

# Praseodymium

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**Praseodymium** is a chemical element with symbol **Pr** and atomic number 59. Praseodymium is a soft, silvery, malleable and ductile metal in the lanthanide group. It is valued for its magnetic, electrical, chemical, and optical properties.<sup>[4]</sup> It is too reactive to be found in native form, and when artificially prepared, it slowly develops a green oxide coating.

The element was named for the color of its primary oxide. In 1841, Swedish chemist Carl Gustav Mosander extracted a rare earth oxide residue he called "didymium" from a residue he called "lanthana", in turn separated from cerium salts. In 1885, the Austrian chemist Baron Carl Auer von Welsbach separated didymium into two salts of different colors, which he named praseodymium and neodymium. The name praseodymium comes from the Greek *prasinós* (πράσινος), meaning "green", and *didymos* (δίδυμος), "twin".

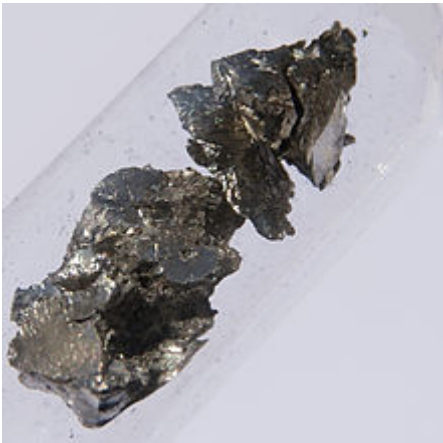
Like most rare earth elements, praseodymium most readily forms trivalent Pr(III) ions. These are yellow-green in water solution, and various shades of yellow-green when incorporated into glasses. Many of praseodymium's industrial uses involve its use to filter yellow light from light sources.

## Characteristics

### Physical properties

Praseodymium is a soft, silvery, malleable, and ductile metal in the lanthanide group. It is somewhat more resistant to corrosion in air than europium, lanthanum, cerium, or neodymium, but it does develop a green oxide coating that spalls off when exposed to air, exposing more metal to oxidation—a centimeter-sized sample of Pr completely oxidizes within a year.<sup>[5]</sup> For this reason, praseodymium is usually stored under a light mineral oil or sealed in glass.

### Praseodymium, <sup>59</sup>Pr



#### General properties

<b>Name, symbol</b>	praseodymium, Pr
<b>Appearance</b>	grayish white

#### Praseodymium in the periodic table

<b>Atomic number</b> ( <i>Z</i> )	59
<b>Group, block</b>	group n/a, f-block
<b>Period</b>	period 6
<b>Element category</b>	<span>☐</span> lanthanide
<b>Standard atomic weight</b> ( <span>±</span> ) ( <i>A</i> <sub>r</sub> )	140.90766(2) <sup>[2]</sup>
<b>Electron configuration</b>	[Xe] 4f <sup>3</sup> 6s <sup>2</sup>
per shell	2, 8, 18, 21, 8, 2

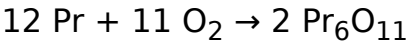
#### Physical properties

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

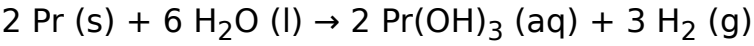
Unlike other rare-earth metals, which show antiferromagnetic or/and ferromagnetic ordering at low temperatures, Pr is paramagnetic at any temperature above 1 K.<sup>[3]</sup>

### Chemical properties

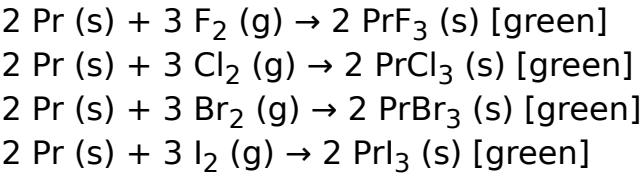
Praseodymium metal tarnishes slowly in air and burns readily at 150 °C to form praseodymium(III,IV) oxide:



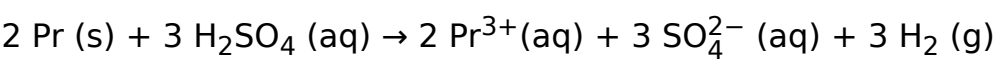
Praseodymium is quite electropositive and reacts slowly with cold water and quite quickly with hot water to form praseodymium (III) hydroxide:



Praseodymium metal reacts with all the halogens:



Praseodymium dissolves readily in dilute sulfuric acid to form solutions containing green Pr(III) ions, which exist as a  $[\text{Pr(OH}_2)_9]^{3+}$  complexes.<sup>[6]</sup>



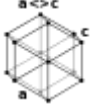
### Compounds

In its compounds, praseodymium occurs in oxidation states +2, +3, +4, and uniquely among the lanthanides, +5. Praseodymium(IV) is a strong oxidant, instantly oxidizing water to elemental oxygen (O<sub>2</sub>), or hydrochloric acid to elemental chlorine (Cl<sub>2</sub>). Thus, in aqueous solution, only the +3 oxidation state is encountered. Praseodymium(III) salts are yellow-green and, in solution, present a fairly simple absorption spectrum in the visible region, with a band in the yellow-

	1208 K (935 °C, 1715 °F)
<b>Boiling point</b>	3403 K (3130 °C, 5666 °F)
<b>Density</b> near r.t.	6.77 g/cm <sup>3</sup>
when liquid, at m.p.	6.50 g/cm <sup>3</sup>
<b>Heat of fusion</b>	6.89 kJ/mol
<b>Heat of vaporization</b>	331 kJ/mol
<b>Molar heat capacity</b>	27.20 J/(mol·K)

