# Ytterbium

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**Ytterbium** is a chemical element with symbol **Yb** and atomic number 70. It is the fourteenth and penultimate element in the lanthanide series, which is the basis of the relative stability of its +2 oxidation state. However, like the other lanthanides, its most common oxidation state is +3, seen in its oxide, halides and other compounds. In aqueous solution, like compounds of other late lanthanides, soluble ytterbium compounds form complexes with nine water molecules. Because of its closed-shell electron configuration, its density and melting and boiling points differ from those of the other lanthanides.

In 1878, the Swiss chemist Jean Charles Galissard de Marignac separated in the rare earth "erbia" another independent component, which he called "ytterbia", for Ytterby, the village in Sweden near where he found the new component of erbium. He suspected that ytterbia was a compound of a new element that he called "ytterbium" (in total, four elements were named after the village, the others being yttrium, terbium and erbium). In 1907, the new earth "lutecia" was separated from ytterbia, from which the element "lutecium" (now lutetium) was extracted by Georges Urbain, Carl Auer von Welsbach, and Charles James. After some discussion, Marignac's name "ytterbium" was retained. A relatively pure sample of the metal was obtained only in 1953. At present, ytterbium is mainly used as a dopant of stainless steel or active laser media, and less often as a gamma ray source.

Natural ytterbium is a mixture of seven stable isotopes, which altogether are present at concentrations of 3 parts per million. This element is mined in China, the United States, Brazil, and India in form of the minerals monazite, euxenite, and xenotime. The ytterbium concentration is low, because the element is found among many other rare earth elements; moreover, it is among the least abundant ones. Once extracted and prepared, ytterbium is somewhat hazardous as an eye and skin irritant. The metal is a fire and explosion hazard.

**Ytterbium, $_{70}$Yb**

| General properties | |
|---|---|
| **Name, symbol** | ytterbium, Yb |
| **Appearance** | silvery white; with a pale yellow tint[1] |
| **Ytterbium in the periodic table** | |
| **Atomic number** (*Z*) | 70 |
| **Group, block** | group n/a, f-block |
| **Period** | period 6 |
| **Element category** | lanthanide |
| **Standard atomic weight** (±) ($A_r$) | 173.045(10)[2] |
| **Electron configuration** | [Xe] $4f^{14}$ $6s^2$ |
| per shell | 2, 8, 18, 32, 8, 2 |
| **Physical properties** | |
| **Phase** | solid |
| **Melting point** | 1097 K (824 °C, 1515 °F) |

## Characteristics

### Physical properties

Ytterbium is a soft, malleable and ductile chemical element that displays a bright silvery luster when in its pure form. It is a rare earth element, and it is readily attacked and dissolved by the strong mineral acids. It reacts slowly with cold water and it oxidizes slowly in air.[3]

Ytterbium has three allotropes labeled by the Greek letters alpha, beta and gamma; their transformation temperatures are −13 °C and 795 °C,[3] although the exact transformation temperature depends on the pressure and stress.[4] The beta allotrope exists at room temperature, and it has a face-centered cubic crystal structure. The high-temperature gamma allotrope has a body-centered cubic crystalline structure.[3] The alpha allotrope has a hexagonal crystalline structure and is stable at low temperatures.[5] Normally, the beta allotrope has a metallic electrical conductivity, but it becomes a semiconductor when exposed to a pressure of about 16,000 atmospheres (1.6 GPa). Its electrical resistivity increases ten times upon compression to 39,000 atmospheres (3.9 GPa), but then drops to about 10% of its room-temperature resistivity at about 40,000 atm (4.0 GPa).[3][6]

In contrast with the other rare-earth metals, which usually have antiferromagnetic and/or ferromagnetic properties at low temperatures, ytterbium is paramagnetic at temperatures above 1.0 kelvin.[7] However, the alpha allotrope is diamagnetic.[4] With a melting point of 824 °C and a boiling point of 1196 °C, ytterbium has the smallest liquid range of all the metals.[3]

