= Actinide =

The actinide / ?ækt?na?d / or actinoid / ?ækt?n??d / (IUPAC nomenclature) series encompasses the 15 metallic chemical elements with atomic numbers from 89 to 103 , actinium through lawrencium .

The actinide series derives its name from the first element in the series , actinium . The informal chemical symbol An is used in general discussions of actinide chemistry to refer to any actinide . All but one of the actinides are f @-@ block elements , corresponding to the filling of the 5f electron shell ; lawrencium , a d @-@ block element , is also generally considered an actinide . In comparison with the lanthanides , also mostly f @-@ block elements , the actinides show much more variable valence . They all have very large atomic and ionic radii and exhibit an unusually large range of physical properties . While actinium and the late actinides (from americium onwards) behave similarly to the lanthanides , the elements thorium through neptunium are much more similar to transition metals in their chemistry .

All actinides are radioactive and release energy upon radioactive decay ; naturally occurring uranium and thorium , and synthetically produced plutonium are the most abundant actinides on Earth . These are used in nuclear reactors and nuclear weapons . Uranium and thorium also have diverse current or historical uses , and americium is used in the ionization chambers of most modern smoke detectors .

Of the actinides , primordial thorium and uranium occur naturally in substantial quantities and small amounts of persisting natural plutonium have also been identified . The radioactive decay of uranium produces transient amounts of actinium and protactinium , and atoms of neptunium and plutonium are occasionally produced from transmutation reactions in uranium ores . The other actinides are purely synthetic elements . Nuclear weapons tests have released at least six actinides heavier than plutonium into the environment ; analysis of debris from a 1952 hydrogen bomb explosion showed the presence of americium , curium , berkelium , californium , einsteinium and fermium .

In presentations of the periodic table , the lanthanides and the actinides are customarily shown as two additional rows below the main body of the table , with placeholders or else a selected single element of each series (either lanthanum or lutetium , and either actinium or lawrencium , respectively) shown in a single cell of the main table , between barium and hafnium , and radium and rutherfordium , respectively . This convention is entirely a matter of aesthetics and formatting practicality ; a rarely used wide @-@ formatted periodic table inserts the lanthanide and actinide series in their proper places , as parts of the table 's sixth and seventh rows (periods) .

= = Discovery , isolation and synthesis = =

Like the lanthanides , the actinides form a family of elements with similar properties . Within the actinides , there are two overlapping groups : transuranium elements , which follow uranium in the periodic table ? and transplutonium elements , which follow plutonium . Compared to the lanthanides , which (except for promethium) are found in nature in appreciable quantities , most actinides are rare . The most abundant , or easily synthesized actinides are uranium and thorium , followed by plutonium , americium , actinium , protactinium and neptunium .

The existence of transuranium elements was suggested by Enrico Fermi based on his experiments in 1934 . However , even though four actinides were known by that time , it was not yet understood that they formed a family similar to lanthanides . The prevailing view that dominated early research into transuranics was that they were regular elements in the 7th period , with thorium , protactinium and uranium corresponding to 6th @-@ period hafnium , tantalum and tungsten , respectively . Synthesis of transuranics gradually undermined this point of view . By 1944 an observation that curium failed to exhibit oxidation states above 4 (whereas its supposed 6th period homolog , platinum , can reach oxidation state of 6) prompted Glenn Seaborg to formulate a so @-@ called " actinide hypothesis " . Studies of known actinides and discoveries of further transuranic elements provided more data in support of this point of view , but the phrase " actinide hypothesis " (the

implication being that " hypothesis " is something that has not been decisively proven) remained in active use by scientists through the late 1950s .

At present , there are two major methods of producing isotopes of transplutonium elements : irradiation of the lighter elements with either neutrons or accelerated charged particles . The first method is most important for applications , as only neutron irradiation using nuclear reactors allows the production of sizeable amounts of synthetic actinides ; however , it is limited to relatively light elements . The advantage of the second method is that elements heavier than plutonium , as well as neutron @-@ deficient isotopes , can be obtained , which are not formed during neutron irradiation .

In 1962 ? 1966 , there were attempts in the United States to produce transplutonium isotopes using a series of six underground nuclear explosions . Small samples of rock were extracted from the blast area immediately after the test to study the explosion products , but no isotopes with mass number greater than 257 could be detected , despite predictions that such isotopes would have relatively long half @-@ lives of ? @-@ decay . This inobservation was attributed to spontaneous fission owing to the large speed of the products and to other decay channels , such as neutron emission and nuclear fission .

