

# Europium

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**Europium** is a chemical element with symbol **Eu** and atomic number 63. It was isolated in 1901 and is named after the continent of Europe.<sup>[4]</sup> It is a moderately hard, silvery metal which readily oxidizes in air and water. Being a typical member of the lanthanide series, europium usually assumes the oxidation state +3, but the oxidation state +2 is also common. All europium compounds with oxidation state +2 are slightly reducing. Europium has no significant biological role and is relatively non-toxic compared to other heavy metals. Most applications of europium exploit the phosphorescence of europium compounds. Europium is one of the least abundant elements in the universe; only about  $5 \times 10^{-8}\%$  of all matter in the universe is europium.

## Characteristics

### Physical properties



About 300 g of dendritic sublimated 99.998% pure europium handled in a glove box

Europium is a ductile metal with a hardness similar to that of lead. It crystallizes in a body-centered cubic lattice.<sup>[5]</sup> Some properties of europium are strongly influenced by its half-filled electron shell. Europium has the second lowest melting point and the lowest density of all lanthanides.<sup>[5]</sup>

Europium becomes a superconductor when it is cooled below 1.8 K and compressed to above 80 GPa. This is because europium is divalent in the metallic state,<sup>[6]</sup> and is converted into the trivalent state by the applied pressure. In the divalent state, the strong local magnetic moment ( $J = 7/2$ ) suppresses the

superconductivity, which is induced by eliminating this local moment ( $J = 0$  in  $\text{Eu}^{3+}$ ).<sup>[7]</sup>

### Chemical properties

## Europium, ${}_{63}\text{Eu}$



### General properties

<b>Name, symbol</b>	europium, Eu
<b>Appearance</b>	silvery white, with a pale yellow tint; <sup>[1]</sup> but rarely seen without oxide discoloration

### Europium in the periodic table

<b>Atomic number</b> ( <i>Z</i> )	63
<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> ( $\pm$ ) ( <i>A</i> <sub>r</sub> )	151.964(1) <sup>[2]</sup>
<b>Electron configuration</b>	[Xe] 4f <sup>7</sup> 6s <sup>2</sup>

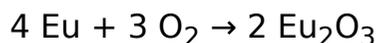


Oxidized europium, coated with yellow europium(II) carbonate

Europium is the most reactive rare earth element. It rapidly oxidizes in air, so that bulk oxidation of a centimeter-sized sample occurs within several days.<sup>[8]</sup> Its reactivity with water is comparable to that of calcium, and the reaction is



Because of the high reactivity, samples of solid europium rarely have the shiny appearance of the fresh metal, even when coated with a protective layer of mineral oil. Europium ignites in air at 150 to 180 °C to form europium(III) oxide:



Europium dissolves readily in dilute sulfuric acid to form pale pink solutions of the hydrated Eu(III), which exist as a nonahydrate:<sup>[9]</sup>



### Eu(II) vs. Eu(III)

Although usually trivalent, europium 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 an electron configuration  $4f^7$  because the half-filled *f*-shell gives more stability. In terms of size and coordination number, europium(II) and barium(II) are similar. For example, the sulfates of both barium and europium(II) are also highly insoluble in water.<sup>[10]</sup> Divalent europium is a mild reducing agent, oxidizing in air to form Eu(III) compounds. In anaerobic, and particularly geothermal conditions, the divalent form is sufficiently stable that it tends to be incorporated into minerals of calcium and the other alkaline earths. This ion-exchange process is the basis of the "negative europium anomaly", the low europium content in many lanthanide minerals such as monazite, relative to the chondritic abundance. Bastnäsite tends to show less of a negative europium anomaly than does monazite, and hence is

per shell 2, 8, 18, 25, 8, 2

### Physical properties

<b>Phase</b>	solid
<b>Melting point</b>	1099 K (826 °C, 1519 °F)
<b>Boiling point</b>	1802 K (1529 °C, 2784 °F)
<b>Density</b> near r.t.	5.264 g/cm <sup>3</sup>
when liquid, at m.p.	5.13 g/cm <sup>3</sup>
<b>Heat of fusion</b>	9.21 kJ/mol
<b>Heat of vaporization</b>	176 kJ/mol
<b>Molar heat capacity</b>	27.66 J/(mol·K)

### Vapor pressure

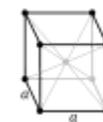
P (Pa)	1	10	100	1 k	10 k	100 k
at T (K)	863	957	1072	1234	1452	1796

### Atomic properties

<b>Oxidation states</b>	<b>3, 2, 1</b> (a mildly basic oxide)
<b>Electronegativity</b>	Pauling scale: 1.2
<b>Ionization energies</b>	1st: 547.1 kJ/mol 2nd: 1085 kJ/mol 3rd: 2404 kJ/mol
<b>Atomic radius</b>	empirical: 180 pm
<b>Covalent radius</b>	198±6 pm

### Miscellanea

**Crystal structure** body-centered cubic (bcc)



the major source of europium today. The development of easy methods to separate divalent europium from the other (trivalent) lanthanides made europium accessible even when present in low concentration, as it usually is.

