Thulium

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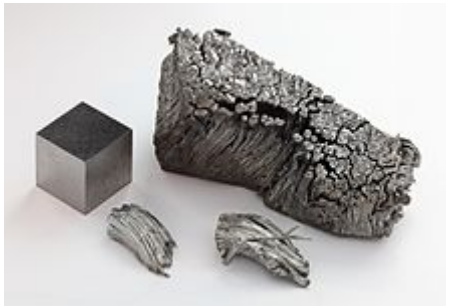
Thulium is a chemical element with symbol **Tm** and atomic number 69. It is the thirteenth and antepenultimate (third-last) element in the lanthanide series. Like the other lanthanides, the most common oxidation state is +3, seen in its oxide, halides and other compounds. In aqueous solution, like compounds of other late lanthanides, soluble thulium compounds form complexes with nine water molecules.

In 1879, Swedish chemist Per Teodor Cleve separated in the rare earth erbia another two previously unknown components, which he called holmia and thulia: these were the oxides of holmium and thulium respectively. A relatively pure sample of thulium metal was first obtained in 1911.

Thulium is the second least abundant of the lanthanides after promethium, which is only found in trace quantities on Earth. It is an easily workable metal with a bright silvery-gray luster. It is fairly soft and slowly tarnishes in air. Despite its high price and rarity, thulium is used as the radiation source in portable X-ray devices and in solid-state lasers. It has no significant biological role and is not particularly toxic.

Thulium, $_{69}$Tm



General properties	
Name, symbol	thulium, Tm
Appearance	silvery gray
Thulium in the periodic table	
Atomic number (Z)	69
Group, block	group n/a, f-block
Period	period 6
Element category	▯ lanthanide
Standard atomic weight (±) (A_r)	168.93422(2)[1]
Electron configuration	[Xe] $4f^{13}$ $6s^2$
per shell	2, 8, 18, 31, 8, 2
Physical properties	
Phase	solid
Melting point	1818 K (1545 °C, 2813 °F)
Boiling point	2223 K (1950 °C, 3542 °F)

Properties

Physical properties

Pure thulium metal has a bright, silvery luster, which tarnishes on exposure to air. The metal can be cut with a knife,[2] as it has a Mohs hardness of 2 to 3; it is malleable and ductile.[3] Thulium is ferromagnetic below 32 K, antiferromagnetic between 32 and 56 K, and paramagnetic above 56 K.[4]

Thulium has two major allotropes: the tetragonal α-Tm and the more stable hexagonal β-Tm.[3]

Chemical properties

Thulium tarnishes slowly in air and burns readily at 150 °C to form thulium(III) oxide:

$$4\ Tm + 3\ O_2 \rightarrow 2\ Tm_2O_3$$

Thulium is quite electropositive and reacts slowly with cold water and quite quickly with hot water to form thulium hydroxide:

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

Thulium reacts with all the halogens. Reactions are slow at room temperature, but are vigorous above 200 °C:

$$2\ Tm\ (s) + 3\ F_2\ (g) \rightarrow 2\ TmF_3\ (s)\ (white)$$
$$2\ Tm\ (s) + 3\ Cl_2\ (g) \rightarrow 2\ TmCl_3\ (s)\ (yellow)$$
$$2\ Tm\ (s) + 3\ Br_2\ (g) \rightarrow 2\ TmBr_3\ (s)\ (white)$$
$$2\ Tm\ (s) + 3\ I_2\ (g) \rightarrow 2\ TmI_3\ (s)\ (yellow)$$

Thulium dissolves readily in dilute sulfuric acid to form solutions containing the pale green Tm(III) ions, which exist as $[Tm(OH_2)_9]^{3+}$ complexes:[5]

$$2\ Tm\ (s) + 3\ H_2SO_4\ (aq) \rightarrow 2\ Tm^{3+}\ (aq) + 3\ SO_4^{2-}\ (aq) + 3\ H_2\ (g)$$

