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**Rhodium**

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| --- | --- |
| Rhodium,  45Rh | |
| [Rhodium powder pressed melted.jpg](https://en.wikipedia.org/wiki/File:Rhodium_powder_pressed_melted.jpg) | |
| **General properties** | |
| **Pronunciation** | [/ˈroʊdiəm/](https://en.wikipedia.org/wiki/Help:IPA/English) ​([*ROH-dee-əm*](https://en.wikipedia.org/wiki/Help:Pronunciation_respelling_key)) |
| **Appearance** | silvery white metallic |
| [**Standard atomic weight**](https://en.wikipedia.org/wiki/Standard_atomic_weight) **(*A*r, standard)** | 102.90549(2)[[1]](https://en.wikipedia.org/wiki/Rhodium#cite_note-CIAAW2016-1) |
| **Rhodium 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 | [Palladium](https://en.wikipedia.org/wiki/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) | | [Co](https://en.wikipedia.org/wiki/Cobalt) ↑ **Rh** ↓ [Ir](https://en.wikipedia.org/wiki/Iridium) | | [ruthenium](https://en.wikipedia.org/wiki/Ruthenium) ← **rhodium** → [palladium](https://en.wikipedia.org/wiki/Palladium) | | | | |
| [**Atomic number**](https://en.wikipedia.org/wiki/Atomic_number)(*Z*) | 45 |
| [**Group**](https://en.wikipedia.org/wiki/Group_(periodic_table)) | [group 9](https://en.wikipedia.org/wiki/Group_9_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)] 4d8 5s1 |
| Electrons per shell | 2, 8, 18, 16, 1 |
| **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) | 2237 [K](https://en.wikipedia.org/wiki/Kelvin) ​(1964 °C, ​3567 °F) |
| [**Boiling point**](https://en.wikipedia.org/wiki/Boiling_point) | 3968 K ​(3695 °C, ​6683 °F) |
| [**Density**](https://en.wikipedia.org/wiki/Density)(near r.t.) | 12.41 g/cm3 |
| when liquid (at m.p.) | 10.7 g/cm3 |
| [**Heat of fusion**](https://en.wikipedia.org/wiki/Enthalpy_of_fusion) | 26.59 [kJ/mol](https://en.wikipedia.org/wiki/Kilojoule_per_mole) |
| [**Heat of vaporization**](https://en.wikipedia.org/wiki/Enthalpy_of_vaporization) | 493 kJ/mol |
| [**Molar heat capacity**](https://en.wikipedia.org/wiki/Molar_heat_capacity) | 24.98 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) | 2288 | 2496 | 2749 | 3063 | 3405 | 3997 | | |
| **Atomic properties** | |
| [**Oxidation states**](https://en.wikipedia.org/wiki/Oxidation_state) | −3, −1, +1,[[2]](https://en.wikipedia.org/wiki/Rhodium#cite_note-2) +2, **+3**, +4, +5, +6 (an [amphoteric](https://en.wikipedia.org/wiki/Amphoterism) oxide) |
| [**Electronegativity**](https://en.wikipedia.org/wiki/Electronegativity) | Pauling scale: 2.28 |
| [**Ionization energies**](https://en.wikipedia.org/wiki/Ionization_energy) | * 1st: 719.7 kJ/mol * 2nd: 1740 kJ/mol * 3rd: 2997 kJ/mol |
| [**Atomic radius**](https://en.wikipedia.org/wiki/Atomic_radius) | empirical: 134 [pm](https://en.wikipedia.org/wiki/Picometre) |
| [**Covalent radius**](https://en.wikipedia.org/wiki/Covalent_radius) | 142±7 pm |
| [Color lines in a spectral range](https://en.wikipedia.org/wiki/File:Rhodium_spectrum_visible.png)  [**Spectral lines**](https://en.wikipedia.org/wiki/Spectral_line) **of rhodium** | |
| **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 rhodium](https://en.wikipedia.org/wiki/File:Cubic-face-centered.svg) |
