

= 346 @. @ 8 pm and c =

1124 pm , and four atoms per unit cell . The crystal consists of a double @-@ hexagonal close packing with the layer sequence ABAC and so is isotypic with ? @-@ lanthanum and several actinides such as ? @-@ curium . The crystal structure of americium changes with pressure and temperature . When compressed at room temperature to 5 GPa , ? @-@ Am transforms to the ? modification , which has a face @-@ centered cubic ( fcc ) symmetry , space group Fm3m and lattice constant a = 489 pm . This fcc structure is equivalent to the closest packing with the sequence ABC . Upon further compression to 23 GPa , americium transforms to an orthorhombic ? @-@ Am structure similar to that of ? @-@ uranium . There are no further transitions observed up to 52 GPa , except for an appearance of a monoclinic phase at pressures between 10 and 15 GPa . There is no consistency on the status of this phase in the literature , which also sometimes lists the ? , ? and ? phases as I , II and III . The ? @-@ ? transition is accompanied by a 6 % decrease in the crystal volume ; although theory also predicts a significant volume change for the ? @-@ ? transition , it is not observed experimentally . The pressure of the ? @-@ ? transition decreases with increasing temperature , and when ? @-@ americium is heated at ambient pressure , at 770 ° C it changes into an fcc phase which is different from ? @-@ Am , and at 1075 ° C it converts to a body @-@ centered cubic structure . The pressure @-@ temperature phase diagram of americium is thus rather similar to those of lanthanum , praseodymium and neodymium .

As with many other actinides , self @-@ damage of the crystal lattice due to alpha @-@ particle irradiation is intrinsic to americium . It is especially noticeable at low temperatures , where the mobility of the produced lattice defects is relatively low , by broadening of X @-@ ray diffraction peaks . This effect makes somewhat uncertain the temperature of americium and some of its properties , such as electrical resistivity . So for americium @-@ 241 , the resistivity at 4 @. @ 2 K increases with time from about 2 μOhm · cm to 10 μOhm · cm after 40 hours , and saturates at about 16 μOhm · cm after 140 hours . This effect is less pronounced at room temperature , due to annihilation of radiation defects ; also heating to room temperature the sample which was kept for hours at low temperatures restores its resistivity . In fresh samples , the resistivity gradually increases with temperature from about 2 μOhm · cm at liquid helium to 69 μOhm · cm at room temperature ; this behavior is similar to that of neptunium , uranium , thorium and protactinium , but is different from plutonium and curium which show a rapid rise up to 60 K followed by saturation . The room temperature value for americium is lower than that of neptunium , plutonium and curium , but higher than for uranium , thorium and protactinium .

Americium is paramagnetic in a wide temperature range , from that of liquid helium , to room temperature and above . This behavior is markedly different from that of its neighbor curium which exhibits antiferromagnetic transition at 52 K. The thermal expansion coefficient of americium is slightly anisotropic and amounts to ( 7 @. @ 5 ± 0 @. @ 2 ) × 10 ? 6 / ° C along the shorter a axis and ( 6 @. @ 2 ± 0 @. @ 4 ) × 10 ? 6 / ° C for the longer c hexagonal axis . The enthalpy of dissolution of americium metal in hydrochloric acid at standard conditions is ? 620 @. @ 6 ± 1 @. @ 3 kJ / mol , from which the standard enthalpy change of formation ( ?fH ° ) of aqueous Am<sup>3+</sup> + ion is ? 621 @. @ 2 ± 2 @. @ 0 kJ / mol ? 1 . The standard potential Am<sup>3+</sup> + / Am<sup>0</sup> is ? 2 @. @ 08 ± 0 @. @ 01 V.

= = Chemical properties = =

Americium readily reacts with oxygen and dissolves well in acids . The most common oxidation state for americium is + 3 , in which americium compounds are rather stable against oxidation and reduction . In this sense , americium is chemically similar to most lanthanides . The trivalent americium forms insoluble fluoride , oxalate , iodate , hydroxide , phosphate and other salts . Other oxidation states have been observed between + 2 and + 7 , which is the widest range among the actinide elements . Their color in aqueous solutions varies as follows : Am<sup>3+</sup> + ( colorless to yellow @-@ reddish ) , Am<sup>4+</sup> + ( yellow @-@ reddish ) , AmVO<sup>2+</sup> + 2 ; ( yellow ) , AmVIO<sup>2+</sup> + 2 ( brown ) and AmVIIO<sup>5+</sup> ?

6 ( dark green ) . All oxidation states have their characteristic optical absorption spectra , with a few sharp peaks in the visible and mid @-@ infrared regions , and the position and intensity of these peaks can be converted into the concentrations of the corresponding oxidation states . For example , Am ( III ) has two sharp peaks at 504 and 811 nm , Am ( V ) at 514 and 715 nm , and Am ( VI ) at 666 and 992 nm .

Americium compounds with oxidation state + 4 and higher are strong oxidizing agents , comparable in strength to the permanganate ion (  $\text{MnO}_4^-$  )

4 ) in acidic solutions . Whereas the  $\text{Am}^{4+}$  ions are unstable in solutions and readily convert to  $\text{Am}^{3+}$  , the + 4 oxidation state occurs well in solids , such as americium dioxide (  $\text{AmO}_2$  ) and americium ( IV ) fluoride (  $\text{AmF}_4$  ) .

All pentavalent and hexavalent americium compounds are complex salts such as  $\text{KAmO}_2\text{F}_2$  ,  $\text{Li}_3\text{AmO}_4$  and  $\text{Li}_6\text{AmO}_6$  ,  $\text{Ba}_3\text{AmO}_6$  ,  $\text{AmO}_2\text{F}_2$  . These high oxidation states Am ( IV ) , Am ( V ) and Am ( VI ) can be prepared from Am ( III ) by oxidation with ammonium persulfate in dilute nitric acid , with silver ( I ) oxide in perchloric acid , or with ozone or sodium persulfate in sodium carbonate solutions . The pentavalent oxidation state of americium was first observed in 1951 . It is present in aqueous solution in the form of  $\text{AmO}^{2+}$

2 ions ( acidic ) or  $\text{AmO}^+$

3 ions ( alkaline ) which are however unstable and subject to several rapid disproportionation reactions :

<formula>

<formula>

= = Chemical compounds = =

= = = Oxygen compounds = = =

Three americium oxides are known , with the oxidation states + 2 (  $\text{AmO}$  ) , + 3 (  $\text{Am}_2\text{O}_3$  ) and + 4 (  $\text{AmO}_2$  ) . Americium ( II ) oxide was prepared in minute amounts and has not been characterized in details . Americium ( III ) oxide is a red @-@ brown solid with a melting point of 2205 ° C. Americium ( IV ) oxide is the main form of solid americium which is used in nearly all its applications . As most other actinide dioxides , it is a black solid with a cubic ( fluorite ) crystal structure .

The oxalate of americium ( III ) , vacuum dried at room temperature , has the chemical formula  $\text{Am}_2(\text{C}_2\text{O}_4)_3 \cdot 7\text{H}_2\text{O}$  . Upon heating in vacuum , it loses water at 240 ° C and starts decomposing into  $\text{AmO}_2$  at 300 ° C , the decomposition completes at about 470 ° C. The initial oxalate dissolves in nitric acid with the maximum solubility of 0 @.@ 25 g / L.

= = = Halides = = =

Halides of americium are known for the oxidation states + 2 , + 3 and + 4 , where the + 3 is most stable , especially in solutions .

Reduction of Am ( III ) compounds with sodium amalgam yields Am ( II ) salts ? the black halides  $\text{AmCl}_2$  ,  $\text{AmBr}_2$  and  $\text{AmI}_2$  . They are very sensitive to oxygen and oxidize in water , releasing hydrogen and converting back to the Am ( III ) state . Specific lattice constants are :