Contrary to most other lanthanides, which have a close-packed hexagonal lattice, ytterbium crystallizes in the face-centered cubic structure. As a result, its density (6.973 g/cm$^3$) is significantly lower than, e.g., those of the neighboring elements thulium (9.32 g/cm$^3$) and lutetium (9.841 g/cm$^3$). The melting and boiling points of ytterbium are also significantly lower than those of thulium and lutetium. These properties stem from the closed-shell electron configuration of ytterbium ([Xe] 4f$^{14}$ 6s$^2$), which causes only the two 6s electrons to be available for metallic bonding (in contrast to the other lanthanides where three electrons are available).[5]

## Chemical properties

| | |
|---|---|
| **Boiling point** | 1469 K (1196 °C, 2185 °F) |
| **Density** near r.t. | 6.90 g/cm$^3$ |
| when liquid, at m.p. | 6.21 g/cm$^3$ |
| **Heat of fusion** | 7.66 kJ/mol |
| **Heat of vaporization** | 129 kJ/mol |
| **Molar heat capacity** | 26.74 J/(mol·K) |

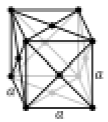
**Vapor pressure**

| **P** (Pa) | **1** | **10** | **100** | **1 k** | **10 k** | **100 k** |
|---|---|---|---|---|---|---|
| **at T** (K) | 736 | 813 | 910 | 1047 | (1266) | (1465) |

**Atomic properties**

| | |
|---|---|
| **Oxidation states** | **3**, 2, 1 (a basic oxide) |
| **Electronegativity** | Pauling scale: 1.1 (?) |
| **Ionization energies** | 1st: 603.4 kJ/mol<br>2nd: 1174.8 kJ/mol<br>3rd: 2417 kJ/mol |
| **Atomic radius** | empirical: 176 pm |
| **Covalent radius** | 187±8 pm |

**Miscellanea**

| | |
|---|---|
| **Crystal structure** | face-centered cubic (fcc)  |
| **Speed of sound** thin rod | 1590 m/s (at 20 °C) |
| **Thermal expansion** | β, poly: 26.3 µm/(m·K) (r.t.) |
| **Thermal conductivity** | 38.5 W/(m·K) |
| **Electrical** | β, poly: 0.250 µΩ·m |

Ytterbium metal tarnishes slowly in air. Finely dispersed ytterbium readily oxidizes in air and under oxygen. Mixtures of powdered ytterbium with polytetrafluoroethylene or hexachloroethane burn with a luminous emerald-green flame.[8] Ytterbium reacts with hydrogen to form various non-stoichiometric hydrides. Ytterbium dissolves slowly in water, but quickly in acids, liberating hydrogen gas.[5]

Ytterbium is quite electropositive, and it reacts slowly with cold water and quite quickly with hot water to form ytterbium(III) hydroxide:[9]

$$2\ Yb\ (s) + 6\ H_2O\ (l) \rightarrow 2\ Yb(OH)_3\ (aq) + 3\ H_2\ (g)$$

Ytterbium reacts with all the halogens:[9]

$$2\ Yb\ (s) + 3\ F_2\ (g) \rightarrow 2\ YbF_3\ (s)\ [\text{white}]$$
$$2\ Yb\ (s) + 3\ Cl_2\ (g) \rightarrow 2\ YbCl_3\ (s)\ [\text{white}]$$
$$2\ Yb\ (s) + 3\ Br_2\ (g) \rightarrow 2\ YbBr_3\ (s)\ [\text{white}]$$
$$2\ Yb\ (s) + 3\ I_2\ (g) \rightarrow 2\ YbI_3\ (s)\ [\text{white}]$$

The ytterbium(III) ion absorbs light in the near infrared range of wavelengths, but not in visible light, so the mineral ytterbia, $Yb_2O_3$, is white in color and the salts of ytterbium are also colorless. Ytterbium dissolves readily in dilute sulfuric acid to form solutions that contain the colorless Yb(III) ions, which exist as nonahydrate complexes:[9]

$$2\ Yb\ (s) + 3\ H_2SO_4\ (aq) \rightarrow 2\ [Yb(H_2O)_9]^{3+}\ (aq) + 3\ SO_4^{2-}\ (aq) + 3\ H_2\ (g)$$