| [**Speed of sound**](https://en.wikipedia.org/wiki/Speed_of_sound)thin rod | 4700 m/s (at 20 °C) |
| [**Thermal expansion**](https://en.wikipedia.org/wiki/Coefficient_of_thermal_expansion) | 8.2 µm/(m·K) (at 25 °C) |
| [**Thermal conductivity**](https://en.wikipedia.org/wiki/Thermal_conductivity) | 150 W/(m·K) |
| [**Electrical resistivity**](https://en.wikipedia.org/wiki/Electrical_resistivity_and_conductivity) | 43.3 nΩ·m (at 0 °C) |
| [**Magnetic ordering**](https://en.wikipedia.org/wiki/Magnetism) | [paramagnetic](https://en.wikipedia.org/wiki/Paramagnetic)[[3]](https://en.wikipedia.org/wiki/Rhodium#cite_note-3) |
| [**Magnetic susceptibility**](https://en.wikipedia.org/wiki/Magnetic_susceptibility) | +111.0·10−6 cm3/mol (298 K)[[4]](https://en.wikipedia.org/wiki/Rhodium#cite_note-4) |
| [**Young's modulus**](https://en.wikipedia.org/wiki/Young%27s_modulus) | 380 GPa |
| [**Shear modulus**](https://en.wikipedia.org/wiki/Shear_modulus) | 150 GPa |
| [**Bulk modulus**](https://en.wikipedia.org/wiki/Bulk_modulus) | 275 GPa |
| [**Poisson ratio**](https://en.wikipedia.org/wiki/Poisson%27s_ratio) | 0.26 |
| [**Mohs hardness**](https://en.wikipedia.org/wiki/Mohs_scale_of_mineral_hardness) | 6.0 |
| [**Vickers hardness**](https://en.wikipedia.org/wiki/Vickers_hardness_test) | 1100–8000 MPa |
| [**Brinell hardness**](https://en.wikipedia.org/wiki/Brinell_hardness_test) | 980–1350 MPa |
| [**CAS Number**](https://en.wikipedia.org/wiki/CAS_Registry_Number) | 7440-16-6 |
| **History** | |
| [**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) (1804) |
| **Main** [**isotopes of rhodium**](https://en.wikipedia.org/wiki/Isotopes_of_rhodium) | |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | | [**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) | | **99Rh** | [syn](https://en.wikipedia.org/wiki/Synthetic_radioisotope) | 16.1 d | [ε](https://en.wikipedia.org/wiki/Electron_capture) | [99Ru](https://en.wikipedia.org/wiki/Ruthenium-99) | | [γ](https://en.wikipedia.org/wiki/Gamma_ray) | – | | **101**[**m**](https://en.wikipedia.org/wiki/Nuclear_isomer)**Rh** | syn | 4.34 d | ε | [101Ru](https://en.wikipedia.org/wiki/Ruthenium-101) | | [IT](https://en.wikipedia.org/wiki/Internal_conversion) | [101Rh](https://en.wikipedia.org/wiki/Rhodium-101) | | γ | – | | **101Rh** | syn | 3.3 y | ε | 101Ru | | γ | – | | **102mRh** | syn | 3.7 y | ε | [102Ru](https://en.wikipedia.org/wiki/Ruthenium-102) | | γ | – | | **102Rh** | syn | 207 d | ε | 102Ru | | [β+](https://en.wikipedia.org/wiki/Positron_emission) | 102Ru | | [β−](https://en.wikipedia.org/wiki/Beta_decay) | [102Pd](https://en.wikipedia.org/wiki/Palladium-102) | | γ | – | | **103Rh** | 100% | [stable](https://en.wikipedia.org/wiki/Stable_isotope) | | | | **105Rh** | syn | 35.36 h | β− | [105Pd](https://en.wikipedia.org/wiki/Palladium-105) | | γ | – | | |
| * [view](https://en.wikipedia.org/wiki/Template:Infobox_rhodium) * [talk](https://en.wikipedia.org/wiki/Template_talk:Infobox_rhodium) * [edit](https://en.wikipedia.org/w/index.php?title=Template:Infobox_rhodium&action=edit)   | [references](https://en.wikipedia.org/wiki/List_of_data_references_for_chemical_elements) | |

