Einsteinium

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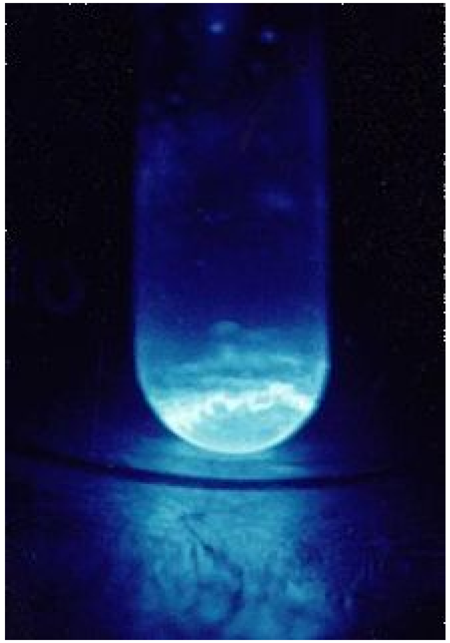
Einsteinium is a synthetic element with symbol **Es** and atomic number 99. It is the seventh transuranic element, and an actinide.

Einsteinium was discovered as a component of the debris of the first hydrogen bomb explosion in 1952, and named after Albert Einstein. Its most common isotope einsteinium-253 (half life 20.47 days) is produced artificially from decay of californium-253 in a few dedicated high-power nuclear reactors with a total yield on the order of one milligram per year. The reactor synthesis is followed by a complex process of separating einsteinium-253 from other actinides and products of their decay. Other isotopes are synthesized in various laboratories, but at much smaller amounts, by bombarding heavy actinide elements with light ions. Owing to the small amounts of produced einsteinium and the short half-life of its most easily produced isotope, there are currently almost no practical applications for it outside of basic scientific research. In particular, einsteinium was used to synthesize, for the first time, 17 atoms of the new element mendelevium in 1955.

Einsteinium is a soft, silvery, paramagnetic metal. Its chemistry is typical of the late actinides, with a preponderance of the +3 oxidation state; the +2 oxidation state is also accessible, especially in solids. The high radioactivity of einsteinium-253 produces a visible glow and rapidly damages its crystalline metal lattice, with released heat of about 1000 watts per gram. Difficulty in studying its properties is due to einsteinium-253's decay to berkelium-249 and then californium-249 at a rate of about 3% per day. The isotope of einsteinium with the longest half life, einsteinium-252 (half life 471.7 days) would be more suitable for investigation of physical properties, but it has proven far more difficult to produce and is available only in minute quantities, and not in bulk.[1] Einsteinium is the element with the highest atomic number which has been observed in macroscopic quantities in its pure form, and this was the common short-lived isotope einsteinium-253.[2]

Like all synthetic transuranic elements, isotopes of einsteinium are very radioactive and are considered highly dangerous to health on ingestion.[3]

Einsteinium, $_{99}$Es



General properties

Name, symbol	einsteinium, Es
Pronunciation	/aɪnˈstaɪniəm/ *eyen-STY-nee-əm*
Appearance	silvery; glows blue in the dark

Einsteinium in the periodic table

Atomic number (*Z*)	99
Group, block	group n/a, f-block
Period	period 7
Element category	actinide

Characteristics

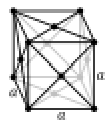
Physical

Einsteinium is a synthetic, silvery-white, radioactive metal. In the periodic table, it is located to the right of the actinide californium, to the left of the actinide fermium and below the lanthanide holmium with which it shares many similarities in physical and chemical properties. Its density of 8.84 g/cm^3 is lower than that of californium (15.1 g/cm^3) and is nearly the same as that of holmium (8.79 g/cm^3), despite atomic einsteinium being much heavier than holmium. The melting point of einsteinium (860 °C) is also relatively low – below californium (900 °C), fermium (1527 °C) and holmium (1461 °C).[3][26] Einsteinium is a soft metal, with the bulk modulus of only 15 GPa, which value is one of the lowest among non-alkali metals.[27]

Contrary to the lighter actinides californium, berkelium, curium and americium which crystallize in a double hexagonal structure at ambient conditions, einsteinium is believed to have a face-centered cubic (*fcc*) symmetry with the space group $Fm\overline{3}m$ and the lattice constant a = 575 pm. However, there is a report of room-temperature hexagonal einsteinium metal with a = 398 pm and c = 650 pm, which converted to the *fcc* phase upon heating to 300 °C.[28]

The self-damage induced by the radioactivity of einsteinium is so strong that it rapidly destroys the crystal lattice,[29] and the energy release during this process, 1000 watts per gram of ^{253}Es, induces a visible glow.[2] These processes may contribute to the relatively low density and melting point of einsteinium.[30] Further, owing to the small size of the available samples, the melting point of einsteinium was often deduced by observing the sample being heated inside an electron microscope.[31] Thus the surface effects in small samples could reduce the melting point value.

