

# Titanium

**Titanium (Ti)**, chemical element, a silvery gray metal of Group 4 (IVb) of the periodic table. Titanium is a lightweight, high-strength, low-corrosion structural metal and is used in alloy form for parts in high-speed aircraft. A compound of titanium and oxygen was discovered (1791) by the English chemist and mineralogist William Gregor and independently rediscovered (1795) and named by the German chemist Martin Heinrich Klaproth.

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Titanium	
atomic number	22
symbol	Ti
electron configuration	[Ar]3d <sup>2</sup> 4s <sup>2</sup>
name	titanium
atomic weight	47.867
acid-base properties of higher-valence oxides	●
crystal structure	⬡
physical state at 20 °C (68 °F)	—

Transition metals	Solid
Hexagonal	Equal relative strength

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## Element Properties

<b>atomic number</b>	22
<b>atomic weight</b>	47.88
<b>melting point</b>	1,660 °C (3,020 °F)
<b>boiling point</b>	3,287 °C (5,949 °F)
<b>density</b>	4.5 g/cm <sup>3</sup> (20 °C)
<b>oxidation states</b>	+2, +3, +4
<b>electron configuration</b>	[Ar]3d <sup>2</sup> 4s <sup>2</sup>

## Occurrence, properties, and uses

Titanium is widely distributed and constitutes 0.44 percent of the Earth's crust. The metal is found combined in practically all rocks, sand, clay, and other soils. It is also present in plants and animals, natural waters and deep-sea dredgings, and meteorites and stars. The two prime commercial minerals are ilmenite and rutile. The metal was isolated in pure form (1910) by the metallurgist Matthew A. Hunter by reducing titanium tetrachloride (TiCl<sub>4</sub>) with sodium in an airtight steel cylinder.



titanium metal

The preparation of pure titanium is difficult because of its reactivity. Titanium cannot be obtained by the common method of reducing the oxide with carbon because a very stable carbide is readily produced, and, moreover, the metal is quite reactive toward oxygen and nitrogen at elevated temperatures. Therefore, special processes have been devised that, after 1950, changed titanium from a laboratory curiosity to an important commercially produced structural metal. In the Kroll

High-purity (99.999 percent) titanium metal.

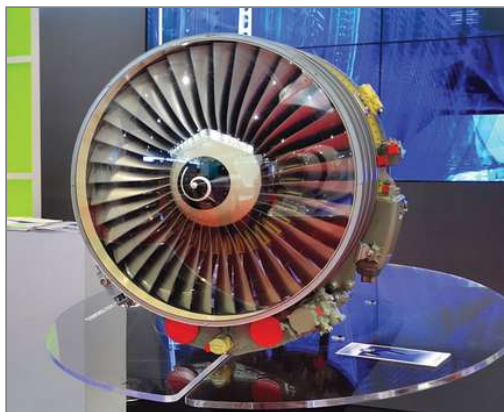
*Alexander C. Wimmer*

process, one of the ores, such as ilmenite ( $\text{FeTiO}_3$ ) or rutile ( $\text{TiO}_2$ ), is treated at red heat with carbon and chlorine to yield titanium tetrachloride,  $\text{TiCl}_4$ , which is fractionally distilled to eliminate impurities such as ferric chloride,  $\text{FeCl}_3$ . The  $\text{TiCl}_4$  is then reduced with molten magnesium at about 800 °C (1,500 °F) in an atmosphere of argon, and metallic titanium is produced as a spongy mass from which the excess of magnesium and magnesium chloride can be removed by volatilization at about 1,000 °C (1,800 °F). The sponge may then be fused in an atmosphere of argon or helium in an electric arc and be cast into ingots. On the laboratory scale, extremely pure titanium can be made by vaporizing the tetraiodide,  $\text{TiI}_4$ , in very pure form and decomposing it on a hot wire in vacuum. (For treatment of the mining, recovery, and refining of titanium, see titanium processing. For comparative statistical data on titanium production, see mining.)

Pure titanium is ductile, about half as dense as iron and less than twice as dense as aluminum; it can be polished to a high lustre. The metal has a very low electrical and thermal conductivity and is paramagnetic (weakly attracted to a magnet). Two crystal structures exist: below 883 °C (1,621 °F), hexagonal close-packed (alpha); above 883 °C, body-centred cubic (beta). Natural titanium consists of five stable isotopes: titanium-46 (8.0 percent), titanium-47 (7.3 percent), titanium-48 (73.8 percent), titanium-49 (5.5 percent), and titanium-50 (5.4 percent).

Titanium is important as an alloying agent with most metals and some nonmetals. Some of these alloys have much higher tensile strengths than does titanium itself. Titanium has excellent corrosion-resistance in many environments because of the formation of a passive oxide surface film. No noticeable corrosion of the metal occurs despite exposure to seawater for more than three years. Titanium resembles other transition metals such as iron and nickel in being hard and refractory. Its combination of high strength, low density (it is quite light in comparison to other metals of similar mechanical and thermal properties), and excellent corrosion-resistance make it useful for many parts of aircraft, spacecraft, missiles, and ships. It also is used in prosthetic devices, because it does not react with fleshy tissue and bone. Titanium has also been utilized as a deoxidizer in steel and as an alloying addition in many steels to reduce grain size, in stainless steel to reduce carbon content, in aluminum to refine grain size, and in copper to produce hardening.

Although at room temperatures titanium is resistant to tarnishing, at elevated temperatures it reacts with oxygen in the air. This is no detriment to the properties of titanium during forging or fabrication of its alloys; the oxide scale is removed after fabrication. In the liquid state, however, titanium is very reactive and reduces all known refractories.



**titanium fan blades**

Titanium wide-chord fan blades on a Safran engine display.

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Titanium is not attacked by mineral acids at room temperature or by hot aqueous alkali; it dissolves in hot hydrochloric acid, giving titanium species in the +3 oxidation state, and hot nitric acid converts it into a hydrous oxide that is rather insoluble in acid or base. The best solvents for the metal are hydrofluoric acid or other acids to which fluoride ions have been added; such mediums dissolve titanium and hold it in solution because of the formation of fluoro complexes.

## Compounds

In its compounds, titanium exhibits oxidation states of +2, +3, and +4, as in the oxygen compounds titanium monoxide,  $\text{TiO}$ , dititanium trioxide,  $\text{Ti}_2\text{O}_3$ , and titanium dioxide,  $\text{TiO}_2$ , respectively. The +4 oxidation state is the most stable.

The chemistry of titanium in the +2 state is rather restricted. By contrast, many compounds are formed by titanium in the +3 state. One of the more important is the trichloride  $\text{TiCl}_3$ , a crystalline form of which is particularly useful as a catalyst in the stereospecific polymerization of propylene to make the commercially valuable polymer polypropylene.

Of the compounds formed by titanium in its +4 state, the dioxide,  $\text{TiO}_2$ , is the most important. This nontoxic, pure white powder is used extensively as a pigment in paints, enamels, and lacquers. It occurs in nature as the minerals brookite, octahedrite, anatase, and rutile.

Another compound of commercial significance is titanium tetrachloride, a colourless liquid used to obtain titanium metal. It is also utilized for skywriting and producing smoke screens and as a catalyst in many organic reactions.

Titanium combines directly with many nonmetals, such as hydrogen, the halogens, nitrogen, carbon, boron, silicon, and sulfur at elevated temperatures. The resulting nitride ( $\text{TiN}$ ), carbide ( $\text{TiC}$ ), and borides ( $\text{TiB}$  and  $\text{TiB}_2$ ) are interstitial compounds that are very stable, hard, and refractory.

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