**Rhodium** is a [chemical element](https://en.wikipedia.org/wiki/Chemical_element) with symbol **Rh** and [atomic number](https://en.wikipedia.org/wiki/Atomic_number) 45. It is a rare, silvery-white, hard, [corrosion-resistant](https://en.wikipedia.org/wiki/Corrosion) and chemically [inert](https://en.wikipedia.org/wiki/Chemically_inert) [transition metal](https://en.wikipedia.org/wiki/Transition_metal). It is a [noble metal](https://en.wikipedia.org/wiki/Noble_metal) and a member of the [platinum group](https://en.wikipedia.org/wiki/Platinum_group). It has only one naturally occurring [isotope](https://en.wikipedia.org/wiki/Isotope), 103Rh. Naturally occurring rhodium is usually found as the free metal, alloyed with similar metals, and rarely as a chemical compound in minerals such as [bowieite](https://en.wikipedia.org/wiki/Bowieite) and [rhodplumsite](https://en.wikipedia.org/wiki/Rhodplumsite). It is one of the rarest and most valuable [precious metals](https://en.wikipedia.org/wiki/Precious_metal).

Rhodium is found in platinum or nickel ores together with the other members of the [platinum group](https://en.wikipedia.org/wiki/Platinum_group) metals. It was [discovered](https://en.wikipedia.org/wiki/Discovery_of_the_chemical_elements) in 1803 by [William Hyde Wollaston](https://en.wikipedia.org/wiki/William_Hyde_Wollaston) in one such ore, and named for the rose color of one of its chlorine compounds, produced after it reacted with the powerful acid mixture [aqua regia](https://en.wikipedia.org/wiki/Aqua_regia).

The element's major use (approximately 80% of world rhodium production) is as one of the [catalysts](https://en.wikipedia.org/wiki/Catalyst) in the [three-way catalytic converters](https://en.wikipedia.org/wiki/Catalytic_converter#Three-way) in automobiles. Because rhodium metal is inert against corrosion and most aggressive chemicals, and because of its rarity, rhodium is usually [alloyed](https://en.wikipedia.org/wiki/Alloy) with [platinum](https://en.wikipedia.org/wiki/Platinum) or [palladium](https://en.wikipedia.org/wiki/Palladium) and applied in high-temperature and corrosion-resistive coatings. [White gold](https://en.wikipedia.org/wiki/Colored_gold#White_gold) is often plated with a thin rhodium layer to improve its appearance while [sterling silver](https://en.wikipedia.org/wiki/Sterling_silver) is often rhodium-plated for tarnish resistance.

Rhodium detectors are used in [nuclear reactors](https://en.wikipedia.org/wiki/Nuclear_reactor) to measure the [neutron flux level](https://en.wikipedia.org/wiki/Neutron_detection).



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**History**

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

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

Rhodium ([Greek](https://en.wikipedia.org/wiki/Greek_language) *rhodon* (ῥόδον) meaning "rose") was [discovered](https://en.wikipedia.org/wiki/Discovery_of_the_chemical_elements) in 1803 by [William Hyde Wollaston](https://en.wikipedia.org/wiki/William_Hyde_Wollaston),[[6]](https://en.wikipedia.org/wiki/Rhodium#cite_note-6) soon after his discovery of [palladium](https://en.wikipedia.org/wiki/Palladium).[[7]](https://en.wikipedia.org/wiki/Rhodium#cite_note-7)[[8]](https://en.wikipedia.org/wiki/Rhodium#cite_note-8)[[9]](https://en.wikipedia.org/wiki/Rhodium#cite_note-contr-9) He used crude [platinum](https://en.wikipedia.org/wiki/Platinum) ore presumably obtained from [South America](https://en.wikipedia.org/wiki/South_America).[[10]](https://en.wikipedia.org/wiki/Rhodium#cite_note-10) His procedure involved dissolving the ore in [aqua regia](https://en.wikipedia.org/wiki/Aqua_regia) and neutralizing the acid with [sodium hydroxide](https://en.wikipedia.org/wiki/Sodium_hydroxide) (NaOH). He then precipitated the platinum as [ammonium chloroplatinate](https://en.wikipedia.org/wiki/Ammonium_chloroplatinate) by adding [ammonium chloride](https://en.wikipedia.org/wiki/Ammonium_chloride) (NH  
4Cl). Most other metals like [copper](https://en.wikipedia.org/wiki/Copper), [lead](https://en.wikipedia.org/wiki/Lead), [palladium](https://en.wikipedia.org/wiki/Palladium) and rhodium were precipitated with [zinc](https://en.wikipedia.org/wiki/Zinc). Diluted [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid) dissolved all but palladium and rhodium. Of these, palladium dissolved in [aqua regia](https://en.wikipedia.org/wiki/Aqua_regia) but rhodium did not,[[11]](https://en.wikipedia.org/wiki/Rhodium#cite_note-11) and the rhodium was precipitated by the addition of [sodium chloride](https://en.wikipedia.org/wiki/Sodium_chloride) as Na  
3[RhCl  
6]·*n*H  
2O. After being washed with ethanol, the rose-red precipitate was reacted with zinc, which [displaced](https://en.wikipedia.org/wiki/Displacement_reaction) the rhodium in the ionic compound and thereby released the rhodium as free metal.[[12]](https://en.wikipedia.org/wiki/Rhodium#cite_note-griffith-12)

