= 712 @.@ 1 ± 0 @.@ 3 pm . They can also be prepared by reacting metallic americium with an appropriate mercury halide HgX2 , where X =
Cl , Br or I :
<formula>
Americium (III) fluoride (AmF3) is poorly soluble and precipitates upon reaction of Am3 + and fluoride ions in weak acidic solutions :
<formula>
The tetravalent americium (IV) fluoride (AmF4) is obtained by reacting solid americium (III) fluoride with molecular fluorine :
<formula>
Another known form of solid tetravalent americium chloride is KAmF5 . Tetravalent americium has also been observed in the aqueous phase . For this purpose , black Am (OH) 4 was dissolved in 15 @-@ M NH3F with the americium concentration of 0 @.@ 01 M. The resulting reddish solution had a characteristic optical absorption spectrum which is similar to that of AmF4 but differed from other oxidation states of americium . Heating the Am (IV) solution to 90 ° C did not result in its disproportionation or reduction , however a slow reduction was observed to Am (III) and assigned to self @-@ irradiation of americium by alpha particles .
Most americium (III) halides form hexagonal crystals with slight variation of the color and exact structure between the halogens . So , chloride (AmCl3) is reddish and has a structure isotypic to uranium (III) chloride (space group P63 / m) and the melting point of 715 ° C. The fluoride is isotypic to LaF3 (space group P63 / mmc) and the iodide to BiI3 (space group R3) . The bromide is an exception with the orthorhombic PuBr3 @-@ type structure and space group Cmcm . Crystals of americium hexahydrate (AmCl3 · 6H2O) can be prepared by dissolving americium dioxide in hydrochloric acid and evaporating the liquid . Those crystals are hygroscopic and have yellow @-@ reddish color and a monoclinic crystal structure .
Oxyhalides of americium in the form AmVIO2X2 , AmVO2X , AmIVOX2 and AmIIIOX can be obtained by reacting the corresponding americium halide with oxygen or Sb2O3 , and AmOCl can also be produced by vapor phase hydrolysis :
<formula>

= = = Chalcogenides and pnictides = = =

The known chalcogenides of americium include the sulfide AmS2 , selenides AmSe2 and Am3Se4 , and tellurides Am2Te3 and AmTe2 . The pnictides of americium (243Am) of the AmX type are known for the elements phosphorus , arsenic , antimony and bismuth . They crystallize in the rock @-@ salt lattice .

= = = Silicides and borides = = =

Americium monosilicide (AmSi) and " disilicide " (nominally AmSix with : 1 @.@ 87 < x < 2 @.@ 0) were obtained by reduction of americium (III) fluoride with elementary silicon in vacuum at 1050 ° C (AmSi) and 1150 ? 1200 ° C (AmSix) . AmSi is a black solid isomorphic with LaSi , it has an orthorhombic crystal symmetry . AmSix has a bright silvery lustre and a tetragonal crystal lattice (space group I41 / amd) , it is isomorphic with PuSi2 and ThSi2 . Borides of americium include AmB4 and AmB6 . The tetraboride can be obtained by heating an oxide or halide of americium with magnesium diboride in vacuum or inert atmosphere .

= = = Organoamericium compounds = = =

Analogous to uranocene , americium forms the organometallic compound amerocene with two cyclooctatetraene ligands , with the chemical formula (?8 @-@ C8H8) 2Am . It also makes the trigonal tricyclopentadienylamericium [(?5 @-@ C5H5) 3Am)] complex with three cyclopentadienyl rings surrounding one atom of americium .

Formation of the complexes of the type Am (n @-@ C3H7 @-@ BTP) 3 , where BTP stands for 2 @,@ 6 @-@ di (1 @,@ 2 @,@ 4 @-@ triazin @-@ 3 @-@ yl) pyridine , in solutions containing n @-@ C3H7 @-@ BTP and Am3 + ions has been confirmed by EXAFS . Some of these BTP @-@ type complexes selectively interact with americium and therefore are useful in its selective separation from lanthanides and another actinides .

= = Biological aspects = =

Americium is an artificial element of recent origin , and thus does not have a biological requirement . It is harmful to life . It has been proposed to use bacteria for removal of americium and other heavy metals from rivers and streams . Thus , Enterobacteriaceae of the genus Citrobacter precipitate americium ions from aqueous solutions , binding them into a metal @-@ phosphate complex at their cell walls . Several studies have been reported on the biosorption and bioaccumulation of americium by bacteria and fungi .

= = Fission = =

The isotope 242mAm (half @-@ life 141 years) has the largest cross sections for absorption of thermal neutrons (5 @,@ 700 barns) , that results in a small critical mass for a sustained nuclear chain reaction . The critical mass for a bare 242mAm sphere is about 9 ? 14 kg (the uncertainty results from insufficient knowledge of its material properties) . It can be lowered to 3 ? 5 kg with a metal reflector and should become even smaller with a water reflector . Such small critical mass is favorable for portable nuclear weapons , but those based on 242mAm are not known yet , probably because of its scarcity and high price . The critical masses of two other readily available isotopes , 241Am and 243Am , are relatively high ? 57 @.@ 6 to 75 @.@ 6 kg for 241Am and 209 kg for 243Am . Scarcity and high price yet hinder application of americium as a nuclear fuel in nuclear reactors .
There are proposals of very compact 10 @-@ kW high @-@ flux reactors using as little as 20 grams of 242mAm . Such low @-@ power reactors would be relatively safe to use as neutron sources for radiation therapy in hospitals .

= = Isotopes = =

About 19 isotopes and 8 nuclear isomers are known for americium . There are two long @-@ lived alpha @-@ emitters , 241Am and 243Am with half @-@ lives of 432 @.@ 2 and 7 @,@ 370 years , respectively , and the nuclear isomer 242m1Am has a long half @-@ life of 141 years . The half @-@ lives of other isotopes and isomers range from 0 @.@ 64 microseconds for 245m1Am to 50 @.@ 8 hours for 240Am . As with most other actinides , the isotopes of americium with odd number of neutrons have relatively high rate of nuclear fission and low critical mass .
Americium @-@ 241 decays to 237Np emitting alpha particles of 5 different energies , mostly at 5 @.@ 486 MeV (85 @.@ 2 %) and 5 @.@ 443 MeV (12 @.@ 8 %) . Because many of the resulting states are metastable , they also emit gamma rays with the discrete energies between 26 @.@ 3 and 158 @.@ 5 keV .
Americium @-@ 242 is a short @-@ lived isotope with a half @-@ life of 16 @.@ 02 h . It mostly (82 @.@ 7 %) converts by ? @-@ decay to 242Cm , but also by electron capture to 242Pu (17 @.@ 3 %) . Both 242Cm and 242Pu transform via nearly the same decay chain through 238Pu down to 234U .
Nearly all (99 @.@ 541 %) of 242m1Am decays by internal conversion to 242Am and the remaining 0 @.@ 459 % by ? @-@ decay to 238Np . The latter breaks down to 238Pu and then to 234U .
Americium @-@ 243 transforms by ? @-@ emission into 239Np , which converts by ? @-@ decay to 239Pu , and the 239Pu changes into 235U by emitting an ? @-@ particle .

Applications

Ionization @-@ type smoke detector

Americium is the only synthetic element to have found its way into the household , where the most common type of smoke detector uses 241Am in the form of americium dioxide as its source of ionizing radiation . This isotope is preferred over 226Ra because it emits 5 times more alpha particles and relatively little harmful gamma radiation . Element collector Theodore Gray mentions in his book The Elements : A Visual Exploration of Every Known Atom in the Universe " You might think that a synthetic radioactive element that follows plutonium (94) ? and has a significantly shorter half @-@ life ? would be some kind of superbomb material , available only to scientists in secret laboratories . Perhaps a mad scientist is studying americium in a lair somewhere , but if you want some yourself you can simply walk into any neighborhood hardware store , supermarket , or Wal @-@ Mart and buy some , no questions asked . " He also adds " The reason is not that americium is fundamentally less dangerous than the elements around it . In fact , the commonly available isotope , 241Am , is significantly more radioactive than weapons @-@ grade plutonium , and at least as toxic . No , the difference is simply that there is a useful application for americium that requires only a very tiny amount , and for which a company was prepared to go through the effort required to carve out and get a regulatory exception . " The amount of americium in a typical new smoke detector is 1 microcurie (37 kBq) or 0 @.@ 29 microgram . This amount declines slowly as the americium decays into neptunium @-@ 237 , a different transuranic element with a much longer half @-@ life (about 2 @.@ 14 million years) . With its half @-@ life of 432 @.@ 2 years , the americium in a smoke detector includes about 3 % neptunium after 19 years , and about 5 % after 32 years . The radiation passes through an ionization chamber , an air @-@ filled space between two electrodes , and permits a small , constant current between the electrodes . Any smoke that enters the chamber absorbs the alpha particles , which reduces the ionization and affects this current , triggering the alarm . Compared to the alternative optical smoke detector , the ionization smoke detector is cheaper and can detect particles which are too small to produce significant light scattering ; however , it is more prone to false alarms .

Radionuclide

As 241Am has a roughly similar half @-@ life to 238Pu (432 @.@ 2 years vs. 87 years) , it has been proposed as an active element of radioisotope thermoelectric generators , for example in spacecraft . Although americium produces less heat and electricity ? the power yield is 114 @.@ 7 mW / g for 241Am and 6 @.@ 31 mW / g for 243Am (cf . 390 mW / g for 238Pu) ? and its radiation poses more threat to humans owing to neutron emission , the European Space Agency is considering using americium for its space probes .

Another proposed space @-@ related application of americium is a fuel for space ships with nuclear propulsion . It relies on the very high rate of nuclear fission of 242mAm , which can be maintained even in a micrometer @-@ thick foil . Small thickness avoids the problem of self @-@ absorption of emitted radiation . This problem is pertinent to uranium or plutonium rods , in which only surface layers provide alpha @-@ particles . The fission products of 242mAm can either directly propel the spaceship or they can heat up a thrusting gas ; they can also transfer their energy to a fluid and generate electricity through a magnetohydrodynamic generator .

One more proposal which utilizes the high nuclear fission rate of 242mAm is a nuclear battery . Its design relies not on the energy of the emitted by americium alpha particles , but on their charge , that is the americium acts as the self @-@ sustaining " cathode " . A single 3 @.@ 2 kg 242mAm charge of such battery could provide about 140 kW of power over a period of 80 days . With all the potential benefits , the current applications of 242mAm are as yet hindered by the scarcity and high price of this nuclear isomer .

=== Neutron source ===

The oxide of 241Am pressed with beryllium is an efficient neutron source . Here americium acts as the alpha source , and beryllium produces neutrons owing to its large cross @-@ section for the (? , n) nuclear reaction :
<formula>
<formula>
The most widespread use of 241AmBe neutron sources is a neutron probe ? a device used to measure the quantity of water present in soil , as well as moisture / density for quality control in highway construction . 241Am neutron sources are also used in well logging applications , as well as in neutron radiography , tomography and other radiochemical investigations .

=== Production of other elements ===

Americium is a starting material for the production of other transuranic elements and transactinides ? for example , 82 @.@ 7 % of 242Am decays to 242Cm and 17 @.@ 3 % to 242Pu . In the nuclear reactor , 242Am is also up @-@ converted by neutron capture to 243Am and 244Am , which transforms by ? @-@ decay to 244Cm :
<formula>
Irradiation of 241Am by 12C or 22Ne ions yields the isotopes 247Es (einsteinium) or 260Db (dubnium) , respectively . Furthermore , the element berkelium (243Bk isotope) had been first intentionally produced and identified by bombarding 241Am with alpha particles , in 1949 , by the same Berkeley group , using the same 60 @-@ inch cyclotron . Similarly , nobelium was produced at the Joint Institute for Nuclear Research , Dubna , Russia , in 1965 in several reactions , one of which included irradiation of 243Am with 15N ions . Besides , one of the synthesis reactions for lawrencium , discovered by scientists at Berkeley and Dubna , included bombardment of 243Am with 18O .

=== Spectrometer ===

Americium @-@ 241 has been used as a portable source of both gamma rays and alpha particles for a number of medical and industrial uses . The 59 @.@ 5409 keV gamma ray emissions from 241Am in such sources can be used for indirect analysis of materials in radiography and X @-@ ray fluorescence spectroscopy , as well as for quality control in fixed nuclear density gauges and nuclear densometers . For example , the element has been employed to gauge glass thickness to help create flat glass . Americium @-@ 241 is also suitable for calibration of gamma @-@ ray spectrometers in the low @-@ energy range , since its spectrum consists of nearly a single peak and negligible Compton continuum (at least three orders of magnitude lower intensity) . Americium @-@ 241 gamma rays were also used to provide passive diagnosis of thyroid function . This medical application is however obsolete .

== Health concerns ==

As a highly radioactive element , americium and its compounds must be handled only in an appropriate laboratory under special arrangements . Although most americium isotopes predominantly emit alpha particles which can be blocked by thin layers of common materials , many of the daughter products emit gamma @-@ rays and neutrons which have a long penetration depth .
If consumed , most of the americium is excreted within a few days , with only 0 @.@ 05 % absorbed in the blood , of which roughly 45 % goes to the liver and 45 % to the bones , and the remaining 10 % is excreted . The uptake to the liver depends on the individual and increases with age . In the bones , americium is first deposited over cortical and trabecular surfaces and slowly redistributes over the bone with time . The biological half @-@ life of 241Am is 50 years in the

bones and 20 years in the liver , whereas in the gonads (testicles and ovaries) it remains permanently ; in all these organs , americium promotes formation of cancer cells as a result of its radioactivity .

Americium often enters landfills from discarded smoke detectors . The rules associated with the disposal of smoke detectors are relaxed in most jurisdictions . In 1994 , 17 @-@ year @-@ old David Hahn extracted the americium from about 100 smoke detectors in an attempt to build a breeder nuclear reactor . There have been a few cases of exposure to americium , the worst case being that of chemical operations technician Harold McCluskey , who at the age of 64 was exposed to 500 times the occupational standard for americium @-@ 241 as a result of an explosion in his lab . McCluskey died at the age of 75 of unrelated pre @-@ existing disease .