## Isotopes

Naturally occurring europium is composed of 2 isotopes, <sup>151</sup>Eu and <sup>153</sup>Eu, with <sup>153</sup>Eu being the most abundant (52.2% natural abundance). While <sup>153</sup>Eu is stable, <sup>151</sup>Eu was recently found to be unstable to alpha decay with half-life of  $5 \frac{+11}{-3} \times 10^{18}$  years,<sup>[11]</sup> giving about 1 alpha decay per two minutes in every kilogram of natural europium. This value is in reasonable agreement with theoretical predictions. Besides the natural radioisotope <sup>151</sup>Eu, 35 artificial radioisotopes have been characterized, the most stable being <sup>150</sup>Eu with a half-life of 36.9 years, <sup>152</sup>Eu with a half-life of 13.516 years, and <sup>154</sup>Eu with a half-life of 8.593 years. All the remaining radioactive isotopes have half-lives shorter than 4.7612 years, and the majority of these have half-lives shorter than 12.2 seconds. This element also has 8 meta states, with the most stable being <sup>150m</sup>Eu ( $t_{1/2}$ =12.8 hours), <sup>152m1</sup>Eu ( $t_{1/2}$ =9.3116 hours) and <sup>152m2</sup>Eu ( $t_{1/2}$ =96 minutes).<sup>[12]</sup>

The primary decay mode for isotopes lighter than <sup>153</sup>Eu is electron capture, and the primary mode for heavier isotopes is beta minus decay. The primary decay products before <sup>153</sup>Eu are isotopes of samarium (Sm) and the primary products after are isotopes of gadolinium (Gd).<sup>[12]</sup>

## Europium as a nuclear fission product

Europium is produced by nuclear fission, but the fission product yields of europium isotopes are low near the top of the mass range for fission products.

Like other lanthanides, many isotopes, especially isotopes with odd mass numbers and neutron-poor isotopes like <sup>152</sup>Eu, have high cross sections for neutron capture, often high enough to be neutron poisons.

<b>Thermal expansion</b>	poly: 35.0 μm/(m·K) (at r.t.)
<b>Thermal conductivity</b>	est. 13.9 W/(m·K)
<b>Electrical resistivity</b>	poly: 0.900 μΩ·m (at r.t.)
<b>Magnetic ordering</b>	paramagnetic <sup>[3]</sup>
<b>Young's modulus</b>	18.2 GPa
<b>Shear modulus</b>	7.9 GPa
<b>Bulk modulus</b>	8.3 GPa
<b>Poisson ratio</b>	0.152
<b>Vickers hardness</b>	165–200 MPa
<b>CAS Number</b>	7440-53-1

### History

<b>Naming</b>	after Europe
<b>Discovery and first isolation</b>	Eugène-Anatole Demarçay (1896, 1901)

### Most stable isotopes of europium

iso	NA	half-life	DM	DE (MeV)	DP
<sup>150</sup> Eu	syn	36.9 y	ε	2.261	<sup>150</sup> Sm
<sup>151</sup> Eu	47.8%	5×10 <sup>18</sup> y	α	1.9644	<sup>147</sup> Pm
<sup>152</sup> Eu	syn	13.54 y	ε	1.874	<sup>152</sup> Sm
			β <sup>−</sup>	1.819	<sup>152</sup> Gd
<sup>153</sup> Eu	52.2%	is stable with 90 neutrons			
<sup>154</sup> Eu	syn	8.59 y	β <sup>−</sup>	1.969	<sup>154</sup> Gd
<sup>155</sup> Eu	syn	4.76 y	β <sup>−</sup>	0.253	<sup>155</sup> Gd

$^{151}\text{Eu}$  is the beta decay product of samarium-151, but since this has a long decay half-life and short mean time to neutron absorption, most  $^{151}\text{Sm}$  instead ends up as  $^{152}\text{Sm}$ .

$^{152}\text{Eu}$  (half-life 13.516 years) and  $^{154}\text{Eu}$  (half-life 8.593 years) cannot be beta decay products because  $^{152}\text{Sm}$  and  $^{154}\text{Sm}$  are non-radioactive, but  $^{154}\text{Eu}$  is the only long-lived "shielded" nuclide, other than  $^{134}\text{Cs}$ , to have a fission yield of more than 2.5 parts per million fissions.<sup>[13]</sup> A larger amount of  $^{154}\text{Eu}$  is produced by neutron activation of a significant portion of the non-radioactive  $^{153}\text{Eu}$ ; however, much of this is further converted to  $^{155}\text{Eu}$ .

$^{155}\text{Eu}$  (half-life 4.7612 years) has a fission yield of 330 parts per million (ppm) for uranium-235 and thermal neutrons; most of it is transmuted to non-radioactive and nonabsorptive gadolinium-156 by the end of fuel burnup.

Overall, europium is overshadowed by caesium-137 and strontium-90 as a radiation hazard, and by samarium and others as a neutron poison.<sup>[14][15][16][17][18][19][20]</sup>

## Occurrence

Europium is not found in nature as a free element. Many minerals contain europium, with the most important sources being bastnäsite, monazite, xenotime and loparite.<sup>[21]</sup>

Depletion or enrichment of europium in minerals relative to other rare earth elements is known as the europium anomaly.<sup>[22]</sup> Europium is commonly included in trace element studies in geochemistry and petrology to understand the processes that form igneous rocks (rocks that cooled from magma or lava). The nature of the europium anomaly found helps reconstruct the relationships within a suite of igneous rocks.

Divalent europium ( $\text{Eu}^{2+}$ ) in small amounts is the activator of the bright blue fluorescence of some samples of the mineral fluorite ( $\text{CaF}_2$ ). The reduction from  $\text{Eu}^{3+}$  to  $\text{Eu}^{2+}$  is induced by irradiation with energetic particles.<sup>[23]</sup> The most outstanding examples of this originated around Weardale and adjacent parts of northern England; it was the fluorite found here that fluorescence was named after in 1852, although it was not until much later that europium was determined to be the cause.<sup>[24][25][26][27][28]</sup>

## Source

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