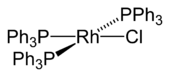
After the discovery, the rare element had only minor applications; for example, by the turn of the century, rhodium-containing thermocouples were used to measure temperatures up to 1800 °C.[[13]](https://en.wikipedia.org/wiki/Rhodium#cite_note-13)[[14]](https://en.wikipedia.org/wiki/Rhodium#cite_note-14) The first major application was electroplating for decorative uses and as corrosion-resistant coating.[[15]](https://en.wikipedia.org/wiki/Rhodium#cite_note-15) The introduction of the three-way [catalytic converter](https://en.wikipedia.org/wiki/Catalytic_converter) by [Volvo](https://en.wikipedia.org/wiki/Volvo) in 1976 increased the demand for rhodium. The previous catalytic converters used platinum or palladium, while the three-way catalytic converter used rhodium to reduce the amount of [NOx](https://en.wikipedia.org/wiki/NOx) in the exhaust.[[16]](https://en.wikipedia.org/wiki/Rhodium#cite_note-16)[[17]](https://en.wikipedia.org/wiki/Rhodium#cite_note-17)[[18]](https://en.wikipedia.org/wiki/Rhodium#cite_note-18)

**Characteristics**

|  |  |  |
| --- | --- | --- |
| [**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) |
| 27 | cobalt | 2, 8, 15, 2 |
| 45 | rhodium | 2, 8, 18, 16, 1 |
| 77 | iridium | 2, 8, 18, 32, 15, 2 |
| 109 | meitnerium | 2, 8, 18, 32, 32, 15, 2 (predicted) |

Rhodium is a hard, silvery, durable metal that has a high [reflectance](https://en.wikipedia.org/wiki/Reflectance). Rhodium metal does not normally form an [oxide](https://en.wikipedia.org/wiki/Oxide), even when heated.[[19]](https://en.wikipedia.org/wiki/Rhodium#cite_note-ASM13B-19) [Oxygen](https://en.wikipedia.org/wiki/Oxygen) is absorbed from the [atmosphere](https://en.wikipedia.org/wiki/Atmosphere) only at the [melting point](https://en.wikipedia.org/wiki/Melting_point) of rhodium, but is released on solidification.[[20]](https://en.wikipedia.org/wiki/Rhodium#cite_note-20) Rhodium has both a higher melting point and lower [density](https://en.wikipedia.org/wiki/Density) than [platinum](https://en.wikipedia.org/wiki/Platinum). It is not attacked by most [acids](https://en.wikipedia.org/wiki/Acid): it is completely insoluble in [nitric acid](https://en.wikipedia.org/wiki/Nitric_acid) and dissolves slightly in [aqua regia](https://en.wikipedia.org/wiki/Aqua_regia).

**Chemical properties**

[](https://en.wikipedia.org/wiki/File:Wilkinson%27s-catalyst-2D.png)

Wilkinson's catalyst

Rhodium belongs to [group 9](https://en.wikipedia.org/wiki/Group_9_element) of the periodic table, but the configuration of electrons in the outermost shells is atypical for the group. This anomaly is also observed in the neighboring elements, [niobium](https://en.wikipedia.org/wiki/Niobium) (41), [ruthenium](https://en.wikipedia.org/wiki/Ruthenium) (44), and [palladium](https://en.wikipedia.org/wiki/Palladium) (46).

|  |  |
| --- | --- |
| **Oxidation states of rhodium** | |
| +0 | Rh 4(CO) 12 |
| +1 | RhCl(PH 3) 2 |
| +2 | Rh 2(O 2CCH 3) 4 |
| **+3** | RhCl 3, Rh 2O 3 |
| +4 | RhF 4, RhO 2 |
| +5 | RhF 5, Sr 3LiRhO 6 |
| +6 | RhF 6 |

The common [oxidation state](https://en.wikipedia.org/wiki/Oxidation_state) of rhodium is +3, but oxidation states from +0 to +6 are also observed.[[21]](https://en.wikipedia.org/wiki/Rhodium#cite_note-Holl-21)

