Terbium

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Terbium is a chemical element with symbol **Tb** and atomic number 65. It is a silvery-white rare earth metal that is malleable, ductile and soft enough to be cut with a knife. The ninth member of the lanthanide series, terbium is a fairly electropositive metal that reacts with water, evolving hydrogen gas. Terbium is never found in nature as a free element, but it is contained in many minerals, including cerite, gadolinite, monazite, xenotime and euxenite.

Swedish chemist Carl Gustaf Mosander discovered terbium as a separate elemental compound in 1843. He detected it as an impurity in yttrium oxide, Y_2O_3. Yttrium and terbium are named after the village of Ytterby in Sweden. Terbium was not isolated in pure form until the advent of ion exchange techniques.

Terbium is used to dope calcium fluoride, calcium tungstate and strontium molybdate, materials that are used in solid-state devices, and as a crystal stabilizer of fuel cells which operate at elevated temperatures. As a component of Terfenol-D (an alloy that expands and contracts when exposed to magnetic fields more than any other alloy), terbium is of use in actuators, in naval sonar systems and in sensors.

Most of the world's terbium supply is used in green phosphors. Terbium oxide is in fluorescent lamps and TV tubes. Terbium green phosphors are combined with divalent europium blue phosphors and trivalent europium red phosphors to provide "trichromatic" lighting technology, a high-efficiency white light used for standard illumination in indoor lighting.

Characteristics

Physical properties

Terbium, $_{65}$Tb

General properties	
Name, symbol	terbium, Tb
Appearance	silvery white
Terbium in the periodic table	
Atomic number (Z)	65
Group, block	group n/a, f-block
Period	period 6
Element category	lanthanide
Standard atomic weight (±) (A_r)	158.92535(2)[1]
Electron configuration	[Xe] $4f^9$ $6s^2$
per shell	2, 8, 18, 27, 8, 2
Physical properties	
Phase	solid
Melting point	1629 K (1356 °C, 2473 °F)
Boiling point	3396 K (3123 °C, 5653 °F)

Terbium is a silvery-white rare earth metal that is malleable, ductile and soft enough to be cut with a knife.[2] It is relatively stable in air compared to the earlier, more reactive lanthanides in the first half of the lanthanide series.[3] Terbium exists in two crystal allotropes with a transformation temperature of 1289 °C between them.[2] The 65 electrons of a terbium atom are arranged in the electron configuration [Xe]$4f^9 6s^2$; normally, only three electrons can be removed before the nuclear charge becomes too great to allow further ionization, but in the case of terbium, the stability of the half-filled [Xe]$4f^7$ configuration allows further ionization of a fourth electron in the presence of very strong oxidizing agents such as fluorine gas.[2]

The terbium(III) cation is brilliantly fluorescent, in a bright lemon-yellow color that is the result of a strong green emission line in combination with other lines in the orange and red. The yttrofluorite variety of the mineral fluorite owes its creamy-yellow fluorescence in part to terbium. Terbium easily oxidizes, and is therefore used in its elemental form specifically for research. Single terbium atoms have been isolated by implanting them into fullerene molecules.[4]

Terbium has a simple ferromagnetic ordering at temperatures below 219 K. Above 219 K, it turns into a helical antiferromagnetic state in which all of the atomic moments in a particular basal plane layer are parallel, and oriented at a fixed angle to the moments of adjacent layers. This unusual antiferromagnetism transforms into a disordered paramagnetic state at 230 K.[5]

Chemical properties

The most common oxidation state of terbium is +3, as in Tb_2O_3. The +4 state is known in TbO_2 and TbF_4.[6][7] Terbium burns readily to form a mixed terbium(III,IV) oxide:[8]

$$8\ Tb + 7\ O_2 \rightarrow 2\ Tb_4O_7$$

Density near r.t.	8.23 g/cm^3
when liquid, at m.p.	7.65 g/cm^3
Heat of fusion	10.15 kJ/mol
Heat of vaporization	391 kJ/mol
Molar heat capacity	28.91 J/(mol·K)

Vapor pressure

P (Pa)	**1**	**10**	**100**	**1 k**	**10 k**	**100 k**
at T (K)	1789	1979	(2201)	(2505)	(2913)	(3491)

Atomic properties

Oxidation states	4, **3**, 2, 1 (a weakly basic oxide)
Electronegativity	Pauling scale: 1.2 (?)
Ionization energies	1st: 565.8 kJ/mol 2nd: 1110 kJ/mol 3rd: 2114 kJ/mol
Atomic radius	empirical: 177 pm
Covalent radius	194±5 pm