Vapor pressure						
P (Pa)	1	10	100	1 k	10 k	100 k
at T (K)	1771	1973	(2227)	(2571)	(3054)	(3779)

Atomic properties	
<b>Oxidation states</b>	5, 4, <b>3</b> , 2 (a mildly basic oxide)
<b>Electronegativity</b>	Pauling scale: 1.13
<b>Ionization energies</b>	1st: 527 kJ/mol 2nd: 1020 kJ/mol 3rd: 2086 kJ/mol
<b>Atomic radius</b>	empirical: 182 pm
<b>Covalent radius</b>	203±7 pm

Miscellanea	
<b>Crystal structure</b>	double hexagonal close-packed (dhcp) 

<b>Speed of sound</b> thin rod	2280 m/s (at 20 °C)
<b>Thermal expansion</b>	α, poly: 6.7 μm/(m·K) (at r.t.)
<b>Thermal conductivity</b>	12.5 W/(m·K)

orange at 589–590 nm (which coincides with the sodium emission doublet), and three bands in the blue/violet region, at 444, 468, and 482 nm, approximately. These positions vary slightly with the counter-ion. Praseodymium oxide, as obtained by the ignition of salts such as the oxalate or carbonate in air, is essentially black in color (with a hint of brown or green) and contains +3 and +4 praseodymium in a somewhat variable ratio, depending upon the conditions of formation. Its formula is conventionally rendered as Pr<sub>6</sub>O<sub>11</sub>. Although praseodymium(V) in the bulk state is unknown, the existence of praseodymium in its +5 oxidation state (corresponding to the [Xe]4f<sup>0</sup>5d<sup>0</sup> configuration) under noble-gas matrix isolation conditions was reported in 2016. The species assigned to the +5 state were identified as [PrO<sub>2</sub>]<sup>+</sup>, its O<sub>2</sub> and Ar adducts, and PrO<sub>2</sub>(η<sup>2</sup>-O<sub>2</sub>).<sup>[7]</sup>

Other praseodymium compounds include:

- Fluorides: PrF<sub>2</sub>, PrF<sub>3</sub>, PrF<sub>4</sub>
- Chlorides: PrCl<sub>3</sub>
- Bromides: PrBr<sub>3</sub>, Pr<sub>2</sub>Br<sub>5</sub>
- Iodides: PrI<sub>2</sub>, PrI<sub>3</sub>, Pr<sub>2</sub>I<sub>5</sub>
- Oxides: PrO<sub>2</sub>, Pr<sub>2</sub>O<sub>3</sub>, Pr<sub>6</sub>O<sub>11</sub>
- Sulfides: PrS, Pr<sub>2</sub>S<sub>3</sub>
- Sulfates: Pr<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub>
- Selenides: PrSe
- Tellurides: PrTe, Pr<sub>2</sub>Te<sub>3</sub>
- Nitrides: PrN
- Carbonates: Pr<sub>2</sub>(CO<sub>3</sub>)<sub>3</sub><sup>[8]</sup>

## Isotopes

Naturally occurring praseodymium is composed of one stable isotope, praseodymium-141,<sup>[9]</sup> which is of use in NMR and EPR spectroscopy.<sup>[10]</sup> 38 radioisotopes have been characterized, with the most stable being praseodymium-143 with a half-life of 13.57 days and praseodymium-142 with a half-life of 19.12 hours.<sup>[9]</sup> All of the remaining radioactive isotopes have half-lives that are less than six hours, and the majority of these have half lives that are less than 10 minutes.<sup>[9]</sup> This element also has 15

Electrical resistivity

α, poly: 0.700 μΩ·m (at r.t.)

Magnetic ordering

paramagnetic<sup>[3]</sup>

Young's modulus

α form: 37.3 GPa

Shear modulus

α form: 14.8 GPa

Bulk modulus

α form: 28.8 GPa

Poisson ratio

α form: 0.281

Vickers hardness

250–745 MPa

Brinell hardness

250–640 MPa

CAS Number

7440-10-0

History

Discovery

Carl Auer von Welsbach (1885)

Most stable isotopes of praseodymium

iso	NA	half-life	DM	DE (MeV)	DP
<b>141Pr</b>	100%	is stable with 82 neutrons			
<b>142Pr</b>	syn	19.12 h	β <sup>−</sup>	2.162	<sup>142</sup> Nd
			ε	0.745	<sup>142</sup> Ce
<b>143Pr</b>	syn	13.57 d	β <sup>−</sup>	0.934	<sup>143</sup> Nd

nuclear isomers, with the longest-lived being praseodymium-138m, praseodymium-134m, and praseodymium-142m.<sup>[9]</sup> The nuclei of nuclear isomers exist in a delicate equilibrium or metastability due to at least one nucleon having an excited energy state.

The isotopes of praseodymium range in mass number from 121 to 159.<sup>[9]</sup> The most common decay mode of 20 isotopes with mass numbers lower than the most abundant stable isotope, praseodymium-141 is  $\beta^+$  decay, primarily forming cerium isotopes (58 protons) as decay products.<sup>[9]</sup> The most common decay mode for 18 isotopes with mass numbers higher than praseodymium-141 is  $\beta^-$  decay, primarily forming neodymium isotopes (60 protons) as decay products.<sup>[9]</sup>

## Source

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