Unlike [ruthenium](https://en.wikipedia.org/wiki/Ruthenium) and [osmium](https://en.wikipedia.org/wiki/Osmium), rhodium forms no volatile oxygen compounds. The known stable oxides include [Rh  
2O  
3](https://en.wikipedia.org/wiki/Rhodium(III)_oxide), [RhO  
2](https://en.wikipedia.org/wiki/Rhodium(IV)_oxide), RhO  
2·*x*H  
2O, Na  
2RhO  
3, Sr  
3LiRhO  
6 and Sr  
3NaRhO  
6.[[22]](https://en.wikipedia.org/wiki/Rhodium#cite_note-22) Halogen compounds are known in nearly the full range of possible oxidation states. [Rhodium(III) chloride](https://en.wikipedia.org/wiki/Rhodium(III)_chloride), rhodium(IV) fluoride, rhodium(V) fluoride and [rhodium(VI) fluoride](https://en.wikipedia.org/wiki/Rhodium_hexafluoride) are examples. The lower oxidation states are stable only in the presence of ligands.[[23]](https://en.wikipedia.org/wiki/Rhodium#cite_note-23)

The best-known rhodium-halogen compound is the [Wilkinson's catalyst](https://en.wikipedia.org/wiki/Wilkinson%27s_catalyst) chlorotris(triphenylphosphine)rhodium(I). This catalyst is used in the [hydroformylation](https://en.wikipedia.org/wiki/Hydroformylation) or [hydrogenation](https://en.wikipedia.org/wiki/Hydrogenation) of [alkenes](https://en.wikipedia.org/wiki/Alkene).[[24]](https://en.wikipedia.org/wiki/Rhodium#cite_note-24)

**Isotopes**

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

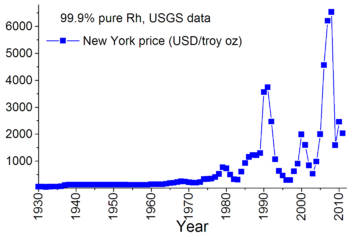
Naturally occurring rhodium is composed of only one [isotope](https://en.wikipedia.org/wiki/Isotope), 103Rh. The most stable [radioisotopes](https://en.wikipedia.org/wiki/Radioisotope) are 101Rh with a [half-life](https://en.wikipedia.org/wiki/Half-life) of 3.3 years, 102Rh with a [half-life](https://en.wikipedia.org/wiki/Half-life) of 207 days, 102mRh with a [half-life](https://en.wikipedia.org/wiki/Half-life) of 2.9 years, and 99Rh with a half-life of 16.1 days. Twenty other radioisotopes have been characterized with [atomic weights](https://en.wikipedia.org/wiki/Atomic_weight) ranging from 92.926 [u](https://en.wikipedia.org/wiki/Atomic_mass_unit) (93Rh) to 116.925 u (117Rh). Most of these have half-lives shorter than an hour, except 100Rh (20.8 hours) and 105Rh (35.36 hours). It has numerous [meta states](https://en.wikipedia.org/wiki/Meta_state), the most stable being 102mRh (0.141 MeV) with a half-life of about 2.9 years and 101mRh (0.157 MeV) with a half-life of 4.34 days (see [isotopes of rhodium](https://en.wikipedia.org/wiki/Isotopes_of_rhodium)).[[25]](https://en.wikipedia.org/wiki/Rhodium#cite_note-nubase-25)

In isotopes weighing less than 103 (the stable isotope), the primary [decay mode](https://en.wikipedia.org/wiki/Decay_mode) is [electron capture](https://en.wikipedia.org/wiki/Electron_capture) and the primary [decay product](https://en.wikipedia.org/wiki/Decay_product) is [ruthenium](https://en.wikipedia.org/wiki/Ruthenium) In isotopes greater than 103, the primary decay mode is [beta emission](https://en.wikipedia.org/wiki/Beta_emission) and the primary product is [palladium](https://en.wikipedia.org/wiki/Palladium).[[26]](https://en.wikipedia.org/wiki/Rhodium#cite_note-26)

**Occurrence**

Rhodium is one of the [rarest elements in the Earth's crust](https://en.wikipedia.org/wiki/Abundance_of_elements_in_Earth%27s_crust), comprising an estimated 0.0002 [parts per million](https://en.wikipedia.org/wiki/Parts-per_notation) (2 × 10−10).[[27]](https://en.wikipedia.org/wiki/Rhodium#cite_note-27) Its rarity affects its price and its use in commercial applications.