Miscellanea

Crystal structure	hexagonal close-packed (hcp) 
Speed of sound thin rod	2620 m/s (at 20 °C)
Thermal expansion	at r.t. α, poly: 10.3 µm/(m·K)
Thermal conductivity	11.1 W/(m·K)
Electrical resistivity	α, poly: 1.150 µΩ·m (at r.t.)
Magnetic ordering	paramagnetic at 300 K

In solution, terbium forms only trivalent ions. Terbium is quite electropositive and reacts slowly with cold water and quite quickly with hot water to form terbium hydroxide:[8]

$$2\ Tb + 6\ H_2O \rightarrow 2\ Tb(OH)_3 + 3\ H_2\uparrow$$

Terbium metal reacts with all the halogens, forming white trihalides:[8]

$$2\ Tb + 3\ X_2 \rightarrow 2\ TbX_3\ (X = F, Cl, Br, I)$$

Terbium dissolves readily in dilute sulfuric acid to form solutions containing the pale pink terbium(III) ions, which exist as a $[Tb(OH_2)_9]^{3+}$ complexes:[8]

$$2\ Tb\ (s) + 3\ H_2SO_4 \rightarrow 2\ Tb^{3+} + 3\ SO_4^{2-} + 3\ H_2\uparrow$$

Compounds

Terbium combines with nitrogen, carbon, sulfur, phosphorus, boron, selenium, silicon and arsenic at elevated temperatures, forming various binary compounds such as TbH_2, TbH_3, TbB_2, Tb_2S_3, TbSe, TbTe and TbN.[7] In those compounds, Tb mostly exhibits the oxidation states +3 and sometimes +2. Terbium(II) halogenides are obtained by annealing Tb(III) halogenides in presence of metallic Tb in tantalum containers. Terbium also forms sesquichloride Tb_2Cl_3, which can be further reduced to TbCl by annealing at 800 °C. This terbium(I) chloride forms platelets with layered graphite-like structure.[9]

Other compounds include

- Chlorides: $TbCl_3$
- Bromides: $TbBr_3$
- Iodides: TbI_3
- Fluorides: TbF_3, TbF_4

Terbium(IV) fluoride is a strong fluorinating agent, emitting relatively pure atomic fluorine when heated[10] rather than the mixture of fluoride vapors emitted from CoF_3 or CeF_4.

Young's modulus	α form: 55.7 GPa
Shear modulus	α form: 22.1 GPa
Bulk modulus	α form: 38.7 GPa
Poisson ratio	α form: 0.261
Vickers hardness	450–865 MPa
Brinell hardness	675–1200 MPa
CAS Number	7440-27-9

History

Naming	after Ytterby (Sweden), where it was mined
Discovery and first isolation	Carl Gustaf Mosander (1842)

Most stable isotopes of terbium

iso	NA	half-life	DM	DE (MeV)	DP
^{157}Tb	syn	71 y	ε	0.060	^{157}Gd
^{158}Tb	syn	180 y	ε	1.220	^{158}Gd
			β−	0.937	^{158}Dy
^{159}Tb	100%	is stable with 94 neutrons			

Isotopes

Naturally occurring terbium is composed of its only stable isotope, terbium-159; the element is thus called mononuclidic and monoisotopic. Thirty six radioisotopes have been characterized, with the heaviest being terbium-171 (with atomic mass of 170.95330(86) u) and lightest being terbium-135 (exact mass unknown).[11] The most stable synthetic radioisotopes of terbium are terbium-158, with a half-life of 180 years, and terbium-157, with a half-life of 71 years. All of the remaining radioactive isotopes have half-lives that are much less than a quarter of a year, and the majority of these have half-lives that are less than half a minute.[11] The primary decay mode before the most abundant stable isotope, ^{159}Tb, is electron capture, which results in production of gadolinium isotopes, and the primary mode after is beta minus decay, resulting in dysprosium isotopes.[11]

The element also has 27 nuclear isomers, with masses of 141–154, 156, and 158 (not every mass number corresponds to only one isomer). The most stable of them are terbium-156m, with half-life of 24.4 hours and terbium-156m2, with half-life of 22.7 hours; this is longer than half-lives of most ground states of radioactive terbium isotopes, except only those with mass numbers 155–161.[11]

External links

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