## Yb(II) vs. Yb(III)

Although usually trivalent, ytterbium readily forms divalent compounds. This behavior is unusual to most lanthanides, which almost exclusively form compounds with an oxidation state of +3. The +2 state has a valence electron configuration of $4f^{14}$ because the fully filled *f*-shell gives more stability. The yellow-green ytterbium(II) ion is a very strong reducing agent and decomposes water, releasing hydrogen gas, and thus only the colorless ytterbium(III) ion occurs in aqueous solution. Samarium and

| | |
|---|---|
| **resistivity** | (at r.t.) |
| **Magnetic ordering** | paramagnetic |
| **Young's modulus** | β form: 23.9 GPa |
| **Shear modulus** | β form: 9.9 GPa |
| **Bulk modulus** | β form: 30.5 GPa |
| **Poisson ratio** | β form: 0.207 |
| **Vickers hardness** | 205–250 MPa |
| **Brinell hardness** | 340–440 MPa |
| **CAS Number** | 7440-64-4 |
| **History** | |
| **Naming** | after Ytterby (Sweden), where it was mined |
| **Discovery** | Jean Charles Galissard de Marignac (1878) |
| **First isolation** | Carl Auer von Welsbach (1906) |
| **Most stable isotopes of ytterbium** | |

thulium also behave this way in the +2 state, but europium(II) is stable in aqueous solution. Ytterbium metal behaves similarly to europium metal and the alkaline earth metals, dissolving in ammonia to form blue electride salts.[5]

## Isotopes

| iso | NA | half-life | DM | DE (MeV) | DP |
|---|---|---|---|---|---|
| **$^{166}$Yb** | syn | 56.7 h | ε | 0.304 | $^{166}$Tm |
| **$^{168}$Yb** | 0.126% | is stable with 98 neutrons | | | |
| **$^{169}$Yb** | syn | 32.026 d | ε | 0.909 | $^{169}$Tm |
| **$^{170}$Yb** | 3.023% | is stable with 100 neutrons | | | |
| **$^{171}$Yb** | 14.216% | is stable with 101 neutrons | | | |
| **$^{172}$Yb** | 21.754% | is stable with 102 neutrons | | | |
| **$^{173}$Yb** | 16.098% | is stable with 103 neutrons | | | |
| **$^{174}$Yb** | 31.896% | is stable with 104 neutrons | | | |
| **$^{175}$Yb** | syn | 4.185 d | $\beta^-$ | 0.470 | $^{175}$Lu |
| **$^{176}$Yb** | 12.887% | is stable with 106 neutrons | | | |
| **$^{177}$Yb** | syn | 1.911 h | $\beta^-$ | 1.399 | $^{177}$Lu |

Natural ytterbium is composed of seven stable isotopes: $^{168}$Yb, $^{170}$Yb, $^{171}$Yb, $^{172}$Yb, $^{173}$Yb, $^{174}$Yb, and $^{176}$Yb, with $^{174}$Yb being the most abundant isotope, at 31.8% of the natural abundance). 27 radioisotopes have been observed, with the most stable ones being $^{169}$Yb with a half-life of 32.0 days, $^{175}$Yb with a half-life of 4.18 days, and $^{166}$Yb with a half-life of 56.7 hours. All of its remaining radioactive isotopes have half-lives that are less than two hours and most of these have half-lives are less than 20 minutes. Ytterbium also has 12 meta states, with the most stable being $^{169m}$Yb ($t_{1/2}$ 46 seconds).[10][11]

The isotopes of ytterbium range in atomic weight from 147.9674 atomic mass unit (u) for $^{148}$Yb to 180.9562 u for $^{181}$Yb. The primary decay mode of ytterbium isotopes lighter than the most abundant stable isotope, $^{174}$Yb, is electron capture, and the primary decay mode for those heavier than $^{174}$Yb is beta decay. The primary decay products of ytterbium isotopes lighter than $^{174}$Yb are thulium isotopes, and the primary decay products of ytterbium isotopes with heavier than $^{174}$Yb are lutetium isotopes.[10][11]

# Source

- Wikipedia: Ytterbium (https://en.wikipedia.org/wiki/Ytterbium)