**Mining and price**

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

Rh price evolution

The industrial extraction of rhodium is complex because the ores are mixed with other metals such as [palladium](https://en.wikipedia.org/wiki/Palladium), [silver](https://en.wikipedia.org/wiki/Silver), [platinum](https://en.wikipedia.org/wiki/Platinum), and [gold](https://en.wikipedia.org/wiki/Gold) and there are very few rhodium-bearing [minerals](https://en.wikipedia.org/wiki/Mineral). It is found in platinum ores and extracted as a white inert metal that is difficult to fuse. Principal sources are located in South Africa; in river sands of the [Ural Mountains](https://en.wikipedia.org/wiki/Ural_Mountains); and in North America, including the [copper](https://en.wikipedia.org/wiki/Copper)-[nickel sulfide](https://en.wikipedia.org/wiki/Nickel_sulfide) mining area of the [Sudbury](https://en.wikipedia.org/wiki/Greater_Sudbury), [Ontario](https://en.wikipedia.org/wiki/Ontario), region. Although the quantity at Sudbury is very small, the large amount of processed nickel ore makes rhodium recovery cost-effective.

The main exporter of rhodium is South Africa (approximately 80% in 2010) followed by Russia.[[28]](https://en.wikipedia.org/wiki/Rhodium#cite_note-USGSYB08-28) The annual world production is 30 [tonnes](https://en.wikipedia.org/wiki/Tonne). The price of rhodium is highly variable. In 2007, rhodium cost approximately eight times more than gold, 450 times more than silver, and 27,250 times more than copper by weight. In 2008, the price briefly rose above $10,000 per ounce ($350,000 per kilogram). The economic slowdown of the 3rd quarter of 2008 pushed rhodium prices sharply back below $1,000 per ounce ($35,000 per kilogram); the price rebounded to $2,750 by early 2010 ($97,000 per kilogram) (more than twice the gold price), but in late 2013, the prices were less than $1000.

Political and financial problems[[*clarification needed*](https://en.wikipedia.org/wiki/Wikipedia:Please_clarify)] led to very low oil prices and oversupply, causing most metals to drop in price. The economies of China, India and other emerging countries slowed in 2014 and 2015. In 2014 alone, 23,722,890 motor vehicles were produced in China, excluding motorbikes.[[*clarification needed*](https://en.wikipedia.org/wiki/Wikipedia:Please_clarify)] This resulted in a rhodium price of 740.00 US-$ per [Troy ounce](https://en.wikipedia.org/wiki/Troy_ounce) (31.1 grams) in late November 2015.[[29]](https://en.wikipedia.org/wiki/Rhodium#cite_note-29)

**Used nuclear fuels**

Main article: [Synthesis of precious metals](https://en.wikipedia.org/wiki/Synthesis_of_precious_metals)

Rhodium is a fission product of [uranium-235](https://en.wikipedia.org/wiki/Uranium-235): each kilogram of fission product contains a significant amount of the lighter platinum group metals. [Used nuclear fuel](https://en.wikipedia.org/wiki/Used_nuclear_fuel) is therefore a potential source of rhodium, but the extraction is complex and expensive, and the presence of rhodium radioisotopes requires a period of cooling storage for multiple half-lives of the longest-lived isotope (about 10 years). These factors make the source unattractive and no large-scale extraction has been attempted.[[30]](https://en.wikipedia.org/wiki/Rhodium#cite_note-30)[[31]](https://en.wikipedia.org/wiki/Rhodium#cite_note-31)[[32]](https://en.wikipedia.org/wiki/Rhodium#cite_note-32)

**Applications**

The primary use of this element is in automobiles as a [catalytic converter](https://en.wikipedia.org/wiki/Catalytic_converter), changing harmful unburned hydrocarbons, carbon monoxide, and nitrogen oxide exhaust emissions into less noxious gases. Of 30,000 kg of rhodium consumed worldwide in 2012, 81% (24,300 kg) went into this application, and 8,060 kg was recovered from old converters. About 964 kg of rhodium was used in the glass industry, mostly for production of fiberglass and flat-panel glass, and 2,520 kg was used in the chemical industry.[[28]](https://en.wikipedia.org/wiki/Rhodium#cite_note-USGSYB08-28)