The metal is divalent and has a noticeably high volatility.[32] In order to reduce the self-radiation damage, most measurements of solid einsteinium and its compounds are performed right after thermal annealing.[33] Also, some compounds are studied under the atmosphere of the reductant gas, for example H_2O+HCl for EsOCl so that the sample is partly regrown during its decomposition.[34]

Standard atomic weight (A_r)	(252)
Electron configuration	[Rn] $5f^{11}$ $7s^2$
per shell	2, 8, 18, 32, 29, 8, 2
Physical properties	
Phase	solid
Melting point	1133 K (860 °C, 1580 °F)
Boiling point	1269 K (996 °C, 1825 °F) *(estimated)*
Density near r.t.	8.84 g/cm^3
Atomic properties	
Oxidation states	2, **3**, 4
Electronegativity	Pauling scale: 1.3
Ionization energies	1st: 619 kJ/mol
Miscellanea	
Crystal structure	face-centered cubic (fcc) 
Magnetic ordering	paramagnetic
CAS Number	7429-92-7
History	
Naming	after Albert Einstein
Discovery	Lawrence Berkeley National Laboratory (1952)

Apart from the self-destruction of solid einsteinium and its compounds, other intrinsic difficulties in studying this element include scarcity – the most common ^{253}Es isotope is available only once or twice a year in sub-milligram amounts – and self-contamination due to rapid conversion of einsteinium to berkelium and then to californium at a rate of about 3.3% per day:[35][36][37]

$$^{253}_{99}\mathrm{Es} \xrightarrow[20\ \mathrm{d}]{\alpha} {}^{249}_{97}\mathrm{Bk} \xrightarrow[314\ \mathrm{d}]{\beta^-} {}^{249}_{98}\mathrm{Cf}$$

Thus, most einsteinium samples are contaminated, and their intrinsic properties are often deduced by extrapolating back experimental data accumulated over time. Other experimental techniques to circumvent the contamination problem include selective optical excitation of einsteinium ions by a tunable laser, such as in studying its luminescence properties.[38]

Most stable isotopes of einsteinium

iso	NA	half-life	DM	DE (MeV)	DP
^{252}Es	syn	471.7 d	α	6.760	^{248}Bk
			ε	1.260	^{252}Cf
			β^-	0.480	^{252}Fm
^{253}Es	syn	20.47 d	SF	–	–
			α	6.739	^{249}Bk
^{254}Es	syn	275.7 d	ε	0.654	^{254}Cf
			β^-	1.090	^{254}Fm
			α	6.628	^{250}Bk
^{255}Es	syn	39.8 d	β^-	0.288	^{255}Fm
			α	6.436	^{251}Bk
			SF	–	–

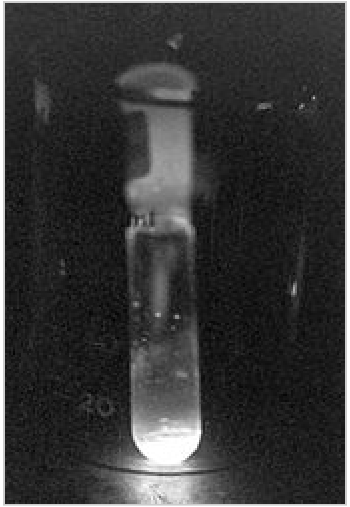
Magnetic properties have been studied for einsteinium metal, its oxide and fluoride. All three materials showed Curie–Weiss paramagnetic behavior from liquid helium to room temperature. The effective magnetic moments were deduced as $10.4 \pm 0.3\ \mu_B$ for Es_2O_3 and $11.4 \pm 0.3\ \mu_B$ for the EsF_3, which are the highest values among actinides, and the corresponding Curie temperatures are 53 and 37 K.[39][40]

Chemical

Like all actinides, einsteinium is rather reactive. Its trivalent oxidation state is most stable in solids and aqueous solution where it induced pale pink color.[41] The existence of divalent einsteinium is firmly established, especially in solid phase; such +2 state is not observed in many other actinides, including protactinium, uranium, neptunium, plutonium, curium and berkelium. Einsteinium(II) compounds can be obtained, for example, by reducing einsteinium(III) with samarium(II) chloride.[42] The oxidation state +4 was postulated from vapor studies and is yet uncertain.[43]

Isotopes

Nineteen nuclides and three nuclear isomers are known for einsteinium with atomic weights ranging from 240 to 258. All are radioactive and the most stable nuclide, ^{252}Es, has a half-life of 471.7 days.[44] Next most stable isotopes are ^{254}Es (half-life 275.7 days),[45] ^{255}Es (39.8 days) and ^{253}Es (20.47 days). All of the remaining isotopes have half-lives shorter than 40 hours, and most of them decay within less than 30 minutes. Of the three nuclear isomers, the most stable is ^{254m}Es with half-life of 39.3 hours.[46]


Glow due to the intense radiation from ~300 µg of ^{253}Es.[25]

Nuclear fission

Einsteinium has a high rate of nuclear fission that results in a low critical mass for a sustained nuclear chain reaction. This mass is 9.89 kilograms for a bare sphere of ^{254}Es isotope, and can be lowered to 2.9 by adding a 30 centimeter thick steel neutron reflector, or even to 2.26 kilograms with a 20 cm thick reflector made of water. However, even this small critical mass greatly exceeds the total amount of einsteinium isolated thus far, especially of the rare ^{254}Es isotope.[47]

Natural occurrence

Because of the short half-life of all isotopes of einsteinium, any primordial einsteinium, that is einsteinium that could possibly be present on the Earth during its formation, has decayed by now. Synthesis of einsteinium from naturally occurring actinides uranium and thorium in the Earth crust requires multiple neutron capture, which is an extremely unlikely event. Therefore, most einsteinium is produced on Earth in scientific laboratories, high-power nuclear reactors, or in nuclear weapons tests, and is present only within a few years from the time of the synthesis.[6] The transuranic elements from americium to fermium, including einsteinium, occurred naturally in the natural nuclear fission reactor at Oklo, but no longer do so.[48] Einsteinium was observed in Przybylski's Star in 2008.[49]

Source

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