= Americium =

Americium is a radioactive transuranic chemical element with symbol Am and atomic number 95 . This member of the actinide series is located in the periodic table under the lanthanide element europium , and thus by analogy was named after the Americas .

Americium was first produced in 1944 by the group of Glenn T. Seaborg from Berkeley , California , at the metallurgical laboratory of University of Chicago . Although it is the third element in the transuranic series , it was discovered fourth , after the heavier curium . The discovery was kept secret and only released to the public in November 1945 . Most americium is produced by uranium or plutonium being bombarded with neutrons in nuclear reactors ? one tonne of spent nuclear fuel contains about 100 grams of americium . It is widely used in commercial ionization chamber smoke detectors , as well as in neutron sources and industrial gauges . Several unusual applications , such as nuclear batteries or fuel for space ships with nuclear propulsion , have been proposed for the isotope 242mAm , but they are as yet hindered by the scarcity and high price of this nuclear isomer .

Americium is a relatively soft radioactive metal with silvery appearance . Its common isotopes are 241Am and 243Am . In chemical compounds , americium usually assumes the oxidation state + 3 , especially in solutions . Several other oxidation states are known , which range from + 2 to + 8 and can be identified by their characteristic optical absorption spectra . The crystal lattice of solid americium and its compounds contain small instrinsic radiogenic defects , due to metamicitization induced by self @-@ irradiation with alpha particles , which accumulates with time ; this can cause a drift of some material properties over time , more noticeable in older samples .

= = History = =

Although americium was likely produced in previous nuclear experiments , it was first intentionally synthesized , isolated and identified in late autumn 1944 , at the University of California , Berkeley , by Glenn T. Seaborg , Leon O. Morgan , Ralph A. James , and Albert Ghiorso . They used a 60 @-@ inch cyclotron at the University of California , Berkeley . The element was chemically identified at the Metallurgical Laboratory (now Argonne National Laboratory) of the University of Chicago . Following the lighter neptunium , plutonium , and heavier curium , americium was the fourth transuranium element to be discovered . At the time , the periodic table had been restructured by Seaborg to its present layout , containing the actinide row below the lanthanide one . This led to americium being located right below its twin lanthanide element europium ; it was thus by analogy named after the Americas : " The name americium (after the Americas) and the symbol Am are suggested for the element on the basis of its position as the sixth member of the actinide rare @-@ earth series , analogous to europium , Eu , of the lanthanide series . "

The new element was isolated from its oxides in a complex , multi @-@ step process . First plutonium @-@ 239 nitrate (239PuNO3) solution was coated on a platinum foil of about 0 @.@ 5 cm2 area , the solution was evaporated and the residue was converted into plutonium dioxide (PuO2) by annealing . After cyclotron irradiation , the coating was dissolved with nitric acid , and then precipitated as the hydroxide using concentrated aqueous ammonia solution . The residue was dissolved in perchloric acid . Further separation was carried out by ion exchange , yielding a certain isotope of curium . The separation of curium and americium was so painstaking that those elements were initially called by the Berkeley group as pandemonium (from Greek for all demons or hell) and delirium (from Latin for madness) .

Initial experiments yielded four americium isotopes : 241Am , 242Am , 239Am and 238Am . Americium @-@ 241 was directly obtained from plutonium upon absorption of one neutron . It decays by emission of a ? @-@ particle to 237Np ; the half @-@ life of this decay was first determined as 510 ± 20 years but then corrected to 432 @.@ 2 years .

<formula>

The times are half @-@ lives

The second isotope 242Am was produced upon neutron bombardment of the already @-@ created

241Am . Upon rapid ? @-@ decay , 242Am converts into the isotope of curium 242Cm (which had been discovered previously) . The half @-@ life of this decay was initially determined at 17 hours , which was close to the presently accepted value of 16 @.@ 02 h .
<formula>
The discovery of americium and curium in 1944 was closely related to the Manhattan Project ; the results were confidential and declassified only in 1945 . Seaborg leaked the synthesis of the elements 95 and 96 on the U.S. radio show for children Quiz Kids five days before the official presentation at an American Chemical Society meeting on 11 November 1945 , when one of the listeners asked whether any new transuranium element beside plutonium and neptunium had been discovered during the war . After the discovery of americium isotopes 241Am and 242Am , their production and compounds were patented listing only Seaborg as the inventor . The initial americium samples weighed a few micrograms ; they were barely visible and were identified by their radioactivity . The first substantial amounts of metallic americium weighing 40 ? 200 micrograms were not prepared until 1951 by reduction of americium (III) fluoride with barium metal in high vacuum at 1100 ° C.

= = Occurrence = =

The longest @-@ lived and most common isotopes of americium , 241Am and 243Am , have half @-@ lives of 432 @.@ 2 and 7 @,@ 370 years , respectively . Therefore , any primordial americium (americium that was present on Earth during its formation) should have decayed by now .
Existing americium is concentrated in the areas used for the atmospheric nuclear weapons tests conducted between 1945 and 1980 , as well as at the sites of nuclear incidents , such as the Chernobyl disaster . For example , the 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 americium ; but due to military secrecy , this result was published only until later in 1956 . Trinitite , the glassy residue left on the desert floor near Alamogordo , New Mexico , after the plutonium @-@ based Trinity nuclear bomb test on 16 July 1945 , contains traces of americium @-@ 241 . Elevated levels of americium were also detected at the crash site of a US Boeing B @-@ 52 bomber aircraft , which carried four hydrogen bombs , in 1968 in Greenland .
In other regions , the average radioactivity of surface soil due to residual americium is only about 0 @.@ 01 picocuries / g (0 @.@ 37 mBq / g) . Atmospheric americium compounds are poorly soluble in common solvents and mostly adhere to soil particles . Soil analysis revealed about 1 @,@ 900 times higher concentration of americium inside sandy soil particles than in the water present in the soil pores ; an even higher ratio was measured in loam soils .
Americium is produced mostly artificially in small quantities , for research purposes . A tonne of spent nuclear fuel contains about 100 grams of various americium isotopes , mostly 241Am and 243Am . Their prolonged radioactivity is undesirable for the disposal , and therefore americium , together with other long @-@ lived actinides , must be neutralized . The associated procedure may involve several steps , where americium is first separated and then converted by neutron bombardment in special reactors to short @-@ lived nuclides . This procedure is well known as nuclear transmutation , but it is still being developed for americium . The transuranic elements from americium to fermium occurred naturally in the natural nuclear fission reactor at Oklo , but no longer do so .

= = Synthesis and extraction = =

= = = Isotope nucleosyntheses = = =

Americium has been produced in small quantities in nuclear reactors for decades , and kilograms of its 241Am and 243Am isotopes have been accumulated by now . Nevertheless , since it was first

offered for sale in 1962 , its price , about 1 @,@ 500 USD per gram of 241Am , remains almost unchanged owing to the very complex separation procedure . The heavier isotope 243Am is produced in much smaller amounts ; it is thus more difficult to separate , resulting in a higher cost of the order 100 @,@ 000 ? 160 @,@ 000 USD / g .

Americium is not synthesized directly from uranium ? the most common reactor material ? but from the plutonium isotope 239Pu . The latter needs to be produced first , according to the following nuclear process :

<formula>

The capture of two neutrons by 239Pu (a so @-@ called (n , ?) reaction) , followed by a ? @-@ decay , results in 241Am :

<formula>

The plutonium present in spent nuclear fuel contains about 12 % of 241Pu . Because it spontaneously converts to 241Am , 241Pu can be extracted and may be used to generate further 241Am . However , this process is rather slow : half of the original amount of 241Pu decays to 241Am after about 15 years , and the 241Am amount reaches a maximum after 70 years .

The obtained 241Am can be used for generating heavier americium isotopes by further neutron capture inside a nuclear reactor . In a light water reactor (LWR) , 79 % of 241Am converts to 242Am and 10 % to its nuclear isomer 242mAm :

79 % : <formula>

10 % : <formula>

Americium @-@ 242 has a half @-@ life of only 16 hours , which makes its further up @-@ conversion to 243Am , extremely inefficient . The latter isotope is produced instead in a process where 239Pu captures four neutrons under high neutron flux :

<formula>

= = = Metal generation = = =

Most synthesis routines yield a mixture of different actinide isotopes in oxide forms , from which isotopes of americium can be separated . In a typical procedure , the spent reactor fuel (e.g. MOX fuel) is dissolved in nitric acid , and the bulk of uranium and plutonium is removed using a PUREX @-@ type extraction (Plutonium ? URanium EXtraction) with tributyl phosphate in a hydrocarbon . The lanthanides and remaining actinides are then separated from the aqueous residue (raffinate) by a diamide @-@ based extraction , to give , after stripping , a mixture of trivalent actinides and lanthanides . Americium compounds are then selectively extracted using multi @-@ step chromatographic and centrifugation techniques with an appropriate reagent . A large amount of work has been done on the solvent extraction of americium . For example , a 2003 EU @-@ funded project codenamed " EUROPART " studied triazines and other compounds as potential extraction agents . A bis @-@ triazinyl bipyridine complex was proposed in 2009 as such a reagent is highly selective to americium (and curium) . Separation of americium from the highly similar curium can be achieved by treating a slurry of their hydroxides in aqueous sodium bicarbonate with ozone , at elevated temperatures . Both Am and Cm are mostly present in solutions in the + 3 valence state ; whereas curium remains unchanged , americium oxidizes to soluble Am (IV) complexes which can be washed away .

Metallic americium is obtained by reduction from its compounds . Americium (III) fluoride was first used for this purpose . The reaction was conducted using elemental barium as reducing agent in a water- and oxygen @-@ free environment inside an apparatus made of tantalum and tungsten .

<formula>

An alternative is the reduction of americium dioxide by metallic lanthanum or thorium :

<formula>

= = Physical properties = =

In the periodic table , americium is located to the right of plutonium , to the left of curium , and

below the lanthanide europium , with which it shares many similarities in physical and chemical properties . Americium is a highly radioactive element . When freshly prepared , it has a silvery @-@ white metallic lustre , but then slowly tarnishes in air . With a density of 12 g / cm3 , americium is less dense than both curium (13 @.@ 52 g / cm3) and plutonium (19 @.@ 8 g / cm3) ; but has a higher density than europium (5 @.@ 264 g / cm3) ? mostly because of its higher atomic mass . Americium is relatively soft and easily deformable and has a significantly lower bulk modulus than the actinides before it : Th , Pa , U , Np and Pu . Its melting point of 1173 ° C is significantly higher than that of plutonium (639 ° C) and europium (826 ° C) , but lower than for curium (1340 ° C) .