**Catalyst**

Rhodium is preferable to the other platinum metals in the [reduction](https://en.wikipedia.org/wiki/Redox) of [nitrogen oxides](https://en.wikipedia.org/wiki/Nitrogen_oxides) to [nitrogen](https://en.wikipedia.org/wiki/Nitrogen) and [oxygen](https://en.wikipedia.org/wiki/Oxygen):[[33]](https://en.wikipedia.org/wiki/Rhodium#cite_note-Whyrhodium-33)

2 NO  
*x* → *x* O  
2 + N  
2

Rhodium [catalysts](https://en.wikipedia.org/wiki/Catalyst) are used in a number of industrial processes, notably in catalytic carbonylation of [methanol](https://en.wikipedia.org/wiki/Methanol) to produce [acetic acid](https://en.wikipedia.org/wiki/Acetic_acid) by the [Monsanto process](https://en.wikipedia.org/wiki/Monsanto_process).[[34]](https://en.wikipedia.org/wiki/Rhodium#cite_note-34) It is also used to catalyze addition of hydrosilanes to molecular [double bonds](https://en.wikipedia.org/wiki/Double_bond), a process important in manufacture of certain silicone rubbers.[[35]](https://en.wikipedia.org/wiki/Rhodium#cite_note-35) Rhodium catalysts are also used to reduce [benzene](https://en.wikipedia.org/wiki/Benzene) to [cyclohexane](https://en.wikipedia.org/wiki/Cyclohexane).[[36]](https://en.wikipedia.org/wiki/Rhodium#cite_note-36)

The complex of a rhodium ion with [BINAP](https://en.wikipedia.org/wiki/BINAP) is a widely used chiral catalyst for [chiral synthesis](https://en.wikipedia.org/wiki/Chiral_synthesis), as in the synthesis of [menthol](https://en.wikipedia.org/wiki/Menthol).[[37]](https://en.wikipedia.org/wiki/Rhodium#cite_note-37)

**Ornamental uses**

Rhodium finds use in [jewelry](https://en.wikipedia.org/wiki/Jewelry) and for decorations. It is [electroplated](https://en.wikipedia.org/wiki/Electroplated) on [white gold](https://en.wikipedia.org/wiki/White_gold) and platinum to give it a reflective white surface at time of sale, after which the thin layer wears away with use. This is known as rhodium flashing in the jewelry business. It may also be used in coating [sterling silver](https://en.wikipedia.org/wiki/Sterling_silver) to protect against tarnish ([silver sulfide](https://en.wikipedia.org/wiki/Silver_sulfide), Ag2S, produced from atmospheric hydrogen sulfide, H2S). Solid (pure) rhodium jewelry is very rare, more because of the difficulty of fabrication (high melting point and poor malleability) than because of the high price.[[38]](https://en.wikipedia.org/wiki/Rhodium#cite_note-38) The high cost ensures that rhodium is applied only as an [electroplate](https://en.wikipedia.org/wiki/Electroplating).

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

Rhodium is rarely seen as jewelry in its pure, solid form. This ring was made by the photographer for his own use as a wedding band from solid, unalloyed .999 rhodium.

Rhodium has also been used for honors or to signify elite status, when more commonly used metals such as silver, gold or platinum were deemed insufficient. In 1979 the [*Guinness Book of World Records*](https://en.wikipedia.org/wiki/Guinness_Book_of_World_Records) gave [Paul McCartney](https://en.wikipedia.org/wiki/Paul_McCartney) a rhodium-plated disc for being history's all-time best-selling songwriter and recording artist.[[39]](https://en.wikipedia.org/wiki/Rhodium#cite_note-39)

**Other uses**

Rhodium is used as an alloying agent for hardening and improving the corrosion resistance[[19]](https://en.wikipedia.org/wiki/Rhodium#cite_note-ASM13B-19) of [platinum](https://en.wikipedia.org/wiki/Platinum) and [palladium](https://en.wikipedia.org/wiki/Palladium). These alloys are used in furnace windings, bushings for glass fiber production, [thermocouple](https://en.wikipedia.org/wiki/Thermocouple) elements, [electrodes](https://en.wikipedia.org/wiki/Electrode) for aircraft [spark plugs](https://en.wikipedia.org/wiki/Spark_plug), and laboratory crucibles.[[40]](https://en.wikipedia.org/wiki/Rhodium#cite_note-40) Other uses include:

* [Electrical contacts](https://en.wikipedia.org/wiki/Switch#Contacts), where it is valued for small [electrical resistance](https://en.wikipedia.org/wiki/Electrical_resistance), small and stable [contact resistance](https://en.wikipedia.org/wiki/Contact_resistance), and great [corrosion](https://en.wikipedia.org/wiki/Corrosion) resistance.[[41]](https://en.wikipedia.org/wiki/Rhodium#cite_note-41)
* Rhodium plated by either [electroplating](https://en.wikipedia.org/wiki/Electroplating) or evaporation is extremely hard and useful for optical instruments.[[42]](https://en.wikipedia.org/wiki/Rhodium#cite_note-42)
* Filters in [mammography](https://en.wikipedia.org/wiki/Mammography) systems for the characteristic X-rays it produces.[[43]](https://en.wikipedia.org/wiki/Rhodium#cite_note-43)
* Rhodium neutron detectors are used in [combustion engineering](https://en.wikipedia.org/w/index.php?title=Combustion_engineering&action=edit&redlink=1) nuclear reactors to measure neutron flux levels – this method requires a digital filter to determine the current neutron flux level, generating three separate signals: immediate, a few seconds delay, and a minute delay, each with its own signal level; all three are combined in the rhodium detector signal. The three [Palo Verde](https://en.wikipedia.org/wiki/Palo_Verde_Nuclear_Generating_Station) nuclear reactors each have 305 rhodium neutron detectors, 61 detectors on each of five vertical levels, providing an accurate 3D "picture" of reactivity and allowing fine tuning to consume the nuclear fuel most economically.[[44]](https://en.wikipedia.org/wiki/Rhodium#cite_note-44)
* [](https://en.wikipedia.org/wiki/File:Rhodium_78g_sample.jpg)

A 78 g sample of rhodium

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

Cut-away of a metal-core catalytic converter

* [](https://en.wikipedia.org/wiki/File:White-gold--rhodium-plated.jpg)

Rhodium-plated white gold wedding ring

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

Rhodium foil and wire

**Precautions**

|  |  |
| --- | --- |
| Rhodium | |
| **Hazards** | |
| [GHS pictograms](https://en.wikipedia.org/wiki/GHS_hazard_pictograms) | None |
| [GHS hazard statements](https://en.wikipedia.org/wiki/GHS_hazard_statement) | H413 |
| [GHS precautionary statements](https://en.wikipedia.org/wiki/GHS_precautionary_statements) | P273, P501[[45]](https://en.wikipedia.org/wiki/Rhodium#cite_note-45) |
| [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) |

Being a [noble metal](https://en.wikipedia.org/wiki/Noble_metal), pure rhodium is inert. However, chemical complexes of rhodium can be reactive. [Median lethal dose](https://en.wikipedia.org/wiki/Median_lethal_dose) (LD50) for rats is 198 mg of rhodium chloride (RhCl  
3) per kilogram of body weight.[[46]](https://en.wikipedia.org/wiki/Rhodium#cite_note-46) Like the other noble metals, all of which are too inert to occur as chemical compounds in nature, rhodium has not been found to serve any biological function. In elemental form, the metal is harmless.[[47]](https://en.wikipedia.org/wiki/Rhodium#cite_note-47)

People can be exposed to rhodium in the workplace by inhalation. The [Occupational Safety and Health Administration](https://en.wikipedia.org/wiki/Occupational_Safety_and_Health_Administration) (OSHA) has specified the legal limit ([Permissible exposure limit](https://en.wikipedia.org/wiki/Permissible_exposure_limit)) for rhodium exposure in the workplace at 0.1 mg/m3 over an 8-hour workday, and the [National Institute for Occupational Safety and Health](https://en.wikipedia.org/wiki/National_Institute_for_Occupational_Safety_and_Health) (NIOSH) has set the [recommended exposure limit](https://en.wikipedia.org/wiki/Recommended_exposure_limit) (REL), at the same level. At levels of 100 mg/m3, rhodium is [immediately dangerous to life or health](https://en.wikipedia.org/wiki/Immediately_dangerous_to_life_or_health).[[48]](https://en.wikipedia.org/wiki/Rhodium#cite_note-48) For soluble compounds, the PEL and REL are both 0.001 mg/m3.[[49]](https://en.wikipedia.org/wiki/Rhodium#cite_note-49)

**See also**

* [Rhodium compounds](https://en.wikipedia.org/wiki/Category:Rhodium_compounds)
* [2000s commodities boom](https://en.wikipedia.org/wiki/2000s_commodities_boom)

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