Berkelium

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Berkelium is a transuranic radioactive chemical element with symbol **Bk** and atomic number 97. It is a member of the actinide and transuranium element series. It is named after the city of Berkeley, California, the location of the University of California Radiation Laboratory where it was discovered in December 1949. This was the fifth transuranium element discovered after neptunium, plutonium, curium and americium.

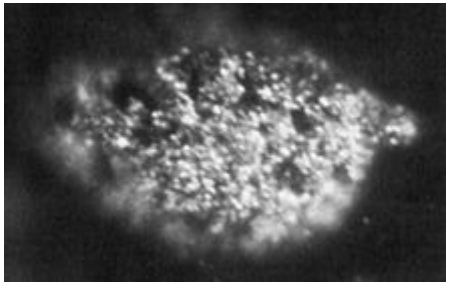
The major isotope of berkelium, ^{249}Bk, is synthesized in minute quantities in dedicated high-flux nuclear reactors, mainly at the Oak Ridge National Laboratory in Tennessee, USA, and at the Research Institute of Atomic Reactors in Dimitrovgrad, Russia. The production of the second-most important isotope ^{247}Bk involves the irradiation of the rare isotope ^{244}Cm with high-energy alpha particles.

Just over one gram of berkelium has been produced in the United States since 1967. There is no practical application of berkelium outside of scientific research which is mostly directed at the synthesis of heavier transuranic elements and transactinides. A 22 milligram batch of berkelium-249 was prepared during a 250-day irradiation period and then purified for a further 90 days at Oak Ridge in 2009. This sample was used to synthesize the element tennessine for the first time in 2009 at the Joint Institute for Nuclear Research, Russia, after it was bombarded with calcium-48 ions for 150 days. This was the culmination of the Russia–US collaboration on the synthesis of elements 113 to 118.

Berkelium is a soft, silvery-white, radioactive metal. The berkelium-249 isotope emits low-energy electrons and thus is relatively safe to handle. It decays with a half-life of 330 days to californium-249, which is a strong emitter of ionizing alpha particles. This gradual transformation is an important consideration when studying the properties of elemental berkelium and its chemical compounds, since the formation of californium brings not only chemical contamination, but also free-radical effects and self-heating from the emitted helium nuclei.

Characteristics

Berkelium, $_{97}$Bk



General properties	
Name, symbol	berkelium, Bk
Appearance	silvery
Berkelium in the periodic table	
Atomic number (Z)	97
Group, block	group n/a, f-block
Period	period 7
Element category	□ actinide
Standard atomic weight (A_r)	(247)
Electron configuration	[Rn] $5f^9\ 7s^2$
per shell	2, 8, 18, 32, 27, 8, 2
Physical properties	
Phase	solid
Melting point	beta: 1259 K (986 °C, 1807 °F)
Boiling point	beta: 2900 K

Physical

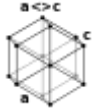
Berkelium is a soft, silvery-white, radioactive actinide metal. In the periodic table, it is located to the right of the actinide curium, to the left of the actinide californium and below the lanthanide terbium with which it shares many similarities in physical and chemical properties. Its density of 14.78 g/cm^3 lies between those of curium (13.52 g/cm^3) and californium (15.1 g/cm^3), as does its melting point of 986 °C, below that of curium (1340 °C) but higher than that of californium (900 °C).[2] Berkelium is relatively soft and has one of the lowest bulk moduli among the actinides, at about 20 GPa (2×10^{10} Pa).[3]

Berkelium(III) ions shows two sharp fluorescence peaks at 652 nanometers (red light) and 742 nanometers (deep red – near infrared) due to internal transitions at the f-electron shell. The relative intensity of these peaks depends on the excitation power and temperature of the sample. This emission can be observed, for example, after dispersing berkelium ions in a silicate glass, by melting the glass in presence of berkelium oxide or halide.[4][5]

Between 70 K and room temperature, berkelium behaves as a Curie–Weiss paramagnetic material with an effective magnetic moment of 9.69 Bohr magnetons (μ_B) and a Curie temperature of 101 K. This magnetic moment is almost equal to the theoretical value of 9.72 μ_B calculated within the simple atomic L-S coupling model. Upon cooling to about 34 K, berkelium undergoes a transition to an antiferromagnetic state.[6] Enthalpy of dissolution in hydrochloric acid at standard conditions is −600 kJ/mol^{-1}, from which the standard enthalpy change of formation ($\Delta_f H°$) of aqueous Bk^{3+} ions is obtained as −601 kJ/mol^{-1}. The standard potential Bk^{3+}/Bk^0 is −2.01 V.[7] The ionization potential of a neutral berkelium atom is 6.23 eV.[8]

Allotropes

At ambient conditions, berkelium assumes its most stable α form which has a hexagonal symmetry, space group *P6$_3$/mmc*, lattice parameters of 341 pm and 1107 pm. The crystal has a double-hexagonal close packing structure with the layer sequence ABAC and so is isotypic (having a similar structure) with α-lanthanum and α-forms of actinides

	(2627 °C, 4760 °F)
Density near r.t.	alpha: 14.78 g/cm^3 beta: 13.25 g/cm^3
Heat of fusion	7.92 kJ/mol (calculated)
Atomic properties	
Oxidation states	2, **3**, 4
Electronegativity	Pauling scale: 1.3
Ionization energies	1st: 601 kJ/mol
Atomic radius	empirical: 170 pm
Miscellanea	
Crystal structure	double hexagonal close-packed (dhcp) 
Thermal conductivity	10 W/(m·K)
Magnetic ordering	paramagnetic
CAS Number	7440-40-6
History	
Naming	after Berkeley, California, where it was discovered
Discovery	Lawrence Berkeley National Laboratory (1949)
Most stable isotopes of berkelium	

