

# Palladium

From Wikipedia, the free encyclopedia

**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

<b>Name, symbol</b>	palladium, Pd
<b>Appearance</b>	silvery white

#### Palladium in the periodic table

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

#### Physical properties

<b>Phase</b>	solid
<b>Melting point</b>	

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.<sup>[3]</sup> 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.<sup>[4]</sup> Palladium(VI) was first observed in 2002.<sup>[5][6]</sup>

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

## Isotopes

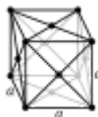
Naturally occurring palladium is composed of seven isotopes, six of which are stable. The most stable radioisotopes are <sup>107</sup>Pd with a half-life of 6.5 million years (found in nature), <sup>103</sup>Pd with 17 days, and <sup>100</sup>Pd with 3.63 days. Eighteen other radioisotopes have been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

For isotopes with atomic mass unit values less than that of the most abundant stable isotope, <sup>106</sup>Pd, 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.<sup>[9]</sup>

	1828.05 K (1554.9 °C, 2830.82 °F)
<b>Boiling point</b>	3236 K (2963 °C, 5365 °F)
<b>Density</b> near r.t.	12.023 g/cm <sup>3</sup>
when liquid, at m.p.	10.38 g/cm <sup>3</sup>
<b>Heat of fusion</b>	16.74 kJ/mol
<b>Heat of vaporization</b>	358 kJ/mol
<b>Molar heat capacity</b>	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	
<b>Oxidation states</b>	0, +1, <b>+2</b> , +3, <b>+4</b> , +5, +6 (a mildly basic oxide)
<b>Electronegativity</b>	Pauling scale: 2.20
<b>Ionization energies</b>	1st: 804.4 kJ/mol 2nd: 1870 kJ/mol 3rd: 3177 kJ/mol
<b>Atomic radius</b>	empirical: 137 pm
<b>Covalent radius</b>	139±6 pm
<b>Van der Waals radius</b>	163 pm

Miscellanea	
<b>Crystal structure</b>	face-centered cubic (fcc) 
<b>Speed of sound</b> thin rod	3070 m/s (at 20 °C)
<b>Thermal</b>	11.8 μm/(m·K) (at 25 °C)

Radiogenic <sup>107</sup>Ag is a decay product of <sup>107</sup>Pd and was first discovered in 1978<sup>[10]</sup> in the Santa Clara<sup>[11]</sup> 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. <sup>107</sup>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.<sup>[12]</sup>

## Source

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

<b>expansion</b>	
<b>Thermal conductivity</b>	71.8 W/(m·K)
<b>Electrical resistivity</b>	105.4 nΩ·m (at 20 °C)
<b>Magnetic ordering</b>	paramagnetic <sup>[2]</sup>
<b>Young's modulus</b>	121 GPa
<b>Shear modulus</b>	44 GPa
<b>Bulk modulus</b>	180 GPa
<b>Poisson ratio</b>	0.39
<b>Mohs hardness</b>	4.75
<b>Vickers hardness</b>	400–600 MPa
<b>Brinell hardness</b>	320–610 MPa
<b>CAS Number</b>	7440-05-3
<b>History</b>	
<b>Naming</b>	after asteroid Pallas, itself named after Pallas Athena
<b>Discovery and first isolation</b>	William Hyde Wollaston (1803)
<b>Most stable isotopes of palladium</b>	

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