= = = From actinium to uranium = = =

Uranium and thorium were the first actinides discovered . Uranium was identified in 1789 by the German chemist Martin Heinrich Klaproth in pitchblende ore . He named it after the planet Uranus , which had been discovered only eight years earlier . Klaproth was able to precipitate a yellow compound (likely sodium diuranate) by dissolving pitchblende in nitric acid and neutralizing the solution with sodium hydroxide . He then reduced the obtained yellow powder with charcoal , and extracted a black substance that he mistook for metal . Only 60 years later , the French scientist Eugène @-@ Melchior Péligot identified it with uranium oxide . He also isolated the first sample of uranium metal by heating uranium tetrachloride with potassium . The atomic mass of uranium was then calculated as 120 , but Dmitri Mendeleev in 1872 corrected it to 240 using his periodicity laws . This value was confirmed experimentally in 1882 by K. Zimmerman .

Thorium oxide was discovered by Friedrich Wöhler in the mineral , which was found in Norway (1827) . Jöns Jacob Berzelius characterized this material in more detail by in 1828 . By reduction of thorium tetrachloride with potassium , he isolated the metal and named it thorium after the Norse god of thunder and lightning Thor . The same isolation method was later used by Péligot for uranium .

Actinium was discovered in 1899 by André @-@ Louis Debierne , an assistant of Marie Curie , in the pitchblende waste left after removal of radium and polonium . He described the substance (in 1899) as similar to titanium and (in 1900) as similar to thorium . The discovery of actinium by Debierne was however questioned in 1971 and 2000 , arguing that Debierne 's publications in 1904 contradicted his earlier work of 1899 ? 1900 . The name actinium comes from the Greek aktis , aktinos (????? , ???????) , meaning beam or ray . This metal was discovered not by its own radiation but by the radiation of the daughter products . Owing to the close similarity of actinium and lanthanum and low abundance , pure actinium could only be produced in 1950 . The term actinide was probably introduced by Victor Goldschmidt in 1937 .

Protactinium was possibly isolated in 1900 by William Crookes . It was first identified in 1913 , when Kasimir Fajans and Oswald Helmuth Göhring encountered the short @-@ lived isotope 234mPa (half @-@ life 1 @.@ 17 minutes) during their studies of the 238U decay . They named the new element brevium (from Latin brevis meaning brief) ; the name was changed to protoactinium (from Greek ?????? + ????? meaning " first beam element ") in 1918 when two groups of scientists , led by the Austrian Lise Meitner and Otto Hahn of Germany and Frederick Soddy and John Cranston of Great Britain , independently discovered 231Pa . The name was shortened to protactinium in 1949 . This element was little characterized until 1960 , when A. G. Maddock and his co @-@ workers in the U.K. produced 130 grams of protactinium from 60 tonnes of waste left after extraction of uranium from its ore .

= = = Neptunium and above = = =

Neptunium (named for the planet Neptune , the next planet out from Uranus , after which uranium was named) was discovered by Edwin McMillan and Philip H. Abelson in 1940 in Berkeley , California . They produced the 239Np isotope (half @-@ life = 2 @.@ 4 days) by bombarding uranium with slow neutrons . It was the first transuranium element produced synthetically .

Transuranium elements do not occur in sizeable quantities in nature and are commonly synthesized via nuclear reactions conducted with nuclear reactors . For example , under irradiation with reactor neutrons , uranium @-@ 238 partially converts to plutonium @-@ 239 :

<formula>

In this way , Enrico Fermi with collaborators , using the first nuclear reactor Chicago Pile @-@ 1 , obtained significant amounts of plutonium @-@ 239 , which were then used in nuclear weapons .

Actinides with the highest mass numbers are synthesized by bombarding uranium , plutonium , curium and californium with ions of nitrogen , oxygen , carbon , neon or boron in a particle accelerator . So , nobelium was produced by bombarding uranium @-@ 238 with neon @-@ 22 as

<formula> .

The first isotopes of transplutonium elements , americium @-@ 241 and curium @-@ 242 , were synthesized in 1944 by Glenn T. Seaborg , Ralph A. James and Albert Ghiorso . Curium @-@ 242 was obtained by bombarding plutonium @-@ 239 with 32 @-@ MeV ? @-@ particles

<formula> .

The americium @-@ 241 and curium @-@ 242 isotopes also were produced by irradiating plutonium in a nuclear reactor . The latter element was named after Marie Curie and her husband Pierre who are noted for discovering radium and for their work in radioactivity .

Bombarding curium @-@ 242 with ? @-@ particles resulted in an isotope of californium 245Cf (1950) , and a similar procedure yielded in 1949 berkelium @-@ 243 from americium @-@ 241 . The new elements were named after Berkeley , California , by analogy with its lanthanide homologue terbium , which was named after the village of Ytterby in Sweden .

In 1945 , B. B. Cunningham obtained the first bulk chemical compound of a transplutonium element , namely americium hydroxide . Over the next three to four years , milligram quantities of americium and microgram amounts of curium were accumulated that allowed production of isotopes of berkelium (Thomson , 1949) and californium (Thomson , 1950) . Sizeable amounts of these elements were produced only in 1958 (Burris B. Cunningham and Stanley G. Thomson) , and the first californium compound (0 @.@ 3 µg of CfOCl) was obtained only in 1960 by B. B. Cunningham and J. C. Wallmann .

Einsteinium and fermium were identified in 1952 ? 1953 in the fallout from the " Ivy Mike " nuclear test (1 November 1952) , the first successful test of a hydrogen bomb . Instantaneous exposure of uranium @-@ 238 to a large neutron flux resulting from the explosion produced heavy isotopes of uranium , including uranium @-@ 253 and uranium @-@ 255 , and their ? @-@ decay yielded einsteinium @-@ 253 and fermium @-@ 255 . The discovery of the new elements and the new data on neutron capture were initially kept secret on the orders of the U.S. military until 1955 due to Cold War tensions . Nevertheless , the Berkeley team were able to prepare einsteinium and fermium by civilian means , through the neutron bombardment of plutonium @-@ 239 , and published this work in 1954 with the disclaimer that it was not the first studies that had been carried out on the elements . The " Ivy Mike " studies were declassified and published in 1955 . The first significant (submicrograms) amounts of einsteinium were produced in 1961 by Cunningham and colleagues , but this has not been done for fermium yet .

The first isotope of mendelevium , 256Md (half @-@ life 87 min) , was synthesized by Albert Ghiorso , Glenn T. Seaborg , Gregory R. Choppin , Bernard G. Harvey and Stanley G. Thompson when they bombarded an 253Es target with alpha particles in the 60 @-@ inch cyclotron of Berkeley Radiation Laboratory ; this was the first isotope of any element to be synthesized one atom at a time .

There were several attempts to obtain isotopes of nobelium by Swedish (1957) and American (1958) groups , but the first reliable result was the synthesis of 256No by the Russian group (

Georgy Flyorov et al .) in 1965 , as acknowledged by the IUPAC in 1992 . In their experiments , Flyorov et al. bombarded uranium @-@ 238 with neon @-@ 22 .

In 1961 , Ghiorso et al. obtained the first isotope of lawrencium by irradiating californium (mostly californium @-@ 252) with boron @-@ 10 and boron @-@ 11 ions . The mass number of this isotope was not clearly established (possibly 258 or 259) at the time . In 1965 , 256Lr was synthesized by Flyorov et al. from 243Am and 18O . Thus IUPAC recognized the nuclear physics teams at Dubna and Berkeley as the co @-@ discoverers of lawrencium .

= = Isotopes = =

Thirty @-@ one isotopes of actinium and eight excited isomeric states of some of its nuclides were identified by 2010 . Three isotopes , 225Ac , 227Ac and 228Ac , were found in nature and the others were produced in the laboratory ; only the three natural isotopes are used in applications . Actinium @-@ 225 is a member of radioactive neptunium series ; it was first discovered in 1947 as a decay product of uranium @-@ 233 , it is an ? @-@ emitter with a half @-@ life of 10 days . Actinium @-@ 225 is less available than actinium @-@ 228 , but is more promising in radiotracer applications . Actinium @-@ 227 (half @-@ life 21 @.@ 77 years) occurs in all uranium ores , but in small quantities . One gram of uranium (in radioactive equilibrium) contains only 2 × 10 ? 10 gram of 227Ac . Actinium @-@ 228 is a member of radioactive thorium series formed by the decay of 228Ra ; it is a ? ? emitter with a half @-@ life of 6 @.@ 15 hours . In one tonne of thorium there is 5 × 10 ? 8 gram of 228Ac . It was discovered by Otto Hahn in 1906 .

Twenty nine isotopes of protactinium are known with mass numbers 212 ? 240 as well as three excited isomeric states . Only 231Pa and 234Pa have been found in nature . All the isotopes have short lifetime , except for protactinium @-@ 231 (half @-@ life 32 @,@ 760 years) . The most important isotopes are 231Pa and 233Pa , which is an intermediate product in obtaining uranium @-@ 233 and is the most affordable among artificial isotopes of protactinium . 233Pa has convenient half @-@ life and energy of ? @-@ radiation , and thus was used in most studies of protactinium chemistry . Protactinium @-@ 233 is a ? @-@ emitter with a half @-@ life of 26 @.@ 97 days .

Uranium has the highest number (25) of both natural and synthetic isotopes . They have mass numbers of 217 ? 242 , and three of them , 234U , 235U and 238U , are present in appreciable quantities in nature . Among others , the most important is 233U , which is a final product of transformations of 232Th irradiated by slow neutrons . 233U has a much higher fission efficiency by low @-@ energy (thermal) neutrons , compared e.g. with 235U . Most uranium chemistry studies were carried out on uranium @-@ 238 owing to its long half @-@ life of 4 @.@ 4 × 109 years .