Thulium reacts with various metallic and non-metallic elements forming a range of binary compounds, including TmN, TmS, TmC_2, Tm_2C_3, TmH_2, TmH_3, $TmSi_2$, $TmGe_3$, TmB_4, TmB_6 and TmB_{12}. In those compounds, thulium exhibits valence states +2 and +3, however, the +3 state is most common and only this state has been observed in thulium solutions.[6] Thulium exists as a Tm^{3+} ion in solution. In this state, the thulium ion is surrounded by nine molecules of water.[2] Tm^{3+} ions exhibit a bright blue luminescence.[2]

Thulium's only known oxide is Tm_2O_3. This oxide is sometimes called "thulia".[7] Reddish-purple thulium(II) compounds can be made by the reduction of thulium(III) compounds. Examples of thulium(II) compounds include the halides (except the fluoride). Some hydrated thulium compounds, such as $TmCl_3 \cdot 7H_2O$ and $Tm_2(C_2O_4)_3 \cdot 6H_2O$ are green or greenish-white.[8] Thulium dichloride reacts very

Density near r.t.	9.32 g/cm^3
when liquid, at m.p.	8.56 g/cm^3
Heat of fusion	16.84 kJ/mol
Heat of vaporization	191 kJ/mol
Molar heat capacity	27.03 J/(mol·K)

Vapor pressure

P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	1117	1235	1381	1570	(1821)	(2217)

Atomic properties

Oxidation states	2, **3** (a basic oxide)
Electronegativity	Pauling scale: 1.25
Ionization energies	1st: 596.7 kJ/mol 2nd: 1160 kJ/mol 3rd: 2285 kJ/mol
Atomic radius	empirical: 176 pm
Covalent radius	190±10 pm

Miscellanea

Crystal structure	hexagonal close-packed (hcp) 
Thermal expansion	poly: 13.3 µm/(m·K) (at r.t.)
Thermal conductivity	16.9 W/(m·K)
Electrical resistivity	poly: 676 nΩ·m (at r.t.)
Magnetic ordering	paramagnetic (at 300 K)
Young's modulus	74.0 GPa
Shear modulus	30.5 GPa

vigorously with water. This reaction results in hydrogen gas and $Tm(OH)_3$ exhibiting a fading reddish color. Combination of thulium and chalcogens results in thulium chalcogenides.[9]

Thulium reacts with hydrogen chloride to produce hydrogen gas and thulium chloride. With nitric acid it yields thulium nitrate, or $Tm(NO_3)_3$.[10]

Isotopes

The isotopes of thulium range from ^{145}Tm to ^{179}Tm. The primary decay mode before the most abundant stable isotope, ^{169}Tm, is electron capture, and the primary mode after is beta emission. The primary decay products before ^{169}Tm are element 68 (erbium) isotopes, and the primary products after are element 70 (ytterbium) isotopes.[11]

Thulium-169 is thulium's longest-lived and most abundant isotope. It is the only isotope of thulium that is thought to be stable, although it is predicted to undergo alpha decay to holmium-165 with a very long half-life.[2] After thulium-169, the next-longest-lived isotopes are thulium-171, which has a half-life of 1.92 years, and thulium-170, which has a half-life of 128.6 days. Most other isotopes have half-lives of a few minutes or less.[12] Thirty-five isotopes and 26 nuclear isomers of thulium have been detected.[2] Most isotopes of thulium lighter than 169 atomic mass units decay via electron capture or beta-plus decay, although some exhibit significant alpha decay or proton emission. Heavier isotopes undergo beta-minus decay.[12]

Bulk modulus	44.5 GPa
Poisson ratio	0.213
Vickers hardness	470–650 MPa
Brinell hardness	470–900 MPa
CAS Number	7440-30-4
History	
Naming	after Thule, a mythical region in Scandinavia
Discovery and first isolation	Per Teodor Cleve (1879)

Most stable isotopes of thulium

iso	NA	half-life	DM	DE (MeV)	DP
^{167}Tm	syn	9.25 d	ε	0.748	^{167}Er
^{168}Tm	syn	93.1 d	ε	1.679	^{168}Er
^{169}Tm	100%	is stable with 100 neutrons			
^{170}Tm	syn	128.6 d	β−	0.968	^{170}Yb
^{171}Tm	syn	1.92 y	β−	0.096	^{171}Yb

Source

- *Wikipediaa: Thilium* .