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**Palladium**

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This article is about the chemical element. For other uses, see [Palladium (disambiguation)](https://en.wikipedia.org/wiki/Palladium_(disambiguation)).

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| --- | --- |
| Palladium,  46Pd | |
| [Palladium (46 Pd).jpg](https://en.wikipedia.org/wiki/File:Palladium_(46_Pd).jpg) | |
| **General properties** | |
| **Pronunciation** | [/pəˈleɪdiəm/](https://en.wikipedia.org/wiki/Help:IPA/English) ​([*pə-LAY-dee-əm*](https://en.wikipedia.org/wiki/Help:Pronunciation_respelling_key)) |
| **Appearance** | silvery white |
| [**Standard atomic weight**](https://en.wikipedia.org/wiki/Standard_atomic_weight) **(*A*r, standard)** | 106.42(1)[[1]](https://en.wikipedia.org/wiki/Palladium#cite_note-CIAAW2016-1) |
| **Palladium in the** [**periodic table**](https://en.wikipedia.org/wiki/Periodic_table) | |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 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[Neon](https://en.wikipedia.org/wiki/Neon) | | [Sodium](https://en.wikipedia.org/wiki/Sodium) | [Magnesium](https://en.wikipedia.org/wiki/Magnesium) |  | | | | | | | | | | | | | | | | | | | | | | | | [Aluminium](https://en.wikipedia.org/wiki/Aluminium) | [Silicon](https://en.wikipedia.org/wiki/Silicon) | [Phosphorus](https://en.wikipedia.org/wiki/Phosphorus) | [Sulfur](https://en.wikipedia.org/wiki/Sulfur) | [Chlorine](https://en.wikipedia.org/wiki/Chlorine) | [Argon](https://en.wikipedia.org/wiki/Argon) | | [Potassium](https://en.wikipedia.org/wiki/Potassium) | [Calcium](https://en.wikipedia.org/wiki/Calcium) | [Scandium](https://en.wikipedia.org/wiki/Scandium) |  | | | | | | | | | | | | | | [Titanium](https://en.wikipedia.org/wiki/Titanium) | [Vanadium](https://en.wikipedia.org/wiki/Vanadium) | [Chromium](https://en.wikipedia.org/wiki/Chromium) | [Manganese](https://en.wikipedia.org/wiki/Manganese) | [Iron](https://en.wikipedia.org/wiki/Iron) | [Cobalt](https://en.wikipedia.org/wiki/Cobalt) | [Nickel](https://en.wikipedia.org/wiki/Nickel) | [Copper](https://en.wikipedia.org/wiki/Copper) | [Zinc](https://en.wikipedia.org/wiki/Zinc) | [Gallium](https://en.wikipedia.org/wiki/Gallium) | [Germanium](https://en.wikipedia.org/wiki/Germanium) | [Arsenic](https://en.wikipedia.org/wiki/Arsenic) | [Selenium](https://en.wikipedia.org/wiki/Selenium) | [Bromine](https://en.wikipedia.org/wiki/Bromine) | [Krypton](https://en.wikipedia.org/wiki/Krypton) | | [Rubidium](https://en.wikipedia.org/wiki/Rubidium) | [Strontium](https://en.wikipedia.org/wiki/Strontium) | [Yttrium](https://en.wikipedia.org/wiki/Yttrium) |  |  | | | | | | | | | | | | | [Zirconium](https://en.wikipedia.org/wiki/Zirconium) | [Niobium](https://en.wikipedia.org/wiki/Niobium) | [Molybdenum](https://en.wikipedia.org/wiki/Molybdenum) | [Technetium](https://en.wikipedia.org/wiki/Technetium) | [Ruthenium](https://en.wikipedia.org/wiki/Ruthenium) | [Rhodium](https://en.wikipedia.org/wiki/Rhodium) | Palladium | [Silver](https://en.wikipedia.org/wiki/Silver) | [Cadmium](https://en.wikipedia.org/wiki/Cadmium) | [Indium](https://en.wikipedia.org/wiki/Indium) | [Tin](https://en.wikipedia.org/wiki/Tin) | [Antimony](https://en.wikipedia.org/wiki/Antimony) | [Tellurium](https://en.wikipedia.org/wiki/Tellurium) | [Iodine](https://en.wikipedia.org/wiki/Iodine) | [Xenon](https://en.wikipedia.org/wiki/Xenon) | | [Caesium](https://en.wikipedia.org/wiki/Caesium) | [Barium](https://en.wikipedia.org/wiki/Barium) | [Lanthanum](https://en.wikipedia.org/wiki/Lanthanum) | [Cerium](https://en.wikipedia.org/wiki/Cerium) | [Praseodymium](https://en.wikipedia.org/wiki/Praseodymium) | [Neodymium](https://en.wikipedia.org/wiki/Neodymium) | [Promethium](https://en.wikipedia.org/wiki/Promethium) | [Samarium](https://en.wikipedia.org/wiki/Samarium) | [Europium](https://en.wikipedia.org/wiki/Europium) | [Gadolinium](https://en.wikipedia.org/wiki/Gadolinium) | [Terbium](https://en.wikipedia.org/wiki/Terbium) | [Dysprosium](https://en.wikipedia.org/wiki/Dysprosium) | [Holmium](https://en.wikipedia.org/wiki/Holmium) | [Erbium](https://en.wikipedia.org/wiki/Erbium) | [Thulium](https://en.wikipedia.org/wiki/Thulium) | [Ytterbium](https://en.wikipedia.org/wiki/Ytterbium) | [Lutetium](https://en.wikipedia.org/wiki/Lutetium) | [Hafnium](https://en.wikipedia.org/wiki/Hafnium) | [Tantalum](https://en.wikipedia.org/wiki/Tantalum) | [Tungsten](https://en.wikipedia.org/wiki/Tungsten) | [Rhenium](https://en.wikipedia.org/wiki/Rhenium) | [Osmium](https://en.wikipedia.org/wiki/Osmium) | [Iridium](https://en.wikipedia.org/wiki/Iridium) | [Platinum](https://en.wikipedia.org/wiki/Platinum) | [Gold](https://en.wikipedia.org/wiki/Gold) | [Mercury (element)](https://en.wikipedia.org/wiki/Mercury_(element)) | [Thallium](https://en.wikipedia.org/wiki/Thallium) | [Lead](https://en.wikipedia.org/wiki/Lead) | [Bismuth](https://en.wikipedia.org/wiki/Bismuth) | [Polonium](https://en.wikipedia.org/wiki/Polonium) | [Astatine](https://en.wikipedia.org/wiki/Astatine) | [Radon](https://en.wikipedia.org/wiki/Radon) | | [Francium](https://en.wikipedia.org/wiki/Francium) | [Radium](https://en.wikipedia.org/wiki/Radium) | [Actinium](https://en.wikipedia.org/wiki/Actinium) | [Thorium](https://en.wikipedia.org/wiki/Thorium) | [Protactinium](https://en.wikipedia.org/wiki/Protactinium) | [Uranium](https://en.wikipedia.org/wiki/Uranium) | [Neptunium](https://en.wikipedia.org/wiki/Neptunium) | [Plutonium](https://en.wikipedia.org/wiki/Plutonium) | [Americium](https://en.wikipedia.org/wiki/Americium) | [Curium](https://en.wikipedia.org/wiki/Curium) | [Berkelium](https://en.wikipedia.org/wiki/Berkelium) | [Californium](https://en.wikipedia.org/wiki/Californium) | [Einsteinium](https://en.wikipedia.org/wiki/Einsteinium) | [Fermium](https://en.wikipedia.org/wiki/Fermium) | [Mendelevium](https://en.wikipedia.org/wiki/Mendelevium) | [Nobelium](https://en.wikipedia.org/wiki/Nobelium) | [Lawrencium](https://en.wikipedia.org/wiki/Lawrencium) | [Rutherfordium](https://en.wikipedia.org/wiki/Rutherfordium) | [Dubnium](https://en.wikipedia.org/wiki/Dubnium) | [Seaborgium](https://en.wikipedia.org/wiki/Seaborgium) | [Bohrium](https://en.wikipedia.org/wiki/Bohrium) | [Hassium](https://en.wikipedia.org/wiki/Hassium) | [Meitnerium](https://en.wikipedia.org/wiki/Meitnerium) | [Darmstadtium](https://en.wikipedia.org/wiki/Darmstadtium) | [Roentgenium](https://en.wikipedia.org/wiki/Roentgenium) | [Copernicium](https://en.wikipedia.org/wiki/Copernicium) | [Nihonium](https://en.wikipedia.org/wiki/Nihonium) | [Flerovium](https://en.wikipedia.org/wiki/Flerovium) | [Moscovium](https://en.wikipedia.org/wiki/Moscovium) | [Livermorium](https://en.wikipedia.org/wiki/Livermorium) | [Tennessine](https://en.wikipedia.org/wiki/Tennessine) | [Oganesson](https://en.wikipedia.org/wiki/Oganesson) | | [Ni](https://en.wikipedia.org/wiki/Nickel) ↑ **Pd** ↓ [Pt](https://en.wikipedia.org/wiki/Platinum) | | [rhodium](https://en.wikipedia.org/wiki/Rhodium) ← **palladium** → [silver](https://en.wikipedia.org/wiki/Silver) | | | | |
| [**Atomic number**](https://en.wikipedia.org/wiki/Atomic_number)(*Z*) | 46 |
| [**Group**](https://en.wikipedia.org/wiki/Group_(periodic_table)) | [group 10](https://en.wikipedia.org/wiki/Group_10_element) |
| [**Period**](https://en.wikipedia.org/wiki/Period_(periodic_table)) | [period 5](https://en.wikipedia.org/wiki/Period_(periodic_table)#Period_5) |
| [**Block**](https://en.wikipedia.org/wiki/Block_(periodic_table)) | [d-block](https://en.wikipedia.org/wiki/D-block) |
| [**Element category**](https://en.wikipedia.org/wiki/Names_for_sets_of_chemical_elements#Category) | [transition metal](https://en.wikipedia.org/wiki/Transition_metal) |
| [**Electron configuration**](https://en.wikipedia.org/wiki/Electron_configuration) | [[Kr](https://en.wikipedia.org/wiki/Krypton)] 4d10 |
| Electrons per shell | 2, 8, 18, 18 |
| **Physical properties** | |
| [**Phase**](https://en.wikipedia.org/wiki/Phase_(matter)) **at**[**STP**](https://en.wikipedia.org/wiki/Standard_conditions_for_temperature_and_pressure) | [solid](https://en.wikipedia.org/wiki/Solid) |
| [**Melting point**](https://en.wikipedia.org/wiki/Melting_point) | 1828.05 [K](https://en.wikipedia.org/wiki/Kelvin) ​(1554.9 °C, ​2830.82 °F) |
| [**Boiling point**](https://en.wikipedia.org/wiki/Boiling_point) | 3236 K ​(2963 °C, ​5365 °F) |
| [**Density**](https://en.wikipedia.org/wiki/Density)(near r.t.) | 12.023 g/cm3 |
| when liquid (at m.p.) | 10.38 g/cm3 |
| [**Heat of fusion**](https://en.wikipedia.org/wiki/Enthalpy_of_fusion) | 16.74 [kJ/mol](https://en.wikipedia.org/wiki/Kilojoule_per_mole) |
| [**Heat of vaporization**](https://en.wikipedia.org/wiki/Enthalpy_of_vaporization) | 358 kJ/mol |
| [**Molar heat capacity**](https://en.wikipedia.org/wiki/Molar_heat_capacity) | 25.98 J/(mol·K) |
| [**Vapor pressure**](https://en.wikipedia.org/wiki/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**](https://en.wikipedia.org/wiki/Oxidation_state) | 0, +1, **+2**, +3, **+4** (a mildly [basic](https://en.wikipedia.org/wiki/Base_(chemistry)) oxide) |
| [**Electronegativity**](https://en.wikipedia.org/wiki/Electronegativity) | Pauling scale: 2.20 |
| [**Ionization energies**](https://en.wikipedia.org/wiki/Ionization_energy) | * 1st: 804.4 kJ/mol * 2nd: 1870 kJ/mol * 3rd: 3177 kJ/mol |
| [**Atomic radius**](https://en.wikipedia.org/wiki/Atomic_radius) | empirical: 137 [pm](https://en.wikipedia.org/wiki/Picometre) |
| [**Covalent radius**](https://en.wikipedia.org/wiki/Covalent_radius) | 139±6 pm |
| [**Van der Waals radius**](https://en.wikipedia.org/wiki/Van_der_Waals_radius) | 163 pm |
| [Color lines in a spectral range](https://en.wikipedia.org/wiki/File:Palladium_spectrum_visible.png)  [**Spectral lines**](https://en.wikipedia.org/wiki/Spectral_line) **of palladium** | |
| **Other properties** | |
| [**Crystal structure**](https://en.wikipedia.org/wiki/Crystal_structure) | ​[face-centered cubic](https://en.wikipedia.org/wiki/Cubic_crystal_system) (fcc)  [Face-centered cubic crystal structure for palladium](https://en.wikipedia.org/wiki/File:Cubic-face-centered.svg) |
| [**Speed of sound**](https://en.wikipedia.org/wiki/Speed_of_sound)thin rod | 3070 m/s (at 20 °C) |
| [**Thermal expansion**](https://en.wikipedia.org/wiki/Coefficient_of_thermal_expansion) | 11.8 µm/(m·K) (at 25 °C) |
| [**Thermal conductivity**](https://en.wikipedia.org/wiki/Thermal_conductivity) | 71.8 W/(m·K) |
| [**Electrical resistivity**](https://en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity) | 105.4 nΩ·m (at 20 °C) |
| [**Magnetic ordering**](https://en.wikipedia.org/wiki/Magnetism) | [paramagnetic](https://en.wikipedia.org/wiki/Paramagnetic)[[2]](https://en.wikipedia.org/wiki/Palladium#cite_note-2) |
| [**Magnetic susceptibility**](https://en.wikipedia.org/wiki/Magnetic_susceptibility) | +567.4·10−6 cm3/mol (288 K)[[3]](https://en.wikipedia.org/wiki/Palladium#cite_note-3) |
| [**Young's modulus**](https://en.wikipedia.org/wiki/Young%27s_modulus) | 121 GPa |
| [**Shear modulus**](https://en.wikipedia.org/wiki/Shear_modulus) | 44 GPa |
| [**Bulk modulus**](https://en.wikipedia.org/wiki/Bulk_modulus) | 180 GPa |
| [**Poisson ratio**](https://en.wikipedia.org/wiki/Poisson%27s_ratio) | 0.39 |
| [**Mohs hardness**](https://en.wikipedia.org/wiki/Mohs_scale_of_mineral_hardness) | 4.75 |
| [**Vickers hardness**](https://en.wikipedia.org/wiki/Vickers_hardness_test) | 400–600 MPa |
| [**Brinell hardness**](https://en.wikipedia.org/wiki/Brinell_hardness_test) | 320–610 MPa |
| [**CAS Number**](https://en.wikipedia.org/wiki/CAS_Registry_Number) | 7440-05-3 |
| **History** | |
| **Naming** | after asteroid [Pallas](https://en.wikipedia.org/wiki/2_Pallas), itself named after [Pallas Athena](https://en.wikipedia.org/wiki/Athena) |
| [**Discovery**](https://en.wikipedia.org/wiki/Timeline_of_chemical_element_discoveries) **and first isolation** | [William Hyde Wollaston](https://en.wikipedia.org/wiki/William_Hyde_Wollaston) (1802) |
| **Main** [**isotopes of palladium**](https://en.wikipedia.org/wiki/Isotopes_of_palladium) | |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | [**Iso­tope**](https://en.wikipedia.org/wiki/Isotope) | [**Abun­dance**](https://en.wikipedia.org/wiki/Natural_abundance) | [**Half-life**](https://en.wikipedia.org/wiki/Half-life) **(*t*1/2)** | [**Decay mode**](https://en.wikipedia.org/wiki/Radioactive_decay) | [**Pro­duct**](https://en.wikipedia.org/wiki/Decay_product) | | **100Pd** | [syn](https://en.wikipedia.org/wiki/Synthetic_radioisotope) | 3.63 d | [ε](https://en.wikipedia.org/wiki/Electron_capture) | [100Rh](https://en.wikipedia.org/wiki/Rhodium-100) | | [γ](https://en.wikipedia.org/wiki/Gamma_ray) | – | | **102Pd** | 1.02% | [stable](https://en.wikipedia.org/wiki/Stable_isotope) | | | | **103Pd** | syn | 16.991 d | ε | [103Rh](https://en.wikipedia.org/wiki/Rhodium-103) | | **104Pd** | 11.14% | stable | | | | **105Pd** | 22.33% | stable | | | | **106Pd** | 27.33% | stable | | | | **107Pd** | [trace](https://en.wikipedia.org/wiki/Trace_radioisotope) | 6.5×106 y | [β−](https://en.wikipedia.org/wiki/Beta_emission) | [107Ag](https://en.wikipedia.org/wiki/Silver-107) | | **108Pd** | 26.46% | stable | | | | **110Pd** | 11.72% | stable | | | | |
| * [view](https://en.wikipedia.org/wiki/Template:Infobox_palladium) * [talk](https://en.wikipedia.org/wiki/Template_talk:Infobox_palladium) * [edit](https://en.wikipedia.org/w/index.php?title=Template:Infobox_palladium&action=edit)   | [references](https://en.wikipedia.org/wiki/List_of_data_references_for_chemical_elements) | |

**Palladium** is a [chemical element](https://en.wikipedia.org/wiki/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](https://en.wikipedia.org/wiki/William_Hyde_Wollaston). He named it after the [asteroid Pallas](https://en.wikipedia.org/wiki/2_Pallas), which was itself named after the [epithet](https://en.wikipedia.org/wiki/Epithet) of the Greek goddess [Athena](https://en.wikipedia.org/wiki/Athena), acquired by her when she slew [Pallas](https://en.wikipedia.org/wiki/Pallas_(daughter_of_Triton)). Palladium, [platinum](https://en.wikipedia.org/wiki/Platinum), [rhodium](https://en.wikipedia.org/wiki/Rhodium), [ruthenium](https://en.wikipedia.org/wiki/Ruthenium), [iridium](https://en.wikipedia.org/wiki/Iridium) and [osmium](https://en.wikipedia.org/wiki/Osmium) form a group of elements referred to as the [platinum group](https://en.wikipedia.org/wiki/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](https://en.wikipedia.org/wiki/Congener_(chemistry)) platinum is used in [catalytic converters](https://en.wikipedia.org/wiki/Catalytic_converter), which convert as much as 90% of the harmful gases in automobile exhaust ([hydrocarbons](https://en.wikipedia.org/wiki/Hydrocarbon), [carbon monoxide](https://en.wikipedia.org/wiki/Carbon_monoxide), and [nitrogen dioxide](https://en.wikipedia.org/wiki/Nitrogen_dioxide)) into less noxious substances ([nitrogen](https://en.wikipedia.org/wiki/Nitrogen), [carbon dioxide](https://en.wikipedia.org/wiki/Carbon_dioxide) and [water vapor](https://en.wikipedia.org/wiki/Water_vapor)). Palladium is also used in electronics, [dentistry](https://en.wikipedia.org/wiki/Dentistry), [medicine](https://en.wikipedia.org/wiki/Medicine), [hydrogen purification](https://en.wikipedia.org/wiki/Hydrogen_purification), chemical applications, groundwater treatment, and jewelry. Palladium is a key component of [fuel cells](https://en.wikipedia.org/wiki/Fuel_cell), which react hydrogen with oxygen to produce electricity, heat, and water.

[Ore](https://en.wikipedia.org/wiki/Ore) [deposits](https://en.wikipedia.org/wiki/Deposit_(geology)) of palladium and other PGMs are rare. The most extensive deposits have been found in the norite belt of the [Bushveld Igneous Complex](https://en.wikipedia.org/wiki/Bushveld_Igneous_Complex) covering the [Transvaal Basin](https://en.wikipedia.org/wiki/Transvaal_Basin) in South Africa; the [Stillwater Complex](https://en.wikipedia.org/wiki/Stillwater_igneous_complex) in [Montana](https://en.wikipedia.org/wiki/Montana), United States; the [Sudbury Basin](https://en.wikipedia.org/wiki/Sudbury_Basin) and [Thunder Bay District](https://en.wikipedia.org/wiki/Thunder_Bay_District) of [Ontario](https://en.wikipedia.org/wiki/Ontario), Canada; and the [Norilsk Complex](https://en.wikipedia.org/wiki/Norilsk) in Russia. [Recycling](https://en.wikipedia.org/wiki/Recycling) is also a source, mostly from scrapped catalytic converters. The numerous applications and limited supply sources result in considerable [investment](https://en.wikipedia.org/wiki/Palladium_as_an_investment) interest.



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**Characteristics**

Palladium belongs to [group 10](https://en.wikipedia.org/wiki/Group_10_element) in the periodic table, but the configuration in the outermost electrons are in accordance with [Hund's rule](https://en.wikipedia.org/wiki/Hund%27s_rule). Electrons in the s-shell migrate to fill the d orbitals because they have less energy.

|  |  |  |
| --- | --- | --- |
| [**Z**](https://en.wikipedia.org/wiki/Atomic_number) | [**Element**](https://en.wikipedia.org/wiki/Chemical_element) | [**No. of electrons/shell**](https://en.wikipedia.org/wiki/Electron_shell) |
| 28 | [nickel](https://en.wikipedia.org/wiki/Nickel) | 2, 8, 16, 2 (or 2, 8, 17, 1) |
| 46 | palladium | 2, 8, 18, 18 |
| 78 | [platinum](https://en.wikipedia.org/wiki/Platinum) | 2, 8, 18, 32, 17, 1 |
| 110 | [darmstadtium](https://en.wikipedia.org/wiki/Darmstadtium) | 2, 8, 18, 32, 32, 16, 2 (predicted) |

Palladium is a soft silver-white metal that resembles platinum. It is the least dense and has the lowest [melting point](https://en.wikipedia.org/wiki/Melting_point) of the platinum group metals. It is soft and ductile when [annealed](https://en.wikipedia.org/wiki/Annealing_(metallurgy)) and is greatly increased in strength and hardness when cold-worked. Palladium dissolves slowly in concentrated [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid), in hot, concentrated [sulfuric acid](https://en.wikipedia.org/wiki/Sulfuric_acid), and when finely ground, in [hydrochloric acid](https://en.wikipedia.org/wiki/Hydrochloric_acid).[[4]](https://en.wikipedia.org/wiki/Palladium#cite_note-CRC-4) It dissolves readily at room temperature in [aqua regia](https://en.wikipedia.org/wiki/Aqua_regia).

Palladium does not react with [oxygen](https://en.wikipedia.org/wiki/Oxygen) at standard temperature (and thus does not tarnish in [air](https://en.wikipedia.org/wiki/Earth%27s_atmosphere)). Palladium heated to 800 °C will produce a layer of palladium(II) oxide (PdO). It tarnishes lightly in a moist atmosphere containing [sulfur](https://en.wikipedia.org/wiki/Sulfur).[[*clarification needed*](https://en.wikipedia.org/wiki/Wikipedia:Please_clarify)][[5]](https://en.wikipedia.org/wiki/Palladium#cite_note-5)

Palladium films with defects produced by alpha particle bombardment at low temperature exhibit superconductivity having Tc=3.2 K.[[6]](https://en.wikipedia.org/wiki/Palladium#cite_note-6)

**Isotopes**

Main article: [Isotopes of palladium](https://en.wikipedia.org/wiki/Isotopes_of_palladium)

Naturally occurring palladium is composed of seven [isotopes](https://en.wikipedia.org/wiki/Isotope), six of which are stable. The most stable [radioisotopes](https://en.wikipedia.org/wiki/Radioisotope) are [107Pd](https://en.wikipedia.org/wiki/Palladium-107) with a [half-life](https://en.wikipedia.org/wiki/Half-life) of 6.5 million years (found in nature), [103Pd](https://en.wikipedia.org/wiki/Pd-103) with 17 days, and 100Pd with 3.63 days. Eighteen other radioisotopes have been characterized with [atomic weights](https://en.wikipedia.org/wiki/Atomic_weight) ranging from 90.94948(64) [u](https://en.wikipedia.org/wiki/Atomic_mass_unit) (91Pd) to 122.93426(64) u (123Pd).[[7]](https://en.wikipedia.org/wiki/Palladium#cite_note-7) 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).[[8]](https://en.wikipedia.org/wiki/Palladium#cite_note-NUBASE-8)

For isotopes with atomic mass unit values less than that of the most abundant stable isotope, 106Pd, the primary [decay mode](https://en.wikipedia.org/wiki/Decay_mode) is [electron capture](https://en.wikipedia.org/wiki/Electron_capture) with the primary [decay product](https://en.wikipedia.org/wiki/Decay_product) being rhodium. The primary mode of decay for those isotopes of Pd with atomic mass greater than 106 is [beta decay](https://en.wikipedia.org/wiki/Beta_decay) with the primary product of this decay being [silver](https://en.wikipedia.org/wiki/Silver).[[8]](https://en.wikipedia.org/wiki/Palladium#cite_note-NUBASE-8)

[Radiogenic](https://en.wikipedia.org/wiki/Radiogenic) 107Ag is a decay product of 107Pd and was first discovered in 1978[[9]](https://en.wikipedia.org/wiki/Palladium#cite_note-9) in the [Santa Clara](https://en.wikipedia.org/wiki/Santa_Clara,_Durango)[[10]](https://en.wikipedia.org/wiki/Palladium#cite_note-10) 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](https://en.wikipedia.org/wiki/Nucleosynthetic) event. 107Pd versus Ag correlations observed in bodies, which have been melted since accretion of the [solar system](https://en.wikipedia.org/wiki/Solar_system), must reflect the presence of short-lived nuclides in the early solar system.[[11]](https://en.wikipedia.org/wiki/Palladium#cite_note-11)

**Compounds**

*See also:* [*Category:Palladium compounds*](https://en.wikipedia.org/wiki/Category:Palladium_compounds)*.*

Palladium compounds primarily exist in the 0 and +2 oxidation state. Other less common states are also recognized. Generally the compounds of palladium are more similar to those of platinum than those of any other element.

|  |  |
| --- | --- |
| [Alpha-palladium(II)-chloride-xtal-3D-balls.png](https://en.wikipedia.org/wiki/File:Alpha-palladium(II)-chloride-xtal-3D-balls.png) | [Pd6Cl12-from-xtal-1996-CM-3D-ellipsoids.png](https://en.wikipedia.org/wiki/File:Pd6Cl12-from-xtal-1996-CM-3D-ellipsoids.png) |
| Structure of *α*-PdCl2 | Structure of *β*-PdCl2 |

**Palladium(II)**

Palladium(II) chloride is the principal starting material for other palladium compounds. It arises by the reaction of palladium with chlorine. It is used to prepare heterogeneous palladium catalysts such as palladium on barium sulfate, palladium on carbon, and palladium chloride on carbon.[[12]](https://en.wikipedia.org/wiki/Palladium#cite_note-12) Solutions of PdCl2 in nitric acid react with [acetic acid](https://en.wikipedia.org/wiki/Acetic_acid) to give [palladium(II) acetate](https://en.wikipedia.org/wiki/Palladium(II)_acetate), also a versatile reagent. PdCl2 reacts with ligands (L) to give square planar complexes of the type PdCl2L2. One example of such complexes is the [benzonitrile](https://en.wikipedia.org/wiki/Benzonitrile) derivative PdX2(PhCN)2.[[13]](https://en.wikipedia.org/wiki/Palladium#cite_note-13)[[14]](https://en.wikipedia.org/wiki/Palladium#cite_note-14)

PdCl2 + 2 L → PdCl2L2 (L = PhCN, PPh3, NH3, etc)

The complex [bis(triphenylphosphine)palladium(II) dichloride](https://en.wikipedia.org/wiki/Bis(triphenylphosphine)palladium(II)_dichloride) is a useful catalyst.[[15]](https://en.wikipedia.org/wiki/Palladium#cite_note-15)

[](https://en.wikipedia.org/wiki/File:Palladium(II)_acetate.jpg)

[Palladium(II) acetate](https://en.wikipedia.org/wiki/Palladium(II)_acetate)

**Palladium(0)**

Palladium forms a range of zerovalent complexes with the formula PdL4, PdL3 and PdL2. For example, reduction of a mixture of PdCl2(PPh3)2 and PPh3 gives [tetrakis(triphenylphosphine)palladium(0)](https://en.wikipedia.org/wiki/Tetrakis(triphenylphosphine)palladium(0)):[[16]](https://en.wikipedia.org/wiki/Palladium#cite_note-16)

2 PdCl2(PPh3)2 + 4 PPh3 + 5 [N2H4](https://en.wikipedia.org/wiki/Hydrazine) → 2 Pd(PPh3)4 + N2 + 4 N2H5+Cl−

Another major palladium(0) complex, [tris(dibenzylideneacetone)dipalladium(0)](https://en.wikipedia.org/wiki/Tris(dibenzylideneacetone)dipalladium(0)) (Pd2(dba)3), is prepared by reducing [sodium tetrachloropalladate](https://en.wikipedia.org/wiki/Sodium_tetrachloropalladate) in the presence of [dibenzylideneacetone](https://en.wikipedia.org/wiki/Dibenzylideneacetone).[[17]](https://en.wikipedia.org/wiki/Palladium#cite_note-17)

Palladium(0), as well as palladium(II), are catalysts in [coupling reactions](https://en.wikipedia.org/wiki/Palladium-catalyzed_coupling_reactions), as has been recognized by the 2010 [Nobel Prize in Chemistry](https://en.wikipedia.org/wiki/Nobel_Prize_in_Chemistry) to [Richard F. Heck](https://en.wikipedia.org/wiki/Richard_F._Heck), [Ei-ichi Negishi](https://en.wikipedia.org/wiki/Ei-ichi_Negishi), and [Akira Suzuki](https://en.wikipedia.org/wiki/Akira_Suzuki_(chemist)). Such reactions are widely practiced for the synthesis of fine chemicals. Prominent coupling reactions include the [Heck](https://en.wikipedia.org/wiki/Heck_reaction), [Suzuki](https://en.wikipedia.org/wiki/Suzuki_reaction), [Sonogashira coupling](https://en.wikipedia.org/wiki/Sonogashira_coupling), [Stille reactions](https://en.wikipedia.org/wiki/Stille_reaction), and the [Kumada coupling](https://en.wikipedia.org/wiki/Kumada_coupling). [Palladium(II) acetate](https://en.wikipedia.org/wiki/Palladium(II)_acetate), [tetrakis(triphenylphosphine)palladium(0)](https://en.wikipedia.org/wiki/Tetrakis(triphenylphosphine)palladium(0)) (Pd(PPh3)4, and [tris(dibenzylideneacetone)dipalladium(0)](https://en.wikipedia.org/wiki/Tris(dibenzylideneacetone)dipalladium(0)) (Pd2(dba)3) serve either as catalysts or precatalysts.[[18]](https://en.wikipedia.org/wiki/Palladium#cite_note-18)

**Other oxidation states**

Although Pd(IV) compounds are comparatively rare, one example is [sodium hexachloropalladate(IV)](https://en.wikipedia.org/w/index.php?title=Sodium_hexachloropalladate(IV)&action=edit&redlink=1), Na2[PdCl6]. A few [compounds of palladium(III)](https://en.wikipedia.org/wiki/Compounds_of_palladium(III)) are also known.[[19]](https://en.wikipedia.org/wiki/Palladium#cite_note-19) Palladium(VI) was claimed in 2002,[[20]](https://en.wikipedia.org/wiki/Palladium#cite_note-pmid11786638-20)[[21]](https://en.wikipedia.org/wiki/Palladium#cite_note-pmid11786632-21) but subsequently disproven.[[22]](https://en.wikipedia.org/wiki/Palladium#cite_note-22)[[23]](https://en.wikipedia.org/wiki/Palladium#cite_note-23)

Mixed valence palladium complexes exist, e.g. Pd4(CO)4(OAc)4Pd(acac)2 forms an infinite Pd chain structure, with alternatively interconnected Pd4(CO)4(OAc)4 and Pd(acac)2 units.[[24]](https://en.wikipedia.org/wiki/Palladium#cite_note-pmid25319757-24)

**History**

[](https://en.wikipedia.org/wiki/File:Wollaston_William_Hyde_Jackson_color.jpg)

[William Hyde Wollaston](https://en.wikipedia.org/wiki/William_Hyde_Wollaston)

William Hyde Wollaston noted the [discovery](https://en.wikipedia.org/wiki/Discovery_of_the_chemical_elements) of a new noble metal in July 1802 in his lab-book and named it palladium in August of the same year. Wollaston purified a quantity of the material and offered it, without naming the discoverer, in a small shop in [Soho](https://en.wikipedia.org/wiki/Soho) in April 1803. After harsh criticism from [Richard Chenevix](https://en.wikipedia.org/wiki/Richard_Chenevix_(chemist)) that palladium is an alloy of platinum and mercury, Wollaston anonymously offered a reward of £20 for 20 grains of synthetic palladium *alloy*.[[25]](https://en.wikipedia.org/wiki/Palladium#cite_note-contr-25) Chenevix received the [Copley Medal](https://en.wikipedia.org/wiki/Copley_Medal) in 1803 after he published his experiments on palladium. Wollaston published the discovery of [rhodium](https://en.wikipedia.org/wiki/Rhodium) in 1804 and mentions some of his work on palladium.[[26]](https://en.wikipedia.org/wiki/Palladium#cite_note-Disco-26)[[27]](https://en.wikipedia.org/wiki/Palladium#cite_note-27) He disclosed that he was the discoverer of palladium in a publication in 1805.[[25]](https://en.wikipedia.org/wiki/Palladium#cite_note-contr-25)[[28]](https://en.wikipedia.org/wiki/Palladium#cite_note-28)

It was named by Wollaston in 1802 after the asteroid [2 Pallas](https://en.wikipedia.org/wiki/2_Pallas), which had been discovered two months earlier.[[4]](https://en.wikipedia.org/wiki/Palladium#cite_note-CRC-4) Wollaston found palladium in crude platinum ore from [South America](https://en.wikipedia.org/wiki/South_America) by dissolving the ore in [aqua regia](https://en.wikipedia.org/wiki/Aqua_regia), neutralizing the solution with [sodium hydroxide](https://en.wikipedia.org/wiki/Sodium_hydroxide), and precipitating platinum as [ammonium chloroplatinate](https://en.wikipedia.org/wiki/Ammonium_chloroplatinate) with [ammonium chloride](https://en.wikipedia.org/wiki/Ammonium_chloride). He added [mercuric cyanide](https://en.wikipedia.org/wiki/Mercuric_cyanide) to form the compound [palladium(II) cyanide](https://en.wikipedia.org/wiki/Palladium(II)_cyanide), which was heated to extract palladium metal.[[26]](https://en.wikipedia.org/wiki/Palladium#cite_note-Disco-26)

[Palladium chloride](https://en.wikipedia.org/wiki/Palladium_chloride) was at one time prescribed as a [tuberculosis](https://en.wikipedia.org/wiki/Tuberculosis) treatment at the rate of 0.065 g per day (approximately one milligram per kilogram of body weight). This treatment had many negative [side-effects](https://en.wikipedia.org/wiki/Adverse_effect_(medicine)), and was later replaced by more effective drugs.[[29]](https://en.wikipedia.org/wiki/Palladium#cite_note-29)

Most palladium is used for [catalytic converters](https://en.wikipedia.org/wiki/Catalytic_converter) in the automobile industry.[[30]](https://en.wikipedia.org/wiki/Palladium#cite_note-Kiel-30) In the run up to year 2000, the Russian supply of palladium to the global market was repeatedly delayed and disrupted[[31]](https://en.wikipedia.org/wiki/Palladium#cite_note-31) for political reasons, the export quota was not granted on time. The ensuing market panic drove the price to an all-time high of $1100 per [troy ounce](https://en.wikipedia.org/wiki/Troy_ounce) in January 2001.[[32]](https://en.wikipedia.org/wiki/Palladium#cite_note-chart-all-32) Around that time, the [Ford Motor Company](https://en.wikipedia.org/wiki/Ford_Motor_Company), fearing that automobile production would be disrupted by a palladium shortage, stockpiled the metal. When prices fell in early 2001, Ford lost nearly [US$](https://en.wikipedia.org/wiki/United_States_dollar)1 billion.[[33]](https://en.wikipedia.org/wiki/Palladium#cite_note-33)

World demand for palladium increased from 100 tons in 1990 to nearly 300 tons in 2000. The global production of palladium from mines was 222 [tonnes](https://en.wikipedia.org/wiki/Tonne) in 2006 according to the [United States Geological Survey](https://en.wikipedia.org/wiki/United_States_Geological_Survey).[[34]](https://en.wikipedia.org/wiki/Palladium#cite_note-USGS07CS-34) Many were concerned about a steady supply of palladium in the wake of Russia's military maneuvers in Ukraine, partly as sanctions could hamper Russian palladium exports; any restrictions on Russian palladium exports would exacerbate what is already expected to be a large palladium deficit in 2014.[[35]](https://en.wikipedia.org/wiki/Palladium#cite_note-35) Those concerns pushed palladium prices to their highest level since 2001.[[36]](https://en.wikipedia.org/wiki/Palladium#cite_note-36) In September 2014 they soared above the $900 per ounce mark. In 2016 however palladium cost around $614 per ounce as Russia managed to maintain stable supplies.[[37]](https://en.wikipedia.org/wiki/Palladium#cite_note-37) In January 2018 palladium futures climbed past $1,100 per ounce for the first time on record, mainly due to the strong demand from the automotive industry.[[38]](https://en.wikipedia.org/wiki/Palladium#cite_note-38)

**Occurrence**

[](https://en.wikipedia.org/wiki/File:2005palladium_(mined).PNG)

Palladium output in 2005

As overall mine production of palladium reached 208,000 kilograms in 2016, Russia was the top producer with 82,000 kilograms, followed by South Africa, Canada and the U.S.[[39]](https://en.wikipedia.org/wiki/Palladium#cite_note-39) Russia's company Norilsk Nickel ranks first among the largest palladium producers globally, it accounts for 39% of the world’s production.[[40]](https://en.wikipedia.org/wiki/Palladium#cite_note-40)

Palladium can be found as a free metal alloyed with gold and other platinum-group metals in [placer](https://en.wikipedia.org/wiki/Placer_mining) deposits of the [Ural Mountains](https://en.wikipedia.org/wiki/Ural_Mountains), [Australia](https://en.wikipedia.org/wiki/Australia), [Ethiopia](https://en.wikipedia.org/wiki/Ethiopia), [North](https://en.wikipedia.org/wiki/North_America) and [South America](https://en.wikipedia.org/wiki/South_America). For the production of palladium, these deposits play only a minor role. The most important commercial sources are [nickel](https://en.wikipedia.org/wiki/Nickel)-[copper](https://en.wikipedia.org/wiki/Copper) deposits found in the [Sudbury Basin](https://en.wikipedia.org/wiki/Sudbury_Basin), [Ontario](https://en.wikipedia.org/wiki/Ontario), and the [Norilsk–Talnakh](https://en.wikipedia.org/wiki/Norilsk) deposits in [Siberia](https://en.wikipedia.org/wiki/Siberia). The other large deposit is the [Merensky Reef](https://en.wikipedia.org/wiki/Merensky_Reef) [platinum group](https://en.wikipedia.org/wiki/Platinum_group) metals deposit within the [Bushveld Igneous Complex](https://en.wikipedia.org/wiki/Bushveld_Igneous_Complex) [South Africa](https://en.wikipedia.org/wiki/South_Africa). The [Stillwater igneous complex](https://en.wikipedia.org/wiki/Stillwater_igneous_complex) of [Montana](https://en.wikipedia.org/wiki/Montana) and the Roby zone ore body of the [Lac des Îles igneous complex](https://en.wikipedia.org/wiki/Lac_des_%C3%8Eles_igneous_complex) of Ontario are the two other sources of palladium in Canada and the United States.[[34]](https://en.wikipedia.org/wiki/Palladium#cite_note-USGS07CS-34)[[41]](https://en.wikipedia.org/wiki/Palladium#cite_note-USGS07YB-41) Palladium is found in the rare minerals [cooperite](https://en.wikipedia.org/wiki/Cooperite_(mineral))[[42]](https://en.wikipedia.org/wiki/Palladium#cite_note-42) and [polarite](https://en.wikipedia.org/wiki/Polarite).[[43]](https://en.wikipedia.org/wiki/Palladium#cite_note-43) Many more Pd minerals are known, but all of them are very rare.[[44]](https://en.wikipedia.org/wiki/Palladium#cite_note-44)

Palladium is also produced in [nuclear fission](https://en.wikipedia.org/wiki/Nuclear_fission) reactors and can be extracted from spent nuclear fuel (see [synthesis of precious metals](https://en.wikipedia.org/wiki/Synthesis_of_precious_metals)), though this source for palladium is not used. None of the existing [nuclear reprocessing](https://en.wikipedia.org/wiki/Nuclear_reprocessing) facilities are equipped to extract palladium from the [high-level radioactive waste](https://en.wikipedia.org/wiki/High-level_radioactive_waste).[[45]](https://en.wikipedia.org/wiki/Palladium#cite_note-45)

**Applications**

[](https://en.wikipedia.org/wiki/File:Aufgeschnittener_Metall_Katalysator_f%C3%BCr_ein_Auto.jpg)

Cross section of a [metal-core catalytic converter](https://en.wikipedia.org/wiki/Catalytic_converter)

[](https://en.wikipedia.org/wiki/File:25_rubles_palladium_1989_Ivan_III.jpg)

The Soviet 25-rouble commemorative [palladium coin](https://en.wikipedia.org/wiki/Palladium_coin) is a rare example of the monetary usage of palladium.

The largest use of palladium today is in catalytic converters.[[46]](https://en.wikipedia.org/wiki/Palladium#cite_note-unctad-46) Palladium is also used in jewelry, [dentistry](https://en.wikipedia.org/wiki/Dentistry),[[46]](https://en.wikipedia.org/wiki/Palladium#cite_note-unctad-46)[[47]](https://en.wikipedia.org/wiki/Palladium#cite_note-47) [watch](https://en.wikipedia.org/wiki/Watch) making, blood sugar test strips, aircraft [spark plugs](https://en.wikipedia.org/wiki/Spark_plug), [surgical instruments](https://en.wikipedia.org/wiki/Surgical_instrument), and [electrical contacts](https://en.wikipedia.org/wiki/Electrical_contact).[[48]](https://en.wikipedia.org/wiki/Palladium#cite_note-48) Palladium is also used to make professional [transverse (concert or classical) flutes](https://en.wikipedia.org/wiki/Transverse_flute).[[49]](https://en.wikipedia.org/wiki/Palladium#cite_note-49) As a commodity, palladium [bullion](https://en.wikipedia.org/wiki/Bullion) has [ISO currency codes](https://en.wikipedia.org/wiki/ISO_currency_code) of XPD and 964. Palladium is one of only four metals to have such codes, the others being [gold](https://en.wikipedia.org/wiki/Gold), [silver](https://en.wikipedia.org/wiki/Silver) and platinum.[[50]](https://en.wikipedia.org/wiki/Palladium#cite_note-50) Because it absorbs hydrogen, palladium is a key component of the controversial [cold fusion](https://en.wikipedia.org/wiki/Cold_fusion) experiments that began in 1989.

**Catalysis**

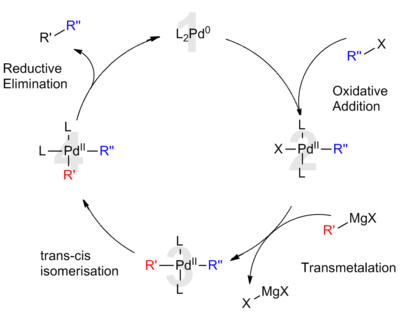
When it is finely divided, as with [palladium on carbon](https://en.wikipedia.org/wiki/Palladium_on_carbon), palladium forms a versatile [catalyst](https://en.wikipedia.org/wiki/Catalyst); it speeds [heterogeneous](https://en.wikipedia.org/wiki/Heterogeneous_catalysis) catalytic processes like [hydrogenation](https://en.wikipedia.org/wiki/Hydrogenation), [dehydrogenation](https://en.wikipedia.org/wiki/Dehydrogenation), and [petroleum cracking](https://en.wikipedia.org/wiki/Cracking_(chemistry)). Palladium is also essential to the [Lindlar catalyst](https://en.wikipedia.org/wiki/Lindlar_catalyst), also called Lindlar's Palladium.[[51]](https://en.wikipedia.org/wiki/Palladium#cite_note-51) A large number of [carbon–carbon bonding](https://en.wikipedia.org/wiki/Carbon%E2%80%93carbon_bond) reactions in [organic chemistry](https://en.wikipedia.org/wiki/Organic_chemistry) are facilitated by palladium compound catalysts. For example:

* [Heck reaction](https://en.wikipedia.org/wiki/Heck_reaction)
* [Suzuki coupling](https://en.wikipedia.org/wiki/Suzuki_coupling)
* [Tsuji-Trost reactions](https://en.wikipedia.org/wiki/Tsuji%E2%80%93Trost_reaction)
* [Wacker process](https://en.wikipedia.org/wiki/Wacker_process)
* [Negishi reaction](https://en.wikipedia.org/wiki/Negishi_coupling)
* [Stille coupling](https://en.wikipedia.org/wiki/Stille_coupling)
* [Sonogashira coupling](https://en.wikipedia.org/wiki/Sonogashira_coupling)

(See [palladium compounds](https://en.wikipedia.org/wiki/Palladium#Compounds) and [palladium-catalyzed coupling reactions](https://en.wikipedia.org/wiki/Palladium-catalyzed_coupling_reactions).)

When dispersed on conductive materials, palladium is an excellent electrocatalyst for oxidation of primary alcohols in alkaline media.[[52]](https://en.wikipedia.org/wiki/Palladium#cite_note-52) Palladium is also a versatile metal for [homogeneous catalysis](https://en.wikipedia.org/wiki/Homogeneous_catalysis), used in combination with a broad variety of [ligands](https://en.wikipedia.org/wiki/Ligand) for highly selective chemical transformations.

In 2010, palladium-catalysed organic reactions were recognized by the [Nobel Prize in Chemistry](https://en.wikipedia.org/wiki/Nobel_Prize_in_Chemistry). A 2008 study showed that palladium is an effective catalyst for carbon-fluoride bonds.[[53]](https://en.wikipedia.org/wiki/Palladium#cite_note-53)

[](https://en.wikipedia.org/wiki/File:Kumada_Catalytic_Cycle.png)

Catalytic cycle for Kumada cross coupling reaction, which is widely used in the synthesis of fine chemicals.

Palladium catalysis is primarily employed in organic chemistry and industrial applications, although its use is growing as a tool for [synthetic biology](https://en.wikipedia.org/wiki/Synthetic_biology); in 2017, effective *in vivo* catalytic activity of palladium [nanoparticles](https://en.wikipedia.org/wiki/Nanoparticles) was demonstrated in mammals to treat disease.[[54]](https://en.wikipedia.org/wiki/Palladium#cite_note-pmid28699627-54)

**Electronics**

The second greatest application of palladium in electronics is in [multilayer ceramic capacitors](https://en.wikipedia.org/wiki/Multilayer_ceramic_capacitor)[[55]](https://en.wikipedia.org/wiki/Palladium#cite_note-55) in which palladium (and palladium-silver alloy) is used for electrodes.[[46]](https://en.wikipedia.org/wiki/Palladium#cite_note-unctad-46) Palladium (sometimes alloyed with nickel) is used for component and connector plating in consumer electronics[[56]](https://en.wikipedia.org/wiki/Palladium#cite_note-56)[[57]](https://en.wikipedia.org/wiki/Palladium#cite_note-57) and in soldering materials. The electronic sector consumed 1.07 million [troy ounces](https://en.wikipedia.org/wiki/Troy_ounce) (33.2 tonnes) of palladium in 2006, according to a [Johnson Matthey](https://en.wikipedia.org/wiki/Johnson_Matthey) report.[[58]](https://en.wikipedia.org/wiki/Palladium#cite_note-matthey-58)

**Technology**

Hydrogen easily diffuses through heated palladium,[[4]](https://en.wikipedia.org/wiki/Palladium#cite_note-CRC-4) and [membrane reactors](https://en.wikipedia.org/wiki/Membrane_reactor) with Pd membranes are used in the production of high purity hydrogen.[[59]](https://en.wikipedia.org/wiki/Palladium#cite_note-59) Palladium is used in [palladium-hydrogen electrode](https://en.wikipedia.org/wiki/Palladium-hydrogen_electrode)s in electrochemical studies. [Palladium(II) chloride](https://en.wikipedia.org/wiki/Palladium(II)_chloride) readily catalyzes carbon monoxide gas to carbon dioxide and is useful in [carbon monoxide detectors](https://en.wikipedia.org/wiki/Carbon_monoxide_detector).[[60]](https://en.wikipedia.org/wiki/Palladium#cite_note-60)

**Hydrogen storage**

Main article: [Palladium hydride](https://en.wikipedia.org/wiki/Palladium_hydride)

Palladium readily [absorbs](https://en.wikipedia.org/wiki/Absorption_(chemistry)) hydrogen at room temperatures, forming [palladium hydride](https://en.wikipedia.org/wiki/Palladium_hydride) PdHx with x less than 1.[[61]](https://en.wikipedia.org/wiki/Palladium#cite_note-61) While this property is common to many transition metals, palladium has a uniquely high absorption capacity and does not lose its ductility until x approaches 1.[[62]](https://en.wikipedia.org/wiki/Palladium#cite_note-gr-62) This property has been investigated in designing an efficient, inexpensive, and safe hydrogen fuel storage medium, though palladium itself is currently prohibitively expensive for this purpose.[[63]](https://en.wikipedia.org/wiki/Palladium#cite_note-grochala-63) The content of hydrogen in palladium can be linked to [magnetic susceptibility](https://en.wikipedia.org/wiki/Magnetic_susceptibility), which decreases with the increase of hydrogen and becomes zero for PdH0.62. At any higher ratio, the [solid solution](https://en.wikipedia.org/wiki/Solid_solution) becomes [diamagnetic](https://en.wikipedia.org/wiki/Diamagnetic).[[64]](https://en.wikipedia.org/wiki/Palladium#cite_note-64)

**Dentistry**

Palladium is used in small amounts (about 0.5%) in some alloys of [dental amalgam](https://en.wikipedia.org/wiki/Dental_amalgam) to decrease corrosion and increase the [metallic lustre](https://en.wikipedia.org/wiki/Lustre_(mineralogy)#Metallic_lustre) of the final restoration.[[65]](https://en.wikipedia.org/wiki/Palladium#cite_note-65)

**Jewelry**

Palladium has been used as a [precious metal](https://en.wikipedia.org/wiki/Precious_metal) in jewelry since 1939 as an alternative to platinum in the alloys called "[white gold](https://en.wikipedia.org/wiki/Colored_gold#White_gold)", where the naturally white color of palladium does not require [rhodium plating](https://en.wikipedia.org/wiki/Plating#Rhodium_plating). Palladium is much less dense than platinum. Similar to gold, palladium can be beaten into [leaf](https://en.wikipedia.org/wiki/Metal_leaf) as thin as 100 nm (​1⁄250,000 in).[[4]](https://en.wikipedia.org/wiki/Palladium#cite_note-CRC-4) Unlike platinum, palladium may discolor at temperatures above 400 °C (752 °F);[[66]](https://en.wikipedia.org/wiki/Palladium#cite_note-66) it is relatively brittle.[[*clarification needed*](https://en.wikipedia.org/wiki/Wikipedia:Please_clarify)]

Palladium is one of the three most popular alloying metals in white gold ([nickel](https://en.wikipedia.org/wiki/Nickel) and silver can also be used).[[46]](https://en.wikipedia.org/wiki/Palladium#cite_note-unctad-46) Palladium-gold is more expensive than nickel-gold, but seldom causes allergic reactions (though certain cross-allergies with nickel may occur).[[67]](https://en.wikipedia.org/wiki/Palladium#cite_note-67)

When platinum became a strategic resource during World War II, many jewelry bands were made out of palladium. Up to as recently as September 2001,[[68]](https://en.wikipedia.org/wiki/Palladium#cite_note-68) palladium was more expensive than platinum and rarely used in jewelry because of the technical difficulty of [casting](https://en.wikipedia.org/wiki/Casting_(metalworking)). Currently, the casting problem has been resolved and use in jewelry has increased because platinum has increased in price while palladium decreased.[[69]](https://en.wikipedia.org/wiki/Palladium#cite_note-wsj-69)

Prior to 2004, the principal use of palladium in jewelry was the manufacture of white gold. In early 2004, when gold and platinum prices rose steeply, China began fabricating volumes of palladium jewelry, consuming 37 [tonnes](https://en.wikipedia.org/wiki/Tonne) in 2005. Changes in the relative price of platinum after 2008 lowered demand for palladium to 17.4 tonnes in 2009.[[70]](https://en.wikipedia.org/wiki/Palladium#cite_note-USGS09YB-70)[[71]](https://en.wikipedia.org/wiki/Palladium#cite_note-USGS06YB-71)

In January 2010, [hallmarks](https://en.wikipedia.org/wiki/Hallmark) for palladium were introduced by assay offices in the United Kingdom, and hallmarking became mandatory for all jewelry advertising pure or alloyed palladium. Articles can be marked as 500, 950, or 999 parts of palladium per thousand of the alloy.

[Fountain pen](https://en.wikipedia.org/wiki/Fountain_pen) [nibs](https://en.wikipedia.org/wiki/Nib_(pen)) made from [gold](https://en.wikipedia.org/wiki/Gold) are sometimes plated with palladium when a silver (rather than gold) appearance is desired. [Sheaffer](https://en.wikipedia.org/wiki/Sheaffer) has used palladium plating for decades, either as an accent on otherwise gold nibs or covering the gold completely.

**Photography**

In the [platinotype](https://en.wikipedia.org/wiki/Platinotype) printing process, photographers make fine-art black-and-white prints using platinum or palladium salts. Often used with platinum, palladium provides an alternative to silver.[[72]](https://en.wikipedia.org/wiki/Palladium#cite_note-72)

**Toxicity**

|  |  |
| --- | --- |
| Palladium | |
| **Hazards** | |
| [GHS pictograms](https://en.wikipedia.org/wiki/GHS_hazard_pictograms) | [The exclamation-mark pictogram in the Globally Harmonized System of Classification and Labelling of Chemicals (GHS)](https://en.wikipedia.org/wiki/File:GHS-pictogram-exclam.svg) |
| [GHS signal word](https://en.wikipedia.org/wiki/Globally_Harmonized_System_of_Classification_and_Labelling_of_Chemicals) | Warning |
| [GHS hazard statements](https://en.wikipedia.org/wiki/GHS_hazard_statement) | H317 |
| [GHS precautionary statements](https://en.wikipedia.org/wiki/GHS_precautionary_statements) | P261, P273, P280, P302+352, P321, P333+313, P363, P501[[73]](https://en.wikipedia.org/wiki/Palladium#cite_note-73) |
| [NFPA 704](https://en.wikipedia.org/wiki/NFPA_704) | NFPA 704 four-colored diamond  [0](https://en.wikipedia.org/wiki/NFPA_704#Red)  [0](https://en.wikipedia.org/wiki/NFPA_704#Blue)  [0](https://en.wikipedia.org/wiki/NFPA_704#Yellow) |

Palladium is a metal with low toxicity. It is poorly absorbed by the [human body](https://en.wikipedia.org/wiki/Human_body) when [ingested](https://en.wikipedia.org/wiki/Ingested). Plants such as the [water hyacinth](https://en.wikipedia.org/wiki/Water_hyacinth) are killed by low levels of palladium salts, but most other plants tolerate it, although tests show that, at levels above 0.0003%, growth is affected. High doses of palladium could be poisonous; tests on [rodents](https://en.wikipedia.org/wiki/Rodents) suggest it may be [carcinogenic](https://en.wikipedia.org/wiki/Carcinogenic), though no clear evidence indicates the element harms humans.[[74]](https://en.wikipedia.org/wiki/Palladium#cite_note-74)

**Precautions**

Like other [platinum-group metals](https://en.wikipedia.org/wiki/Platinum-group_metal), bulk Pd is quite inert. Although [contact dermatitis](https://en.wikipedia.org/wiki/Contact_dermatitis) has been reported, data on the effects are limited. It has been shown that people with an allergic reaction to palladium also react to nickel, making it advisable to avoid the use of dental alloys containing palladium on those so allergic.[[30]](https://en.wikipedia.org/wiki/Palladium#cite_note-Kiel-30)[[75]](https://en.wikipedia.org/wiki/Palladium#cite_note-75)[[76]](https://en.wikipedia.org/wiki/Palladium#cite_note-76)[[77]](https://en.wikipedia.org/wiki/Palladium#cite_note-77)[[78]](https://en.wikipedia.org/wiki/Palladium#cite_note-78)

Some palladium is emitted with the exhaust gases of cars with [catalytic converters](https://en.wikipedia.org/wiki/Catalytic_converter). Between 4 and 108 ng/km of palladium particulate is released by such cars, while the total uptake from food is estimated to be less than 2 µg per person a day. The second possible source of palladium is dental restoration, from which the uptake of palladium is estimated to be less than 15 µg per person per day. People working with palladium or its compounds might have a considerably greater uptake. For soluble compounds such as [palladium chloride](https://en.wikipedia.org/wiki/Palladium_chloride), 99% is eliminated from the body within 3 days.[[30]](https://en.wikipedia.org/wiki/Palladium#cite_note-Kiel-30)

The [median lethal dose](https://en.wikipedia.org/wiki/Median_lethal_dose) (LD50) of soluble palladium compounds in mice is 200 mg/kg for [oral](https://en.wikipedia.org/wiki/Oral_administration) and 5 mg/kg for [intravenous administration](https://en.wikipedia.org/wiki/Intravenous_administration).[[30]](https://en.wikipedia.org/wiki/Palladium#cite_note-Kiel-30)

**See also**

* [2000s commodities boom](https://en.wikipedia.org/wiki/2000s_commodities_boom)
* [Palladium as an investment](https://en.wikipedia.org/wiki/Palladium_as_an_investment)
* [Pseudo palladium](https://en.wikipedia.org/wiki/Pseudo_palladium)

**References**

 *Meija, J.; et al. (2016).* [*"Atomic weights of the elements 2013 (IUPAC Technical Report)"*](https://www.degruyter.com/downloadpdf/j/pac.2016.88.issue-3/pac-2015-0305/pac-2015-0305.xml)*.* [*Pure and Applied Chemistry*](https://en.wikipedia.org/wiki/Pure_and_Applied_Chemistry)*.* ***88*** *(3): 265–91.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1515/pac-2015-0305*](https://doi.org/10.1515%2Fpac-2015-0305)*.*

  *Lide, D. R., ed. (2005). "Magnetic susceptibility of the elements and inorganic compounds".* [*CRC Handbook of Chemistry and Physics*](https://web.archive.org/web/20110303222309/http:/www-d0.fnal.gov/hardware/cal/lvps_info/engineering/elementmagn.pdf) *(PDF) (86th ed.). Boca Raton (FL): CRC Press.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*0-8493-0486-5*](https://en.wikipedia.org/wiki/Special:BookSources/0-8493-0486-5)*.*

  *Weast, Robert (1984). CRC, Handbook of Chemistry and Physics. Boca Raton, Florida: Chemical Rubber Company Publishing. pp. E110.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*0-8493-0464-4*](https://en.wikipedia.org/wiki/Special:BookSources/0-8493-0464-4)*.*

  *Hammond, C. R. (2004). "The Elements". Handbook of Chemistry and Physics (81st ed.). CRC press.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-8493-0485-9*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-8493-0485-9)*.*

  *Craig, Bruce D.; Anderson, David S. (1995). "Atmospheric Environment".* [*Handbook of corrosion data*](https://books.google.com/books?id=KXwgAZJBWb0C&pg=RA1-PT126)*. ASM International. p. 126.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-87170-518-1*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-87170-518-1)*.*

  B. Strizker, Phys. Rev. Lett., 42, 1769 (1979).

  [*"Atomic Weights and Isotopic Compositions for Palladium (NIST)"*](http://physics.nist.gov/PhysRefData/Compositions/index.html)*. Retrieved 12 November 2009.*

  *Georges, Audi; Bersillon, O.; Blachot, J.; Wapstra, A. H. (2003).* [*"The NUBASE Evaluation of Nuclear and Decay Properties"*](http://hal.in2p3.fr/in2p3-00014184)*. Nuclear Physics A.* ***729****: 3–128.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*2003NuPhA.729....3A*](http://adsabs.harvard.edu/abs/2003NuPhA.729....3A)*.* [*CiteSeerX*](https://en.wikipedia.org/wiki/CiteSeerX)[*10.1.1.692.8504*](https://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.692.8504)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/j.nuclphysa.2003.11.001*](https://doi.org/10.1016%2Fj.nuclphysa.2003.11.001)*.*

  *Kelly, W. R.; Gounelle, G. J.; Hutchison, R. (1978). "Evidence for the existence of 107Pd in the early solar system".* [*Geophysical Research Letters*](https://en.wikipedia.org/wiki/Geophysical_Research_Letters)*.* ***359*** *(1787): 1079–1082.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*2001RSPTA.359.1991R*](http://adsabs.harvard.edu/abs/2001RSPTA.359.1991R)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1098/rsta.2001.0893*](https://doi.org/10.1098%2Frsta.2001.0893)*.*

  [*"Mexico's Meteorites"*](https://web.archive.org/web/20060506085632/http:/www.mexicogemstones.com/pdf/MexicoMeteorites.pdf) *(PDF). mexicogemstones.com. Archived from* [*the original*](http://mexicogemstones.com/pdf/MexicoMeteorites.pdf) *(PDF) on 2006-05-06.*

  *Chen, J. H.; Wasserburg, G. J. (1990). "The isotopic composition of Ag in meteorites and the presence of 107Pd in protoplanets". Geochimica et Cosmochimica Acta.* ***54*** *(6): 1729–1743.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1990GeCoA..54.1729C*](http://adsabs.harvard.edu/abs/1990GeCoA..54.1729C)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/0016-7037(90)90404-9*](https://doi.org/10.1016%2F0016-7037%2890%2990404-9)*.*

  *Mozingo, Ralph (1955).* [*"Palladium Catalysts"*](http://www.orgsyn.org/demo.aspx?prep=cv3p0685)*.* [*Organic Syntheses*](https://en.wikipedia.org/wiki/Organic_Syntheses)*.*; *Collective Volume,* ***3****, p. 685*

  *Anderson, Gordon K.; Lin, Minren; Sen, Ayusman; Gretz, Efi (1990). "Bis(Benzonitrile)Dichloro Complexes of Palladium and Platinum".* [*Inorganic Syntheses*](https://en.wikipedia.org/wiki/Inorganic_Syntheses)*. Inorganic Syntheses.* ***28****: 60–63.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/9780470132593.ch13*](https://doi.org/10.1002%2F9780470132593.ch13)*.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-470-13259-3*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-470-13259-3)*.*

  *Zalevskaya, O. A; Vorob'eva, E. G; Dvornikova, I. A; Kuchin, A. V (2008). "Palladium complexes based on optically active terpene derivatives of ethylenediamine". Russian Journal of Coordination Chemistry.* ***34*** *(11): 855–857.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1134/S1070328408110110*](https://doi.org/10.1134%2FS1070328408110110)*.*

  *Miyaura, Norio; Suzuki, Akira (1993).* [*"Palladium-catalyzed reaction of 1-alkenylboronates with vinylic halides: (1Z,3E)-1-Phenyl-1,3-octadiene"*](http://www.orgsyn.org/demo.aspx?prep=cv8p0532)*.* [*Organic Syntheses*](https://en.wikipedia.org/wiki/Organic_Syntheses)*.*; *Collective Volume,* ***8****, p. 532*

  *Coulson, D. R.; Satek, L. C.; Grim, S. O. (1972). "23. Tetrakis(triphenylphosphine)palladium(0)".* [*Inorg. Synth.*](https://en.wikipedia.org/wiki/Inorg._Synth.) *Inorganic Syntheses.* ***13****: 121–124.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/9780470132449.ch23*](https://doi.org/10.1002%2F9780470132449.ch23)*.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-470-13244-9*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-470-13244-9)*.*

  *Takahashi, Y; Ito, Ts; Sakai, S; Ishii, Y (1970). "A novel palladium(0) complex; bis(dibenzylideneacetone)palladium(0)". Journal of the Chemical Society D: Chemical Communications (17): 1065.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1039/C29700001065*](https://doi.org/10.1039%2FC29700001065)*.*

  *Crabtree, Robert H. (2009). "Application to Organic Synthesis".* [*The Organometallic Chemistry of the Transition Metals*](https://books.google.com/?id=WLb962AKlSEC&pg=PA392)*. John Wiley and Sons. p. 392.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-470-25762-3*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-470-25762-3)*.*

  *Powers, David C; Ritter, Tobias (2011). "Palladium(III) in Synthesis and Catalysis". Higher Oxidation State Organopalladium and Platinum Chemistry. Topics in Organometallic Chemistry.* ***35****. pp. 129–156.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/978-3-642-17429-2\_6*](https://doi.org/10.1007%2F978-3-642-17429-2_6)*.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-3-642-17428-5*](https://en.wikipedia.org/wiki/Special:BookSources/978-3-642-17428-5)*.* [*PMC*](https://en.wikipedia.org/wiki/PubMed_Central)[*3066514*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3066514)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*21461129*](https://www.ncbi.nlm.nih.gov/pubmed/21461129)*.*

  *Chen, W; Shimada, S; Tanaka, M (2002). "Synthesis and Structure of Formally Hexavalent Palladium Complexes". Science.* ***295*** *(5553): 308–310.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1126/science.1067027*](https://doi.org/10.1126%2Fscience.1067027)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*11786638*](https://www.ncbi.nlm.nih.gov/pubmed/11786638)*.*

  *Crabtree, R. H (2002). "CHEMISTRY: A New Oxidation State for Pd?". Science.* ***295*** *(5553): 288–289.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1126/science.1067921*](https://doi.org/10.1126%2Fscience.1067921)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*11786632*](https://www.ncbi.nlm.nih.gov/pubmed/11786632)*.*

  *Aullón, G; Lledós, A; Alvarez, S (2002). "Hexakis(silyl)palladium(VI) or palladium(II with eta2-disilane ligands?". Angewandte Chemie (International Ed. In English).* ***41*** *(11): 1956–9.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*19750645*](https://www.ncbi.nlm.nih.gov/pubmed/19750645)*.*

  *Sherer, E. C; Kinsinger, C. R; Kormos, B. L; Thompson, J. D; Cramer, C. J (2002). "Electronic structure and bonding in hexacoordinate silyl-palladium complexes". Angewandte Chemie (International Ed. In English).* ***41*** *(11): 1953–6.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*19750644*](https://www.ncbi.nlm.nih.gov/pubmed/19750644)*.*

  *Yin, Xi; Warren, Steven A; Pan, Yung-Tin; Tsao, Kai-Chieh; Gray, Danielle L; Bertke, Jeffery; Yang, Hong (2014). "A Motif for Infinite Metal Atom Wires". Angewandte Chemie International Edition.* ***53*** *(51): 14087–14091.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/anie.201408461*](https://doi.org/10.1002%2Fanie.201408461)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*25319757*](https://www.ncbi.nlm.nih.gov/pubmed/25319757)*.*

  *Usselman, Melvyn (1978). "The Wollaston/Chenevix controversy over the elemental nature of palladium: A curious episode in the history of chemistry". Annals of Science.* ***35*** *(6): 551–579.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1080/00033797800200431*](https://doi.org/10.1080%2F00033797800200431)*.*

  *Griffith, W. P. (2003).* [*"Rhodium and Palladium – Events Surrounding Its Discovery"*](http://www.platinummetalsreview.com/dynamic/article/view/47-4-175-183)*. Platinum Metals Review.* ***47*** *(4): 175–183.*

  [*Wollaston, W. H.*](https://en.wikipedia.org/wiki/William_Hyde_Wollaston) *(1804).* [*"On a New Metal, Found in Crude Platina"*](https://books.google.com/books?id=7AZGAAAAMAAJ&pg=PA419)*.* [*Philosophical Transactions of the Royal Society of London*](https://en.wikipedia.org/wiki/Philosophical_Transactions_of_the_Royal_Society_of_London)*.* ***94****: 419–430.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1098/rstl.1804.0019*](https://doi.org/10.1098%2Frstl.1804.0019)*.*

  [*Wollaston, W. H.*](https://en.wikipedia.org/wiki/William_Hyde_Wollaston) *(1805). "On the Discovery of Palladium; With Observations on Other Substances Found with Platina".* [*Philosophical Transactions of the Royal Society of London*](https://en.wikipedia.org/wiki/Philosophical_Transactions_of_the_Royal_Society_of_London)*.* ***95****: 316–330.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1098/rstl.1805.0024*](https://doi.org/10.1098%2Frstl.1805.0024)*.*

  *Garrett, Christine E.; Prasad, Kapa (2004). "The Art of Meeting Palladium Specifications in Active Pharmaceutical Ingredients Produced by Pd-Catalyzed Reactions". Advanced Synthesis & Catalysis.* ***346*** *(8): 889–900.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/adsc.200404071*](https://doi.org/10.1002%2Fadsc.200404071)*.*

  *Kielhorn, Janet; Melber, Christine; Keller, Detlef; Mangelsdorf, Inge (2002). "Palladium – A review of exposure and effects to human health". International Journal of Hygiene and Environmental Health.* ***205*** *(6): 417–32.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1078/1438-4639-00180*](https://doi.org/10.1078%2F1438-4639-00180)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*12455264*](https://www.ncbi.nlm.nih.gov/pubmed/12455264)*.*

  *Williamson, Alan.* [*"Russian PGM Stocks"*](http://www.lbma.org.uk/assets/5d_Williamson_lbmaconf2003.pdf) *(PDF). The LBMA Precious Metals Conference 2003. The London Bullion Market Association. Retrieved 2 October 2010.*

  [*"Historical Palladium Prices and Price Chart"*](http://www.infomine.com/investment/metal-prices/palladium/all/)*. InvestmentMine. Retrieved 2015-01-27.*

  [*"Ford fears first loss in a decade"*](http://news.bbc.co.uk/1/hi/business/1763406.stm)*. BBC News. 16 January 2002. Retrieved 19 September 2008.*

  [*"Platinum-Group Metals"*](http://minerals.usgs.gov/minerals/pubs/commodity/platinum/platimcs07.pdf) *(PDF). Mineral Commodity Summaries.* [*United States Geological Survey*](https://en.wikipedia.org/wiki/United_States_Geological_Survey)*. January 2007.*

  *Nat Rudarakanchana (2014-03-27).* [*"Palladium Fund Launches In South Africa, As Russian Supply Fears Warm Prices"*](http://www.ibtimes.com/palladium-fund-launches-south-africa-russian-supply-fears-warm-prices-1563708)*. International Business Times.*

  *Rosenfeld, Everett (2014-08-20).* [*"The other commodity that's leaping on Ukraine war"*](https://www.cnbc.com/2014/08/20/palladium-prices-russia-conflict-pushes-price-for-commodity-higher.html)*. CNBC. Retrieved 2018-01-29.*

  [*"Palladium Rally Is About More Than Just Autos"*](https://www.bloomberg.com/view/articles/2017-08-30/palladium-rally-is-about-more-than-just-autos)*. Bloomberg.com. 2017-08-30. Retrieved 2018-01-29.*

  [*"Don't Expect Palladium Prices To Plunge | OilPrice.com"*](https://oilprice.com/Metals/Commodities/Dont-Expect-Palladium-Prices-to-Plunge.html)*. OilPrice.com. Retrieved 2018-01-29.*

  [*"USGS Minerals Information: Mineral Commodity Summaries"*](https://minerals.usgs.gov/minerals/pubs/mcs/)*. minerals.usgs.gov. Retrieved 2018-01-29.*

  [*"«Norilsk Nickel» Group announces preliminary consolidated production results for 4 th quarter and full 2016, and production outl"*](https://www.nornickel.com/news-and-media/press-releases-and-news/norilsk-nickel-group-announces-preliminary-consolidated-production-results-for-4-th-quarter-and-full-2016-and-production-outlook-for-2017/?sphrase_id=316142)*. Nornickel. Retrieved 2018-01-29.*

  [*"Platinum-Group Metals"*](http://minerals.usgs.gov/minerals/pubs/commodity/platinum/myb1-2007-plati.pdf) *(PDF). Mineral Yearbook 2007.* [*United States Geological Survey*](https://en.wikipedia.org/wiki/United_States_Geological_Survey)*. January 2007.*

  *Verryn, Sabine M. C.; Merkle, Roland K. W. (1994). "Compositional variation of cooperite, braggite, and vysotskite from the Bushveld Complex". Mineralogical Magazine.* ***58*** *(2): 223–234.* [*Bibcode*](https://en.wikipedia.org/wiki/Bibcode)*:*[*1994MinM...58..223V*](http://adsabs.harvard.edu/abs/1994MinM...58..223V)*.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1180/minmag.1994.058.391.05*](https://doi.org/10.1180%2Fminmag.1994.058.391.05)*.*

  *Genkin, A. D.; Evstigneeva, T. L. (1986). "Associations of platinum- group minerals of the Norilsk copper-nickel sulfide ores". Economic Geology.* ***8l*** *(5): 1203–1212.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.2113/gsecongeo.81.5.1203*](https://doi.org/10.2113%2Fgsecongeo.81.5.1203)*.*

  <http://www.mindat.org>

  *Kolarik, Zdenek; Renard, Edouard V. (2003).* [*"Recovery of Value Fission Platinoids from Spent Nuclear Fuel. Part I PART I: General Considerations and Basic Chemistry"*](http://www.platinummetalsreview.com/pdf/pmr-v47-i2-074-087.pdf) *(PDF). Platinum Metals Review.* ***47*** *(2): 74–87.*

  [*"Palladium"*](https://web.archive.org/web/20061206003556/http:/www.unctad.org/infocomm/anglais/palladium/uses.htm)*.* [*United Nations Conference on Trade and Development*](https://en.wikipedia.org/wiki/United_Nations_Conference_on_Trade_and_Development)*. Archived from* [*the original*](http://www.unctad.org/infocomm/anglais/palladium/uses.htm) *on 6 December 2006. Retrieved 5 February 2007.*

  *Rushforth, Roy (2004).* [*"Palladium in Restorative Dentistry: Superior Physical Properties make Palladium an Ideal Dental Metal"*](http://www.platinummetalsreview.com/article/48/1/30-31/)*. Platinum Metals Review.* ***48*** *(1).*

  *Hesse, Rayner W. (2007). "palladium".* [*Jewelry-making through history: an encyclopedia*](https://books.google.com/?id=DIWEi5Hg93gC&pg=PA146)*. Greenwood Publishing Group. p. 146.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-313-33507-5*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-313-33507-5)*.*

  *Toff, Nancy (1996).* [*The flute book: a complete guide for students and performers*](https://books.google.com/?id=pCSanDD4CtsC&pg=PA20)*. Oxford University Press. p. 20.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-19-510502-5*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-19-510502-5)*.*

  *Weithers, Timothy Martin (2006). "Precious Metals".* [*Foreign exchange: a practical guide to the FX markets*](https://books.google.com/books?id=2neeMTPKtEMC&pg=PA34)*. p. 34.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-471-73203-7*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-471-73203-7)*.*

  *Brown, William Henry; Foote, Christopher S; Iverson, Brent L (2009). "Catalytic reduction".* [*Organic chemistry*](https://books.google.com/books?id=mTHQB7MkUFsC&pg=PA270)*. Cengage Learning. p. 270.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-495-38857-9*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-495-38857-9)*.*

  *Tsuji, Jiro (2004).* [*Palladium reagents and catalysts: new perspectives for the 21st century*](https://books.google.com/?id=RDT0OUdlj0MC&pg=PA90)*. John Wiley and Sons. p. 90.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-470-85032-9*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-470-85032-9)*.*

  *Drahl, Carmen (2008). "Palladium's Hidden Talent". Chemical & Engineering News.* ***86*** *(35): 53–56.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/cen-v086n035.p053*](https://doi.org/10.1021%2Fcen-v086n035.p053)*.*

  *Miller, Miles A; Askevold, Bjorn; Mikula, Hannes; Kohler, Rainer H; Pirovich, David; Weissleder, Ralph (2017).* [*"Nano-palladium is a cellular catalyst for in vivo chemistry"*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5510178)*. Nature Communications.* ***8****: 15906.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1038/ncomms15906*](https://doi.org/10.1038%2Fncomms15906)*.* [*PMC*](https://en.wikipedia.org/wiki/PubMed_Central)[*5510178*](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5510178)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*28699627*](https://www.ncbi.nlm.nih.gov/pubmed/28699627)*.*

  *Zogbi, Dennis (3 February 2003).* [*"Shifting Supply and Demand for Palladium in MLCCs"*](http://www.ttiinc.com/object/ME_Zogbi_20030203.html)*. TTI, Inc.*

  *Mroczkowski, Robert S. (1998).* [*Electronic connector handbook: theory and applications*](https://books.google.com/books?id=XGkw8YR-uXsC&pg=SA3-PA30)*. McGraw-Hill Professional. pp. 3–.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-07-041401-3*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-07-041401-3)*.*

  *Harper, Charles A. (1997).* [*Passive electronic component handbook*](https://books.google.com/books?id=OtlKBAcFBQAC&pg=PA580)*. McGraw-Hill Professional. pp. 580–.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-07-026698-8*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-07-026698-8)*.*

  *Jollie, David (2007).* [*"Platinum 2007"*](https://web.archive.org/web/20080216100834/http:/www.platinum.matthey.com/uploaded_files/2007/07_palladium.pdf) *(PDF).* [*Johnson Matthey*](https://en.wikipedia.org/wiki/Johnson_Matthey)*. Archived from* [*the original*](http://www.platinum.matthey.com/uploaded_files/2007/07_palladium.pdf) *(PDF) on 2008-02-16.*

  *Shu, J.; Grandjean, B. P. A.; Neste, A. Van; Kaliaguine, S. (1991). "Catalytic palladium-based membrane reactors: A review". The Canadian Journal of Chemical Engineering.* ***69*** *(5): 1036.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1002/cjce.5450690503*](https://doi.org/10.1002%2Fcjce.5450690503)*.*

  *Allen, T. H.; Root, W. S. (1955).* [*"An improved palladium chloride method for the determination of carbon monoxide in blood"*](http://www.jbc.org/content/216/1/319.short)*. The Journal of Biological Chemistry.* ***216*** *(1): 319–323.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*13252031*](https://www.ncbi.nlm.nih.gov/pubmed/13252031)*.*

  *Manchester, F. D.; San-Martin, A.; Pitre, J. M. (1994). "The H-Pd (hydrogen-palladium) System". Journal of Phase Equilibria.* ***15****: 62–83.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1007/BF02667685*](https://doi.org/10.1007%2FBF02667685)*.*

  [*Greenwood, Norman N.*](https://en.wikipedia.org/wiki/Norman_Greenwood)*; Earnshaw, Alan (1997). Chemistry of the Elements (2nd ed.).* [*Butterworth-Heinemann*](https://en.wikipedia.org/wiki/Butterworth-Heinemann)*. pp. 1150–151.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*0-08-037941-9*](https://en.wikipedia.org/wiki/Special:BookSources/0-08-037941-9)*.*

  *Grochala, Wojciech; Edwards, Peter P. (2004). "Thermal Decomposition of the Non-Interstitial Hydrides for the Storage and Production of Hydrogen". Chemical Reviews.* ***104*** *(3): 1283–316.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1021/cr030691s*](https://doi.org/10.1021%2Fcr030691s)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*15008624*](https://www.ncbi.nlm.nih.gov/pubmed/15008624)*.*

  Mott, N. F. and Jones, H. (1958) *The Theory of Properties of metals and alloys*. Oxford University Press. [ISBN](https://en.wikipedia.org/wiki/International_Standard_Book_Number) [0-486-60456-X](https://en.wikipedia.org/wiki/Special:BookSources/0-486-60456-X). p. 200

  *Colon, Pierre; Pradelle-Plasse, Nelly; Galland, Jacques (2003). "Evaluation of the long-term corrosion behavior of dental amalgams: influence of palladium addition and particle morphology". Dental Materials.* ***19*** *(3): 232–9.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1016/S0109-5641(02)00035-0*](https://doi.org/10.1016%2FS0109-5641%2802%2900035-0)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*12628436*](https://www.ncbi.nlm.nih.gov/pubmed/12628436)*.*

  *Gupta, Dinesh C.; Langer, Paul H.; ASTM Committee F-1 on Electronics (1987).* [*Emerging semiconductor technology: a symposium*](https://books.google.com/books?id=u-a9LvarW-8C&pg=PA273)*. ASTM International. pp. 273–.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-8031-0459-4*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-8031-0459-4)*.*

  *Hindsen, M.; Spiren, A.; Bruze, M. (2005). "Cross-reactivity between nickel and palladium demonstrated by systemic administration of nickel". Contact Dermatitis.* ***53*** *(1): 2–8.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1111/j.0105-1873.2005.00577.x*](https://doi.org/10.1111%2Fj.0105-1873.2005.00577.x)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*15982224*](https://www.ncbi.nlm.nih.gov/pubmed/15982224)*.*

  [*"Daily Metal Prices: September 2001"*](https://web.archive.org/web/20081029170752/http:/www.platinum.matthey.com/prices/September2001.php)*. Johnson Matthey. Archived from* [*the original*](http://www.platinum.matthey.com/prices/September2001.php) *on 29 October 2008.*

  *Holmes, E. (13 February 2007). "Palladium, Platinum's Cheaper Sister, Makes a Bid for Love".* [*Wall Street Journal*](https://en.wikipedia.org/wiki/Wall_Street_Journal) *(Eastern edition). pp. B.1.*

  [*"Platinum-Group Metals"*](http://minerals.usgs.gov/minerals/pubs/commodity/platinum/myb1-2009-plati.pdf) *(PDF). Mineral Yearbook 2009.* [*United States Geological Survey*](https://en.wikipedia.org/wiki/United_States_Geological_Survey)*. January 2007.*

  [*"Platinum-Group Metals"*](http://minerals.usgs.gov/minerals/pubs/commodity/platinum/myb1-2006-plati.pdf) *(PDF). Mineral Yearbook 2006.* [*United States Geological Survey*](https://en.wikipedia.org/wiki/United_States_Geological_Survey)*. January 2007.*

  *Ware, Mike (2005). "Book Review of : Photography in Platinum and Palladium". Platinum Metals Review.* ***49*** *(4): 190–195.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1595/147106705X70291*](https://doi.org/10.1595%2F147106705X70291)*.*

  <https://www.sigmaaldrich.com/MSDS/MSDS/DisplayMSDSPage.do?country=US&language=en&productNumber=373192&brand=ALDRICH&PageToGoToURL=https%3A%2F%2Fwww.sigmaaldrich.com%2Fcatalog%2Fproduct%2Faldrich%2F373192%3Flang%3Den>

  *Emsley, John (2011). Nature's Building Blocks: An A-Z Guide to the Elements. Oxford University Press. pp. 384, 387.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-0-19-960563-7*](https://en.wikipedia.org/wiki/Special:BookSources/978-0-19-960563-7)*.*

  *Zereini, Fathi; Alt, Friedrich (2006). "Health Risk Potential of Palladium".* [*Palladium emissions in the environment: analytical methods, environmental assessment and health effects*](https://books.google.com/?id=OnNZqylS_Z8C&pg=PA549)*. Springer Science & Business. pp. 549–563.* [*ISBN*](https://en.wikipedia.org/wiki/International_Standard_Book_Number)[*978-3-540-29219-7*](https://en.wikipedia.org/wiki/Special:BookSources/978-3-540-29219-7)*.*

  *Wataha, J. C.; Hanks, C. T. (1996). "Biological effects of palladium and risk of using palladium in dental casting alloys". Journal of Oral Rehabilitation.* ***23*** *(5): 309–20.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1111/j.1365-2842.1996.tb00858.x*](https://doi.org/10.1111%2Fj.1365-2842.1996.tb00858.x)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*8736443*](https://www.ncbi.nlm.nih.gov/pubmed/8736443)*.*

  *Aberer, Werner; Holub, Henriette; Strohal, Robert; Slavicek, Rudolf (1993). "Palladium in dental alloys – the dermatologists' responsibility to warn?". Contact Dermatitis.* ***28*** *(3): 163–5.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1111/j.1600-0536.1993.tb03379.x*](https://doi.org/10.1111%2Fj.1600-0536.1993.tb03379.x)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*8462294*](https://www.ncbi.nlm.nih.gov/pubmed/8462294)*.*

* 1.  *Wataha, John C.; Shor, Kavita (2010). "Palladium alloys for biomedical devices". Expert Review of Medical Devices.* ***7*** *(4): 489–501.* [*doi*](https://en.wikipedia.org/wiki/Digital_object_identifier)*:*[*10.1586/erd.10.25*](https://doi.org/10.1586%2Ferd.10.25)*.* [*PMID*](https://en.wikipedia.org/wiki/PubMed_Identifier)[*20583886*](https://www.ncbi.nlm.nih.gov/pubmed/20583886)*.*

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* [Special Market Report on Palladium and Precious Metals](http://www.twst.com/tt/info/info1677.htm)
* Wikisource *"*[*Palladium*](https://en.wikisource.org/wiki/1911_Encyclop%C3%A6dia_Britannica/Palladium_(chemistry))*".* [*Encyclopædia Britannica*](https://en.wikipedia.org/wiki/Encyclop%C3%A6dia_Britannica_Eleventh_Edition)*.* ***20*** *(11th ed.). 1911. pp. 636–637.*

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