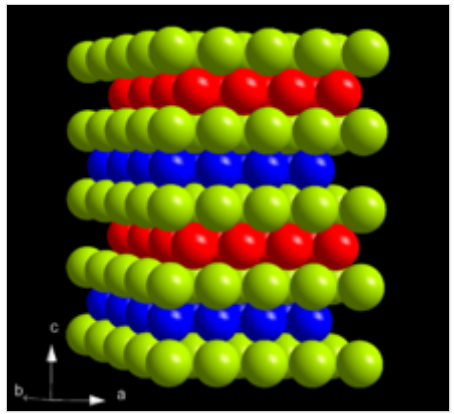
beyond curium.[9] This crystal structure changes with pressure and temperature. When compressed at room temperature to 7 GPa, α-berkelium transforms to the beta modification, which has a face-centered cubic (*fcc*) symmetry and space group $Fm\bar{3}m$. This transition occurs without change in volume, but the enthalpy increases by 3.66 kJ/mol.[10] Upon further compression to 25 GPa, berkelium transforms to an orthorhombic γ-berkelium structure similar to that of α-uranium. This transition is accompanied by a 12% volume decrease and delocalization of the electrons at the 5f electron shell.[11] No further phase transitions are observed up to 57 GPa.[3][12]

Upon heating, α-berkelium transforms into another phase with an *fcc* lattice (but slightly different from β-berkelium), space group $Fm\bar{3}m$ and the lattice constant of 500 pm; this *fcc* structure is equivalent to the closest packing with the sequence ABC. This phase is metastable and will gradually revert to the original α-berkelium phase at room temperature.[9] The temperature of the phase transition is believed to be quite close to the melting point.[13][14][15]

iso	NA	half-life	DM	DE (MeV)	DP
^{245}Bk	syn	4.94 d	ε	0.810	^{245}Cm
			α	6.455	^{241}Am
^{246}Bk	syn	1.8 d	α	6.070	^{242}Am
			ε	1.350	^{246}Cm
^{247}Bk	syn	1380 y	α	5.889	^{243}Am
^{248}Bk	syn	>300 y[1]	α	5.803	^{244}Am
^{249}Bk	syn	330 d	α	5.526	^{245}Am
			SF	–	–
			β^-	0.125	^{249}Cf

Chemical

Like all actinides, berkelium dissolves in various aqueous inorganic acids, liberating gaseous hydrogen and converting into the berkelium(III) state. This trivalent oxidation state (+3) is the most stable, especially in aqueous solutions, but tetravalent (+4) and possibly divalent (+2) berkelium compounds are also known. The existence of divalent berkelium salts is uncertain and has only been reported in mixed lanthanum chloride-strontium chloride melts.[16][17] A similar behavior is observed for the lanthanide analogue of berkelium, terbium.[18] Aqueous solutions of Bk^{3+} ions are green in most acids. The color of Bk^{4+} ions is yellow in hydrochloric acid and orange-yellow in sulfuric acid.[16][19][20] Berkelium does not react rapidly with oxygen at room temperature, possibly due to the formation of a protective oxide layer surface. However, it reacts with molten metals, hydrogen, halogens, chalcogens and pnictogens to form various binary compounds.[6][13]



Double-hexagonal close packing with the layer sequence ABAC in the crystal structure of α-berkelium (A: green, B: blue, C: red)

Isotopes

About twenty isotopes and six nuclear isomers (excited states of an isotope) of berkelium have been characterized with the mass numbers ranging from 235 to 254. All of them are radioactive. The longest half-lives are observed for ^{247}Bk (1,380 years), ^{248}Bk (over 300 years) and ^{249}Bk (330 days); the half-lives of the other isotopes range from microseconds to several days. The isotope which is the easiest to synthesize is berkelium-249. This emits mostly soft β-particles which are inconvenient for detection. Its alpha radiation is rather weak – 1.45×10^{-3}% with respect to the β-radiation – but is sometimes used to detect this isotope. The second important berkelium isotope, berkelium-247, is an alpha-emitter, as are most actinide isotopes.[21][22]

Occurrence

All berkelium isotopes have a half-life far too short to be primordial. Therefore, any primordial berkelium, that is, berkelium present on the Earth during its formation, has decayed by now.

On Earth, berkelium is mostly concentrated in certain areas, which were used for the atmospheric nuclear weapons tests between 1945 and 1980, as well as at the sites of nuclear incidents, such as the Chernobyl disaster, Three Mile Island accident and 1968 Thule Air Base B-52 crash. Analysis of the debris at the testing site of the first U.S. hydrogen bomb, Ivy Mike, (1 November 1952, Enewetak Atoll), revealed high concentrations of various actinides, including berkelium. For reasons of military secrecy, this result was published only in 1956.[23]

Nuclear reactors produce mostly, among the berkelium isotopes, berkelium-249. During the storage and before the fuel disposal, most of it beta decays to californium-249. The latter has a half-life of 351 years, which is relatively long when compared to the other isotopes produced in the reactor,[24] and is therefore undesirable in the disposal products.

The transuranic elements from americium to fermium, including berkelium, occurred naturally in the natural nuclear fission reactor at Oklo, but no longer do so.[25]

External links

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