrons			