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**Annotated
BIBLIOGRAPHY
of
THE CHEMISTRY
and
PHYSICS
of
AMERICIUM**

by: H. W. Miller

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In memory of

Dr. Alfred Chetham-Strode, Jr.

known to most of us as

Chet

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INTRODUCTION

AN annotated bibliography of americium has been prepared to assist those interested in the chemistry and physics of this element in performing a rapid survey of the available literature. Only the non-classified literature has been abstracted. With the exception of a few papers concerned with the physiological aspects of americium, this bibliography is complete up to the year 1965.

For the most part, the information contained herein, was obtained from the *Chemical Abstracts* and the *Nuclear Science Abstracts*. The resumes given do not necessarily represent an entire summary of the papers presented since emphasis is placed only on americium, and in many instances references to other elements are omitted.

This bibliography has been divided into two main sections; chemistry and physics. The two main sections are further subdivided into specific categories. Frequently, it was difficult to determine if a paper might be designed more properly as chemistry or as physics. In instances where a paper was designated as chemistry, it was difficult also to decide if the paper was analytical chemistry or separation and purification chemistry. In such cases, the decision was left to the discretion of the author.

Each paper has been abstracted once and placed in only one section. To resolve problems of overlapping areas one must refer to the subject index. In addition to the two main divisions of chemistry and physics, an author index, a subject index, and an index of organization symbols has been provided.

SECTION I

CHEMISTRY

REFERENCES

I. HISTORY

1

THE TRANSURANIUM ELEMENTS. G. T. Seaborg and E. Segré. *Nature*, 159, 863-5 (1947).

A discussion is given of the formation, discovery, and identification of Pu, Np, Am, and Cm.

2

THE CHEMISTRY OF THE ACTINIDE ELEMENTS. J. J. Katz and G. T. Seaborg. London, Methuen and Co., Ltd., 1957, p 520.

The actinides are treated thoroughly, including important literature citations up to 1956. Sections on Ac, Th, U, Pa, Np, Pu, Am, Cm, and transcurium elements are presented which give information on history, isotopes occurrence, and isolation, properties, compounds, and properties of compounds. Data on atomic weights, x-ray energies, and nuclear spins of the actinide nuclides are appended.

3

THE FIRST ISOLATIONS OF THE TRANSURANIUM ELEMENTS - A HISTORICAL SURVEY. J. C. Wallmann. *J. Chem. Ed.*, 36, 340-3 (1959).

A history of the isolation which included purification of the element from contaminants and measurement of the property of the element is given for Pu, Np, Am, Cm, Bk, and Cf.

4

A SURVEY OF RESEARCH ON THE TRANSURANIC ELEMENTS. M. B. Waldron. *Contemporary Phys.*, 2, 385-402 (1961).

The history, behavior, production, properties, and experimental background of the transuranic elements are reviewed. For comparison, the properties of the lanthanide elements and the remaining actinide elements are discussed.

II. VAPOR PRESSURE

5

THE VAPOR PRESSURE OF AMERICIUM. N. D. Erway and O. C. Simpson. *J. Chem. Phys.*, 18, 953-7 (1950).

The vapor pressure of americium from a dilute solution in plutonium has been measured by a modification of

the Knudsen effusion method. The resulting vapor pressure for pure americium in the temperature range 1450°K to 1820°K is given by the equation

$$\log_{10} P_{\text{mm}} = 7.02 - (11,300)/T$$

6

THE VAPOR PRESSURE OF AMERICIUM TRIFLUORIDE. M. C. Jones (thesis). AECD-3270; UCRL-1438 (1951).

The vapor pressure of AmF_3 has been measured by the method of molecular effusion between 800°C and 1200°C. A ΔH_0 of sublimation of 109.4 kcal/mole was calculated from the measured vapor pressures assuming $\Delta C_p = -14$ ev. This value was also used in the calculation of the free energy of sublimation equation $\Delta F = 109,400 - 2.3(-14) T \log T - 151.1T$.

7

VAPOR PRESSURE OF AmF_3 AND Am METAL. S. C. Carniglia (thesis). UCRL-2389 (1953).

The vapor pressure of PuF_3 , AmF_3 , and Am^0 metal have been measured by a modification of the Knudsen effusion method. The vapor pressure of americium metal obeyed the equation

$$\log P_{(\text{mm})} = 7.563 - 13,162/T - \log T$$

from the melting point, 1100°K to 1450°K.

8

VAPOR PRESSURE OF AMERICIUM TRIFLUORIDE AND PLUTONIUM TRIFLUORIDE, HEATS AND FREE ENERGIES OF SUBLIMATION. S. C. Carniglia and B. B. Cunningham. *J. Am. Chem. Soc.*, 77, 1451-3 (1955).

The vapor pressure of solid AmF_3 was measured in the temperature range -1100°K to -1300°K by the Knudsen method. The experimental data together with an assumed ΔC_p of sublimation of $-14 \text{ cal mole}^{-1} \text{ deg}^{-1}$ yield ΔC_p of sublimation of $-14 \text{ cal mole}^{-1} \text{ deg}^{-1}$ yield.

AmF_3 sample D-1 $\Delta F (\text{cal}) = 112,650 + 32.24 T \log T - 155.55T$; AmF_3 sample E, $\Delta F = 112,690 + 32.24 T \log T - 155.45T$.

9

TWIN KNUDSEN EFFUSION APPARATUS FOR SMALL SAMPLES OF RADIOACTIVE MATERIAL. S. C. Carniglia and B. B. Cunningham. *Rev. Sci. Instr.*, 26, 485-8 (1955).

A twin Knudsen apparatus for the measurement of vapor pressures is described. The apparatus has been employed in the temperature range 1140°K to 142°K using approximately 1 mg samples of PuF₃, AmF₃, and Am metal. Radiometric assay of condensed effluents yielded vapor pressure data in the range 5×10^{-7} mm to 2×10^{-3} mm. This was consistent within a mean deviation of ± 5 percent.

- 10
HEAT OF SUBLIMATION OF URANIUM, NEPTUNIUM, PLUTONIUM AND AMERICIUM TETRAFLUORIDES. E. G. Chudenov and D. Ya. Choporov. NP-7516. The vapor pressure and heat of sublimation of active element fluorides were studied by means of a modified Knudsen method. Tables of sublimation heat and entropy calculated from the obtained vapor pressure values are presented.

III. THERMODYNAMICS

- 11
THE ESTIMATION OF HEATS OF FORMATION. L. Brewer. UCRL-49 (February 1948). The heats of formation of some compounds of Th, Np, and Am are estimated. The procedure is particularly suited for lanthanide and actinide elements because of the similarity of the ionic radii and types of bonding.
- 12
THE HEAT OF REACTION OF AMERICIUM METAL WITH 1.5 M HCl AND A NOTE ON THE HEATS OF FORMATION OF La³⁺(aq) AND Pr³⁺(aq). H. R. Lohr and B. B. Cunningham. AECD-2902 (1950). The heat of reaction of americium metal with 1.5 M HCl has been measured to be -162.3 ± 2.7 kcal/mole at 25°C.
- 13
HEATS OF REACTION OF SOME OXIDES OF AMERICIUM AND PRASEODYMIUM WITH NITRIC ACID AND AN ESTIMATE OF THE POTENTIALS OF THE Am(III)–Am(IV) and Pr(III)–Pr(IV) COUPLES. L. Eyring, B. B. Cunningham, and H. R. Lohr. AECD-2897 (1950). Procedures and results obtained for the above heats of reaction and related information are reported.

- 14
HEAT AND FREE ENERGY OF THE REACTION: $\text{AmCl}_3(\text{c}) + \text{H}_2\text{O}(\text{g}) = \text{AmOCl}(\text{c}) + 2\text{HCl}(\text{g})$. A. Broido and B. B. Cunningham. AECD-2918 (1950). Equilibrium constants of various temperatures in the range 400°C to 575°C have been determined for the

vapor phase hydrolysis of AmCl₃. The entropy change in the hydrolysis reaction was calculated to be $\Delta S_{298}^\circ = 36.7$ cal/deg/mole. The heat of reaction was $\Delta H_{298}^\circ = 23.9$ kcal/mole. The heat of formation of AmOCl(c) is calculated to be -251.3 ± 2.7 kcal/mole at 298°K.

- 15
HEATS OF FORMATION OF SOME AQUEOUS IONS OF AMERICIUM. H. R. Lohr. AECD-3011; UCRL-686 (1950). The heat of formation of Am³⁺(aq) was measured in 1.5 M HCl at 25°C and found to be -161.3 ± 1.4 kcal/mole. The heat of formation of Am⁴⁺(aq) was calculated to be -112.2 kcal/mole.
- 16
HEAT AND FREE ENERGY OF THE REACTION $\text{AmCl}_3(\text{s}) + \text{H}_2\text{O}(\text{g}) = \text{AmOCl}(\text{s}) + 2\text{HCl}(\text{g})$. C. W. Koch and B. B. Cunningham. AECD-3493; UCRL-2006. Equilibrium constants for the reaction $\text{AmCl}_3(\text{s}) + \text{H}_2\text{O}(\text{g}) = \text{AmOCl}(\text{s}) + 2\text{HCl}(\text{g})$ have been measured at various temperatures between 682°K and 880°K. Calculated thermodynamic constants for the reaction are as follows:
- $\Delta F_{785}^\circ = -4.06$ kcal $\Delta H_{785}^\circ = 20.01$ kcal $\Delta S_{785}^\circ = 30.6$ eu. $\Delta F_{298}^\circ = +11.45$ kcal $\Delta H_{298}^\circ = 21.38$ kcal $\Delta S_{298}^\circ = 33.3$ eu.
- 17
THERMODYNAMICS OF THE AQUEOUS IONS OF AMERICIUM. S. R. Gunn (thesis). UCRL-2541 (1954). The heats of reduction of AmO₂⁺ and AmO₂⁺⁺ by Fe⁺⁺ in 1 M HClO₄ were determined. The following values were obtained.

$$\Delta H_{\text{AmO}_2^+} - \Delta H_{\text{Am}^{3+}} = -44.6 \pm 1.0 \text{ kcal}$$

$$\Delta H_{\text{AmO}_2^{++}} - \Delta H_{\text{Am}^{3+}} = 7.8 \pm 0.2 \text{ kcal}$$

Using estimated entropies, the oxidation potentials derived for the corresponding couples were

$$E_{\text{Am}^{3+} - \text{AmO}_2^+} = -1.80 \pm 0.02 \text{ v}$$

$$E_{\text{Am}^{3+} - \text{AmO}_2^{++}} = -1.70 \pm 0.01 \text{ v}_1$$

- 18
THE HEATS OF FORMATION OF AmO₂⁺(aq) AND AmO₂⁺⁺(aq) IN 1 M HClO₄. S. R. Gunn and B. B. Cunningham. *J. Am. Chem. Soc.*, 79, 1563-5 (1957). The heats of reaction of AmO₂⁺(aq) and AmO₂⁺⁺(aq) with Fe²⁺(aq) in 1 M HClO₄ have been measured to be

-72.2 ± 1.0 and -99.1 ± 0.2 kcal, respectively. The heats of $\text{AmO}_2^+(\text{aq})$ and $\text{AmO}_2^{2+}(\text{aq})$ are calculated to be -207.7 ± 2.9 and -170.8 ± 2.7 kcal, respectively. The entropy difference, $S_{\text{AmO}_2^{2+}(\text{aq})} - S_{\text{AmO}_2^+(\text{aq})}$ is calculated to be -16 ± 4 eu. The autoreduction of AmO_2^+ and AmO_2^{2+} and the disproportionation of AmO_2^+ have been investigated.

19

HEATS OF FORMATION OF $\text{Pu}^{+3}(\text{aq})$, $\text{PuCl}_3(\text{c})$, $\text{PuOCl}(\text{c})$, $\text{Am}^{+3}(\text{aq})$, $\text{AmCl}_3(\text{c})$, AND $\text{AmOCl}(\text{c})$. J. Fuger and B. B. Cunningham. *J. Inorg. Nucl. Chem.*, 25, 1423-9 (1963).

The following heats of solution were measured: $\text{AmCl}_3(\text{c})$ in 1.5 M HCl, -30.60 ± 0.2 ; $\text{AmCl}_3(\text{c})$ in 0.001 M HCl, -33.36 ± 0.25 kcal/mole $^{-1}$. On combination with other thermodynamic data the results yield the following standard heats of formation at 298°K: Am^{+3} -162.4 ± 3 ; $\text{AmCl}_3(\text{c})$ -249.2 ± 3 ; $\text{AmOCl}(\text{c})$ $-227.6 \pm 3(\text{aq})$, all in kcal/mole.

IV. METALS AND ALLOYS

20

THE PREPARATION AND SOME PROPERTIES OF AMERICIUM METAL. E. F. Westrum, Jr., and L. Eyring. AECD-2980 (1950).

Americium is indicated as occupying a homologous position to that of europium which is a metal of abnormally low density compared to its lanthanide neighbors. AmF_3 was prepared by hydrofluorination of the hydroxide. The metal was prepared by the reduction of the trifluoride with Ba. The hydride was prepared by contacting the metal with H_2 at 50°C.

21

THE PREPARATION AND SOME PROPERTIES OF AMERICIUM METAL. E. F. Westrum, Jr., and L. Eyring. UCRL-1055 (1951).

AmF_3 prepared by the action of HF and AmO_2 was reduced to metal at the 40- to 200- μg scale by reduction with Ba metal in a high vacuum microfurnace at 1100°C. High yields of silvery, very malleable and ductile metal globules were obtained. The density was determined to be 11.7 ± 0.3 g/cc. The heat of solution of the metal in 1.5 M (aq) HCl was determined as -160 ± 4 kcal/mole.

22

METHODS OF ALLOYING REACTIVE METALS WITH ALUMINUM OR BERYLLIUM. British Patent 751,441. Halides of americium are mixed with Al or Be and the mass heated to 700°C and 1200°C in a vacuum of about 10^{-3} mm Hg until the metal is reduced and alloyed.

23

METHOD OF ALLOYING REACTIVE METALS WITH ALUMINUM OR BERYLLIUM. O. J. C. Runnalls. U.S. Patent 2,809,887 (October 15, 1957).

A halide of one or more of the reactive metals, Np, Ce, and Am, is mixed with Al or Be. The mass is heated at 700°C to 1200°C while maintaining a vacuum of above 10^{-3} mm of Hg or better, until the halide of the reactive metal is reduced and the metal itself alloys with the reducing metal.

24

METHOD OF MAKING ALLOYS OF Be WITH Pu AND THE LIKE. O. J. C. Runnalls. U.S. Patent 2,875,041 (1959).

The production of alloys of Be with one or more of the metals, U, Pu, Ac, Am, Cm, Th, and Ce, is described. A halide salt of the metal to be alloyed with the Be is heated at 1300°C in the presence of Be to reduce the halide to metal and cause the latter to alloy directly with the Be.

25

CHEMISTRY DIVISION SEMIANNUAL REPORT (FOR) DECEMBER 1958 THROUGH MAY 1959. UCRL-8867 (1959).

Experiments were continued on the preparation of Am, americium nitride and americium monoxide.

26

CHEMISTRY DIVISION SEMIANNUAL REPORT (FOR) JUNE THROUGH NOVEMBER 1959. UCRL-9093 (1959).

Americium and plutonium monoxides were prepared by the direct reaction between molten metals and oxygen that was generated from Ag_2O by thermal decomposition. Two methods for preparing Am metal are being studied.

27

PREPARATION AND CRYSTAL STRUCTURE OF AMERICIUM METAL. D. B. McWhan, J. C. Wallmann, B. B. Cunningham, L. B. Asprey, F. H. Ellinger, and W. H. Zachariasen. *J. Inorg. Nucl. Chem.*, 15, 185-7 (1960).

The crystal structure of americium was studied using metals produced by two different methods which are described. Diffraction data are presented for the metal.

28

ALLOYS OF BERYLLIUM WITH PLUTONIUM AND THE LIKE. O. J. C. Runnalls. Canadian Patent 615,734 (March 7, 1961).

A method for producing alloys of Be with at least one of a group of metals consisting of U, Pu, Ac, Am, Cm, Th, and Ce is presented. The method consists of mixing a fluoride of at least one of the metals with Be

and heating the mass at 1000°C to 1350°C in a vacuum to reduce the fluoride and alloy the reduced metal. These alloys are useful as neutron source materials.

29

CRYSTAL STRUCTURE AND PHYSICAL PROPERTIES OF AMERICIUM METAL. D. B. McWhan.

UCRL-9659 (May 1961).

The methods for preparing milligram quantities of pure, well crystallized Am metal are discussed. A high and low temperature x-ray powder camera for small radioactive samples is presented. Am metal prepared by the reduction of AmF_3 with Ba vapor was indexed as hexagonal close packed with $a = 3.4681 \pm 0.0008 \text{ \AA}$ and $c = 11.240 \pm 0.005 \text{ \AA}$ at 20°C. The proposed structure type is that of La metal. Am metal condensed on a Ta wire or quartz fiber from vapor phase was found to be face centered cubic ($a = 4.895 \pm 0.005 \text{ \AA}$). The following physical properties of Am metal were determined: m.p. = $995 \pm 4^\circ\text{C}$, density (x ray) = $13.671 \pm 0.005 \text{ g/cm}^3$ (20°C), metallic radius = $1.730 \text{ \AA}$.

30

CRYSTAL STRUCTURE, THERMAL EXPANSION, AND MELTING POINT OF AMERICIUM METAL.

D. B. McWhan, B. B. Cunningham, and J. C. Wallmann. *J. Inorg. Nucl. Chem.*, 24, 1025-38 (1962).

The methods for the preparation of milligram quantities of pure, well crystallized Am metal are discussed in detail. Am metal prepared by the reduction of AmF_3 with Ba vapor was indexed as hexagonal close packed with $a = 3.4681 \pm 0.0008 \text{ \AA}$ and $c = 11.241 \pm 0.003 \text{ \AA}$ at 20°C. Am metal condensed on a Ta wire or quartz fiber from the vapor phase was found to be face centered cubic ($a = 4.894 \pm 0.005 \text{ \AA}$). The following physical properties of Am metal were determined: m.p. = $994 \pm 7^\circ\text{C}$, density (x ray) = $13.671 \pm 0.005 \text{ g/cm}^3$ (20°C), metallic radius (CN-12) = $1.730 \text{ \AA}$, Coef. of Thermal Exp. (20°C): $\alpha_1 = 7.5 \pm 0.2 \times 10^{-6} \text{ }^\circ\text{C}^{-1}$ and $\alpha_c = 6.2 \pm 0.4 \times 10^{-6} \text{ }^\circ\text{C}^{-1}$.

31

PREPARATION OF AMERICIUM METAL. K. W. R. Johnson and J. A. Leary. LA-2992 (1963).

The first preparation of Am metal on a macroscopic scale is reported. A total of 22.5 g of Am metal was prepared in three reductions by reaction of AmO_2 with La *in vacuo*. The product from two of the three reductions were cast into ingots, the largest ingot weighing 10.5 grams. Average overall yield was 74 percent.

32

PREPARATION OF NEPTUNIUM-237 AND AMERICIUM-241 METAL ON THE MULTIGRAM SCALE.

K. W. R. Johnson, J. A. Leary, and A. N. Morgan. LADC-6402 (1964).

Am-241 metal was produced by the reduction of AmO_2 by La metal.

V. CRYSTAL STRUCTURE

33

CRYSTAL CHEMICAL STUDIES OF THE 5f-SERIES OF ELEMENTS. PART VI. THE Ce_2S_3 - Ce_3S_4 TYPE STRUCTURE. W. H. Zachariasen. *Acta Cryst.*, 2, 57-60 (1949).

The compounds Ce_2S_3 , La_2S_3 , Pu_2S_3 , Ac_2S_3 , and Am_2S_3 are shown to be iso-structural. Crystallographic data are given.

34

NEW CRYSTAL STRUCTURES. PART II. W. H. Zachariasen. AECD-1949.

The compound AmO has been found to have the sodium chloride structure. Cell constants are given.

35

CRYSTAL STRUCTURES OF AMERICIUM COMPOUNDS. D. H. Templeton and C. H. Dauben. AECD-3521; UCRL-2101.

The crystal structures of several compounds of Am have been determined by the x-ray powder diffraction method. AmF_3 is hexagonal (LaF_3 type) with $a = 4.067 \pm 0.001 \text{ \AA}$ and $c = 7.225 \pm 0.002 \text{ \AA}$ for pseudocell. AmO_2 is cubic (CaF_2 type) with $a = 4.00 \pm 0.01 \text{ \AA}$ and $c = 6.78 \pm 0.01 \text{ \AA}$. The metal parameter is $0.18 \pm 0.01 \text{ \AA}$. Am_2O_3 is cubic when prepared at 600°C and hexagonal when prepared at 800°C. For the cubic form (Mn_2O_3 type) $a = 11.03 \pm 0.01 \text{ \AA}$. The metal parameter is $-0.030 \pm 0.002 \text{ \AA}$. For the hexagonal form (La_2O_3 type) $a = 3.817 \pm 0.005 \text{ \AA}$ and $c = 5.971 \pm 0.010 \text{ \AA}$.

36

CHEMISTRY DIVISION QUARTERLY REPORT. UCRL-3415 (June 1956).

The crystal structure of americium was investigated.

37

CRYSTAL STRUCTURE, THERMAL EXPANSION, AND MELTING POINT OF AMERICIUM METAL.

D. B. McWhan, B. B. Cunningham, and J. C. Wallmann. *J. Inorg. Nucl. Chem.*, 24, 1025-38 (1962). Same as 30.

38

PREPARATION AND CRYSTAL DATA FOR LANTHANIDE AND ACTINIDE TRI-IODIDES.

L. B. Asprey, T. K. Keenan, and F. H. Kruse.
LADC-6087 (1963).

Lattice parameters and crystal structure for AmI_3 has been determined. AmI_3 is hexagonal. Treatment of AmI_3 with hydrogen at elevated temperatures gave no evidence of divalent compounds of americium.

VI. MAGNETIC SUSCEPTIBILITY

39

PARAMAGNETISM AND ELECTRONIC STRUCTURE OF AQUEOUS IONS OF ELEMENTS 92 TO 95.

J. J. Howland, Jr., and M. Calvin. ANL-JJK-130 (March 1948).

It is shown that the configuration of the electrons in incomplete shells for the aqueous actinide ions from Np(VI) to Am(III) must be $(5f)^{1-6}$. Assumptions of configurations of the types $(6d)^{1-6}$ or $6d(5f)^{1-5}$ would generally fail to explain the observed magnetic susceptibilities of the solutions of these ions. If the electrons in unfilled orbitals are influenced only slightly by neighboring atoms [$5f$'s are shielded by a $(6s)^2(6p)^6$ shell] then the macroscopic paramagnetism of solutions can be quantitatively deduced from the electronic structure of the central atom in the ion.

40

PARAMAGNETIC SUSCEPTIBILITIES AND ELECTRONIC STRUCTURE OF AQUEOUS CATIONS OF ELEMENTS 92 TO 95.

J. J. Howland, Jr., and M. Calvin. AECD-2440 (December 1948).

Magnetic susceptibilities per gram atomic weight of elements 92 to 95 in most of their oxidation states were measured at 20°C and 0.1 ml of solution which was 0.005 to 0.09 M. The (paramagnetic) values obtained in c.m.u. $\times 10^6$ were

$\text{U}^{+4} - 3690$	$\text{Np}^{+4} - 4000$	$\text{Am}^{+3} - 720$
$\text{Np}^{+6} - 2060$	$\text{Pu}^{+4} - 1610$	
$\text{Np}^{+5} - 4120$	$\text{Pu}^{+3} - 370$	

41

PARAMAGNETIC SUSCEPTIBILITIES AND ELECTRONIC STRUCTURES OF AQUEOUS CATIONS OF ELEMENTS 92 TO 95.

J. J. Howland, Jr., and M. Calvin. UCRL-206 (November 1948).

Magnetic susceptibilities per gram atomic weight of elements 92 to 95 in most of their oxidation states were measured on 0.1 ml of solution which was 0.007 to 0.09 M in heavy element. The paramagnetic value for Am(III) in cgs units $\times 10^6$ is 720.

42

THE MAGNETIC SUSCEPTIBILITIES OF SOME COMPOUNDS OF AMERICIUM AND CURIUM.

W. W. T. Crane, J. C. Wallmann, and B. B. Cunningham. UCRL-846 (1950).

The susceptibility of AmF_3 , corrected for diamagnetic contributions, was found to be $(1040 \pm 300) \times 10^{-6}$, $(1290 \pm 300) \times 10^{-6}$, and $(1740 \pm 300) \times 10^{-6}$ at temperatures of 295° , 199° , and 77°K . These values are in agreement with a $5f^6$ configuration of Am^{+3} .

43

CRYSTAL STRUCTURE AND MAGNETIC SUSCEPTIBILITY OF AMERICIUM METAL.

P. Graf, B. B. Cunningham, C. H. Dauben, J. C. Wallmann, D. H. Templeton, and H. Ruben. *J. Am. Chem. Soc.*, 78, 2340 (1956).

The x-ray diffraction powder patterns of Am were indexed as double hexagonal close packed $a = 3.642 \pm 0.005\text{\AA}$, and $c = 11.76 \pm 0.01\text{\AA}$. The space group is D_{6h}^4 , and the atomic positions are: two Am in (0,0,0), (0,0,1/2); two Am in (1/3,2/3,3/4), (2/3,1/3,1/4). The Am radius is $1.82\text{\AA}$ and the calculated density is $11.87 \pm 0.05 \text{ g/cm}^3$.

VII. ELECTRONIC CONFIGURATION

44

FISSION OF THE ATOMIC NUCLEI. PART I. TRANSURANIUM ELEMENTS.

B. C. Purkayastha. *Nucleonics*, 3, No. 5, 2-21 (1948).

The present knowledge of the transuranic elements is reviewed. Techniques of ultramicrochemistry are summarized and the electronic structure of the actinide series is discussed.

45

ELECTRONIC STRUCTURE OF THE HEAVIEST ELEMENTS.

G. T. Seaborg. AECD-2517 (1948).

All evidence indicates that the $5f$ electron shell is being filled in the heaviest elements giving rise to an actinide series.

46

THE PROPERTIES OF AMERICIUM AND EUROPIUM IN THEIR HOMOLGY IN THE PERIODIC TABLE.

G. E. Villar. *Anales fac. quem farm*, 4, 33-40 (1955).

The physical and chemical properties of americium and europium are compared. The differences which are found, especially in the valences, indicate that the electron shells are not necessarily the same. A

$5f^6, 6d^1, 7s^2$ configuration is suggested for Am although spectroscopic evidence indicates that europium has a $4f^7, 6s^2$ configuration.

47

THE ELECTRONIC STRUCTURE AND MAGNETIC PROPERTIES OF ACTINYL IONS. PART II. NEPTUNYL AND THE GROUND STATES OF OTHER ACTINYLS. S. P. McGeynn and J. K. Smith. *J. Mol. Spectroscopy*, 6, 188-98 (January 1961).

The ground states, electron configurations, and magnetic susceptibilities of PuO_2^{+2} , NpO_2^{+2} , AmO_2^{+2} , PuO_2^{+1} , AmO_2^{+1} , and UO_2^{+1} are also discussed.

48

LOW LYING LEVELS IN CERTAIN ACTINIDE ATOMS. B. R. Judd. *Phys. Rev.*, 125, 613-25 (1962). Calculating the order and properties of low-lying levels in configurations of the type $5f^n 6d$ falls into (a) the chance of a coupling scheme to define the basic eigenfunctions; (b) the evaluation of the matrix elements of the spin orbit interaction and of the Coulomb interaction in the form of linear combinations of certain radical integrals; (c) the estimation of radical integrals; and (d) the diagonalization of the energy matrices. Analyses of U_{11} , Pu_{11} , and Am_{11} show that the last parameter decreases, advancing along the actinide series. This decline is interpreted as being due to the collapse of the $5f$ shell. Where experimental data are available, agreement with theory is good.

49

TEMPERATURE EFFECTS ON URANYL STATE IN NITRIC ACID SOLUTIONS. B. G. Pozharskii. *Radiokhimiya*, 4, 561-70 (1962).

In aqueous solution uranyl ions have the structures $[\text{UO}_2(\text{H}_2\text{O})_2]^{+2}$. The OH groups form plane covalent complexes with Me(VI) in the center by means of f^3d hybrid bonds. The stability of aqueous solutions drops from uranyl to americyl due to the increased number of bare f -electrons.

50

ENERGY LEVELS OF Am(IV) IN LaCl_3 . J. G. Conway. *J. Chem. Phys.*, 40, 2504-7 (1964); UCRL-11099.

It was possible to assign the 10 lowest energy levels of Am(IV). By using these assignments and the complete spin orbit matrices, a fit was obtained with $5f$ hydrogenic wave functions. For Am(IV) the hydrogenic values are $F_2 = 268.6 \text{ cm}$ and $\zeta = 2605 \text{ cm}^{-1}$.

51

ELECTRONIC ENERGY LEVELS OF THE LIGHTER ACTINIDES: U^{+3} , Np^{+3} , Pu^{+3} , Am^{+3} , AND Cm^{+3} .

W. T. Carnall and B. G. Wyborne. *J. Chem. Phys.*, 40, 3428-33 (1964).

The results of a systematic theoretical and experimental study of the energy levels of the light actinides, in various solution media, are presented. The actinides show very large departures from Russell-Saunders coupling with spin orbit constants approximately twice those of the corresponding lanthanides. A pronounced tendency towards jj coupling is noted.

VIII. SPECTROSCOPY

A. Absorption

52

THE ABSORPTION SPECTRA OF TRANSURANIC SALTS IN CRYSTALS. S. Fried and F. J. Leitz. ANL-JJK-137 (March 1948).

Absorption spectra in the visible and near ultraviolet regions, were taken of the anhydrous salts UCl_4 , NpCl_3 , AmCl_3 , and AmBr_3 at room temperature and at that of liquid nitrogen. The spectra of the salts of americium were found to be among the sharpest known from crystals even at room temperature.

53

THE FIRST ISOLATION OF AMERICIUM IN THE FORM OF PURE COMPOUNDS; THE SPECIFIC ALPHA ACTIVITY AND HALF-LIFE OF Am-241. B. B. Cunningham and L. B. Asprey. AECD-2946 (1950).

The alpha half-life of Am-241 was found to be 490 ± 14 years. The absorption spectrum of Am(III) in 1 M HNO_3 in the range 3500 to 8000 $m\mu$ is given.

54

THE SOLUTION ABSORPTION SPECTRA OF AMERICIUM(III), (V), AND (VI). S. E. Stephanou, J. P. Nigon, and R. A. Penneman. AECD-3362; LADC-1147 (1952).

This investigation was undertaken to obtain data on the absorption spectra of Am(V) and Am(VI); and to search for vibrational fine structure in Am(V) and (VI) similar to that reported for U(VI), Np(V), Np(VI), and Pu(VI). This fine structure has been interpreted as arising from symmetrical metal-oxygen vibration in ions of the type MO_2^+ and MO_2^{++} .

55

ABSORPTION SPECTRA OF LANTHANIDE AND ACTINIDE RARE EARTHS; II TRANSITION PROBABILITIES FOR $+3$ IONS IN THE TWO SERIES.

D. C. Stewart. AECD-3351; ANL-WMM-960 (1952). Absorption curves for U^{+3} , Pu^{+3} , and Am^{+3} were determined in $HClO_4$. The measurements were also extended into the ultraviolet. Calculated transition probabilities of the electron quantum states are given.

- 56 THE ABSORPTION SPECTRUM OF HYDRATED AMERICIUM CHLORIDE. B. J. Stover and J. G. Conway. AECD-3403; UCRL-1778 (1952).
The absorption spectrum of hydrated $AmCl_3$ was determined at room temperature and at liquid nitrogen temperature. Data are presented in tabular form.
- 57 TETRAVALENT AMERICIUM AND CURIUM; THE ABSORPTION SPECTRA OF THE TRI- AND TETRA-FLUORIDES OF THESE ELEMENTS. L. B. Asprey and T. K. Keenan. *J. Inorg. Nucl. Chem.*, 7, 27-31 (1958).
A technique has been developed for spectral examination of submilligram amounts of solid compounds. The absorption spectra of $Cm(IV)$ fluoride and $Am(IV)$ fluoride have been measured over the region 3500 to 20,000Å.
- 58 ABSORPTION SPECTRUM AND ZEEMAN EFFECT OF Am^{+3} IN $LaCl_3$. J. B. Gruber and J. G. Conway. *J. Chem. Phys.*, 36, 191-3 (1962).
The polarized absorption and Zeeman effect of Am^{+3} in $LaCl_3$ was studied from 2000 to 8000Å. In almost every instance the peaks or lines observed are sharp, completely polarized, and appear in definite groupings.
- 59 CORRELATIONS OF ABSORPTION SPECTRA OF AMERICIUM AND EUROPIUM IN CRYSTALS AND IN SOLUTIONS. D. S. Gorbenko-Germanov. *Fiz. Probl. Spektroskopii, Akad. Nauk, SSSR, Materialy 13-go (Trinadsatogo) Soveshch, Leningrad, 1960, 1, 242-7* (1962).
The absorption spectra of $Am(III)$ and $Eu(III)$ were investigated at 3000 to 11,000Å in $HClO_4$ and H_2SO_4 and at 4500 to 8500Å in sulfate crystals to determine the properties of the electron transitions. The energies of the 7F sublevel multiplets, the shielding constant, and the effective nuclear charge were determined.
- 60 NEW STUDIES ON THE M ABSORPTION SPECTRA OF TRANSURANIUM ELEMENTS (PLUTONIUM AND AMERICIUM). Y. Cauchois, C. Bonnelle, and L. de Bersuder. *Compt. Rend.*, 257, 2980-3 (1963).
The M absorption spectra of metallic Pu and PuO_2 are compared. The same technique is extended to Am and AmO_2 .
- 61 MISSING BAND IN THE SPECTRUM OF THE TRI-POSITIVE AMERICIUM ION. J. G. Conway and B. R. Judd. *J. Chem. Phys.*, 41, 1526 (1964); UCRL-11401.
Two alternative explanations are given for the missing band for the transition $^7F_0 \rightarrow ^5D_1$ which should lie at 17,500 cm^{-1} in the spectra of Am^{+3} . Either the calculation is inadequate, and there is no level in this vicinity above 7F_0 , or else the transition probability for $^7F_0 \rightarrow ^5D_1$ is exceptionally small.
- 62 LOW-LYING ENERGY LEVELS OF TRIVALENT AMERICIUM. W. T. Carnall, P. R. Fields, and B. G. Wyborne. *J. Chem. Phys.*, 41, 2195-6 (1964).
The magnetic dipole oscillator strength for the transition from the ground state of Am^{+3} to the predicted level at 17,000 cm^{-1} was computed to be -5×10^{-10} . Measurements of the solution absorption spectrum of Am^{+3} were made. A very weak broad absorption band was found near the predicted energy with an oscillator strength of 2.4×10^{-7} .
- B. Emission
- 63 THE SPECTRA OF THE HEAVY ELEMENTS. F. S. Tomkins and M. Fred. AECD-2478 (December 1948).
The spectrum lines of several heavy elements were measured in the region 2650 to 4370Å. Tables are presented giving wavelengths accurate to the first decimal place and the intensity of the lines for Pa, Np, Pu, and Am.
- 64 THE EMISSION SPECTRUM OF AMERICIUM. PART I. R. P. Thorne. AERE-C/R-1309 (1953).
Some 230 lines of the emission spectrum of americium have been recorded. The ranges covered were from 2000 to 10,000Å using a high-wattage spark unit and from 2500 to 5000Å by arcing at 3 amps, d.c.
- 65 THE SPARK SPECTRUM OF AMERICIUM. R. P. Thorne. *Spectrochim. Acta*, 8, 71-87 (1956).
The wavelengths of some 1300 lines of the spark spectrum of Am have been measured in the spectral

range 2500 to 8000 Å. The spectrum consisted of a number of strong and a multitude of weaker lines.

66

THE ATOMIC SPECTRUM OF AMERICIUM. M. N. Oganov, A. R. Striganov, and Yu. P. Sobolev. *Optika L. Spektroskopiya*, 1, 965-71 (1956); AEC-tr-2919.

67

PRELIMINARY TERM ANALYSIS OF Am(I) AND Am(II) SPECTRA. M. Fred and F. S. Tomkins. *J. Opt. Soc. Amer.*, 47, 1076-87 (1957). Wavelengths of over 3000 Am lines have been measured with a 30-ft spectrograph, and intensities compared in a number of sources leading to assignment of most lines as Am(I) or Am(II). Hyperfine structure and isotope shifts have been measured in high orders for many lines. The ground states of Am(I) and Am(II) are $5f^7 7s$ and $5f^7 s^2$, respectively. The ionization potential of Am(I) is 6.0 eV. Most of the levels have not been identified but are believed to be built on $5f^6 d$ instead of $5f^7$. The binding energy of $5f^7$ as compared to $5f^6 d$ is $10,000 \text{ cm}^{-1}$ smaller than in Eu and is related to the higher valences found in the 5f elements as compared to the 4f elements. The ratio of nuclear magnetic moments of Am-241 and Am-243 is $\mu_{241}/\mu_{243} = 1.008$.

68

EVALUATION OF ELECTROSTATIC ENERGY LEVELS OF f^6 . J. B. Gruber and J. G. Conway. *J. Chem. Phys.*, 34, 632-8 (February 1961), UCRL-9310.

The 119 electrostatic energy levels for an nf^6 configuration were calculated for three different sets of Slater F_k ratios: $4f^6$ hydrogenic $F_4/F_2 = 0.1381$, $F_6/F_2 = 0.01511$; $5f^6$ hydrogenic $F_4/F_2 = 0.1422$, $F_6/F_2 = 0.0161$; and $5f^6$ based on Hartree-Fock calculation for normal uranium atom $F_4/F_2 = 0.159$, $F_6/F_2 = 0.0204$. The results show that the intermediate field matrices are essential to a quantitative analysis of the Eu(IV) and Am(IV) spectra, and that Zeeman studies are needed to identify certain levels.

C. Fluorescence

69

FLUORESCENCE SPECTRUM OF Am^{+3} IN LaCl_3 . D. M. Gruen, J. G. Conway, R. D. McLaughlin, and B. B. Cunningham. *J. Chem. Phys.*, 24, 1115-6 (1956). The fluorescence of Am in LaCl_3 is self excited at room temperature owing to its radioactivity. The 34 lines observed are listed with their visually estimated intensities.

D. Infrared

70

INFRARED SPECTRA AND STRUCTURE OF URANYL AND TRANSURANIUM(V) AND (VI) IONS IN AQUEOUS PERCHLORIC ACID SOLUTION. L. H. Jones and R. A. Penneman. AECD-3363; LADC-1144 (1952).

Infrared spectra of aqueous solutions of U(VI), Np(VI), Pu(VI), Am(VI), Np(V), and Am(V) ions show conclusively that these ions exist as symmetrical XO_2^{++} and XO_2^+ , the former being linear or very nearly so.

71

AN ANALYSIS OF THE INFRARED ABSORPTION SPECTRUM OF $\text{Am}^{+3}(5f^6)$ IN LaCl_3 . J. B. Gruber. *J. Chem. Phys.*, 35, 2186-92 (1961).

The polarized infrared absorption spectrum of single crystals of $\text{Am}^{+3}(5f^6)$ in LaCl_3 was studied from 0.79 to 16.0. In almost every instance the spectrum is sharp and completely polarized, and it appears in definite groupings. A theoretical analysis is presented for the crystal field split $7f_j$ levels.

72

THE VISIBLE AND NEAR INFRARED ABSORPTION SPECTRA OF SOME TRIVALENT ACTINIDE AND LANTHANIDE ELEMENTS IN DClO_4 AND IN MOLTEN NITRATE SALTS. W. T. Carnall and P. R. Fields. *Developments in Applied Spectroscopy*, New York, Plenum Press, 1962, Vol I, pp 233-47; TID-13242.

Observations of absorption spectra of trivalent actinide and lanthanide ions in $\text{LiNO}_3\text{-KNO}_3$ eutectic at 150°C in the region lying between 0.36 and 2.5μ are reported. It was also possible to observe portions of this region in deuterated solvents and thus to compare, over an extended range, the effects of different ligand fields on 4f and 5f electrons.

IX. SEPARATION AND PURIFICATION

A. Precipitation Techniques

73

QUANTITATIVE SEPARATION OF AMERICIUM AND PLUTONIUM USING CUPFERRON. J. P. Nigon and R. A. Penneman. AECU-1006; LADC-793.

As little as $0.1 \mu\text{g}$ of Am could be recovered quantitatively from 10 mg of Pu (a factor of 100,000). The effects of added Fe and La and of temperature on the separation are presented.

74

SEPARATION OF AMERICIUM FROM LANTHANUM BY FRACTIONAL OXALATE PRECIPITATIONS FROM HOMOGENEOUS SOLUTION. J. A. Hermann. AECD-3637; LAMS-1625 (1954).

A separation of americium from americium-lanthanum mixtures is obtained by fractional precipitation of dilanthanum trioxalate from homogeneous solution. The precipitatory agent is generated through the slow hydrolyses of dimethyl oxalate. Americium is enriched in the precipitate.

75

SEPARATION OF AMERICIUM FROM PROMETHIUM. R. E. Pressly. U.S. Patent 2,893,827 (1959).

Pm-147 is separated from Am in acidic solution by adding fluosilicic acid, heating to form a Pm precipitate, and separating the precipitate from solution. The precipitate is redissolved by addition of boric acid and HNO_3 , and reprecipitated by fluosilicic acid. This procedure is repeated six or more times to obtain an Am free Pm precipitate.

76

CO-PRECIPITATION OF Am(III) WITH BINARY POTASSIUM LANTHANUM SULFATE IN SULFURIC ACID. V. I. Grebenshchikova and N. B. Chernyavskaya. *Radiokhimiya*, 3, 650-3 (1961).

The influence of complexing on the distribution coefficient of Am(III) in sulfuric acid was analyzed. The composition of binary potassium-lanthanum sulfates in sulfuric acid was analyzed and the crystallization of Am(III) and La(III) in various sulfuric acid concentrations was determined.

77

SEPARATION OF Np^{+4} , Pu^{+4} , AND Am^{+3} FROM SOLUTIONS BY THE SULFATE METHOD. V. I. Grebenshchikova and N. B. Chernyavskaya. *Radiokhimiya*, 4, 232-4 (1962).

Distribution coefficients for Np^{+4} , Pu^{+4} , and Am^{+3} in K_2SO_4 were determined, and it was found that quantitative amounts of Pu could be separated from unsaturated K_2SO_4 .

B. Oxidation Techniques

78

METHOD FOR SEPARATION OF AMERICIUM FROM SOLUTIONS CONTAINING THE SAME. L. B. Werner. U.S. Patent 2,577,097 (1951).

The separation is accomplished by using a hypochlorite to oxidize the americium to the pentavalent state in strong carbonate solution, thereby obtaining an insoluble americium compound.

79

SOME CHEMICAL PROPERTIES OF CURIUM. D. C. Feay (thesis). UCRL-2547 (1954).

A procedure for separating curium from americium utilizing the oxidation of americium by peroxydisulfate in very dilute solutions of acid is given.

C. Chromatographic Techniques

80

MATERIALS TESTING REACTOR – ENGINEERING TEST REACTOR, TECHNICAL BRANCHES. IDO-16658 (February 15, 1961).

The chromatographic method used in purifying Pu-241 from Am-241 is outlined.

81

EXTRACTION – CHROMATOGRAPHIC ISOLATION OF AMERICIUM AND CURIUM. V. M. Vdovenko, A. S. Krivochatskii, M. P. Kovolskaya, E. A. Smirnova, S. M. Kulikov, N. A. Alkeseeva, and L. M. Belov. A/CONF. 28/P/345 (1964).

Methods for the separation of Am and Cm from HNO_3 solutions of Mg-ceramic fuel blocks were investigated. The actinides are first separated from the macro-components by extraction. Then Pu(IV) is extracted using TTA. The subsequent separation of fission rare earths from Am and Cm was studied by the extraction from LiCl solution using D2EHPA and TDA chloride in different diluents. A chromatographic method of purification is described to separate remaining impurities, mainly lanthanides.

D. Combined Techniques

82

CHEMICAL PROCEDURES USED IN BOMBARDMENT WORK AT BERKELEY. W. W. Meinke. AECD-3084; UCRL-732 (1951).

Detailed procedures are outlined for the chemical separation of V, Mn, Co, Ni, Se, Cr, Ru, Ag, Cd, In, Sn, Sb, I, Ac, Np, Pu, Am, and Cm; and the heavy rare earths: Sm, Eu, Lu, Yb, Er, Ho, Dy, Tb, and Gd, from various targets.

83

THE SEPARATION AND PURIFICATION OF MILLIGRAM QUANTITIES OF AMERICIUM. P. D. Herniman. AERE-C/R-1113 (1953).

A method is described for the separation and purification of Am from solutions containing relatively large amounts of Fe, U, and Pu.

84

THE ISOLATION OF AMERICIUM-241. J. Milsted. AERE-C/R-1102 (1953).

Americium has been isolated by conventional chemical methods without the addition of any rare-earth carriers. The source of the material was the β decay of Pu-241 in Pu extracted from pile irradiated U. The identity of the product was confirmed by alpha-energy, emission and absorption spectra, and gamma-ray measurements. There is evidence that rare-earth impurities were very small.

85

NEW ISOTOPES OF AMERICIUM, BERKELIUM, AND CALIFORNIUM. A. Ghiorso, S. G. Thompson, G. R. Choppin, and B. G. Harvey. *Phys. Rev.*, 94, 1081 (1954).

As a result of neutron irradiation of Am-243 and Bk-249, it has been possible to make new observations on the radioactive decay of Am-244. After bombardment, the Am-244 was rapidly purified by a combination of precipitation and ion-exchange techniques. The Am-244 was found to decay by emission of β particles; and its half-life is 26 minutes. Only one β endpoint, at 1.5 Mev, could be resolved. There were no prominent gamma rays.

86

THE SEPARATION AND PURIFICATION OF Am-241 AND THE ABSORPTION SPECTRA OF TERVALENT AND QUINQUEVALENT Am SOLUTIONS. G. R. Hall and P. D. Herniman. *J. Chem. Soc.*, 2214-21 (1954). The separation and purification of 25 mg of Am-241 produced by the beta decay of Pu-241 is described. The absorption spectra of Am(III) in perchloric acid and in HCl have been measured. The disproportionation and self reduction of Am(V) in HCl has been observed. Self reduction occurs only in dilute acid, but in concentrated acid disproportionation predominates.

87

PRODUCTION OF Pu-246 IN THE MTR. H. Diamond and R. F. Barnes. ANL-5361 (1954).

The separation of Pu-246 from fission products and of Am-246 from Pu-246 is described.

88

A BATCH PROCESS FOR THE RECOVERY OF Am-241 FROM KILOGRAM AMOUNTS OF PLUTONIUM. J. P. Butler and J. S. Merritt. CRC-661; AECL-353 (1956). By precipitating PuO_4 from Pu solutions 1 to 2 N in acid, the Am can be recovered in the supernatant in about 98 percent yield. This method may also be used as a final step in the purification of Pu. From 2.03 kg

of Pu processed, 0.8 g of Am-241 has been recovered. The Am was purified by standard precipitation methods and ion-exchange methods. The yield of Am-241 through the purification was 98.4 percent.

89

THE ISOLATION OF AMERICIUM-241 IN 100 MILLI-GRAM QUANTITIES FROM LARGE AMOUNTS OF IMPURITIES. F. Weigel. UCRL-3934 (1957).

The preparation of pure Am samples on the order of 100 mg is described. The separation procedures used on five different starting materials are described, and the efficiency of some separation methods is discussed in view of personal experience.

90

AMERICIUM AND NEPTUNIUM RECOVERY PROCESSES. W. H. Lewis. A/CONF. 15/P/537. Second U.N. International Conference on the Peaceful Uses of Atomic Energy, 1958.

Solvent extraction processes were developed on a pilot plant scale for recovering Np-237 and Am-241 from irradiated U and fuel cycle wastes. Americium was separated from a fuel cycle waste containing large quantities of La and Ce. Final purification of the Am was achieved by ion exchange.

91

THE INVESTIGATION OF THE AMERICIUM CHEMISTRY. G. N. Yakovlev and V. N. Kosyakov. A/CONF. 15/R/2127.

A number of methods are known for the separation of Am and Cm, including precipitation reactions, extraction, and chromatographic methods. New data are presented and discussed. Some problems of Am chemistry are examined, such as the solubility of low soluble compounds, the composition and absorption spectra of crystals of double sulfates of Am(III) with alkali metals, and oxidation reduction reactions occurring in Am solutions of different valences. The results of studies of disproportionation reactions of Am(V) depending on acidity, acid anion, and temperature are given.

92

TRANSURANIC STUDIES: STATUS AND PROBLEM STATEMENT. R. E. Leuze. CF-59-4-108 (April 29, 1959).

The purpose of the transuranic program is to develop separation processes for the transuranic elements, primarily those produced by long term neutron irradiation of Pu-239. The program includes Am-Cm recovery, and reprocessing the irradiated plutonium and Am-Cm fractions. Am-Cm is to be extracted by TBP from a neutral nitrate solution; partial rare earth removal (La)

by Am-Cm extraction into 100 percent TBP from 15 M HNO_3 ; additional rare earth removal by extraction into 0.48 M mono-2-ethylhexylphosphoric acid from 12 M HCl ; and Am-Cm purification by chloride-anion exchange.

93

FINAL SAFETY ANALYSIS REPORT OF AMERICIUM PROCESSING TO BE PERFORMED BY THE MARTIN COMPANY. J. Watcher. MND-P-2347 (May 1960).
A process for purifying Am-241 and a Heavy Element Processing Facility for the subsequent fabrication of AmO_2 -Al elements are described.

94

THE TRANSPLUTONIUM ELEMENTS (PART II).
W. Kraak. *Atoomenergie Haar Toepassingen*, 5, 1-10 (1963).
The chemical separation methods and properties of the heaviest elements of the periodic system Am, Cm, Bk, Cf, Es, Fm, and Md were described.

95

TRANSURANIUM QUARTERLY PROGRESS REPORT FOR PERIOD ENDING FEBRUARY 28, 1963. W. D. Burch. ORNL-3482 (1963).
The development of separation processes for the trans-uranium elements is reported.

96

ACCURATE NUCLEAR FUEL BURNUP ANALYSES.
B. F. Rider, C. O. Ruiz, P. S. Luke, Jr., J. P. Peterson, Jr., and F. R. Smith. GEAP-4430 (1963).
The determination of the behavior of heavy elements such as Pu, Am, and Cm in the Nd separation was studied.

E. Volatility Techniques

97

FRACTIONATION OF FISSION PRODUCTS AND HEAVY ELEMENTS BY VOLATILIZATION METHODS.
N. D. Erway and O. C. Simpson. CC-3625 (1946).
A fractionating crucible having a number of collector plates was used to separate long-lived fission product oxides by volatilization. The degree of separation of Am-242 from Am-241 was determined by pulse analysis of the alpha activities.

F. Electrolytic Techniques

98

SEPARATION OF TRACES OF URANIUM, NEPTUNIUM, PLUTONIUM, AND AMERICIUM

BY ELECTROLYSIS. A. G. Samartseva.
Atomnaya Energ., 8, 324-9 (1960).

An electrolytic method is suggested for separating U, Np, Pu, and Am traces from acid solutions. The yield is independent of anion concentration but dependent on pH.

99

PURIFICATION OF AMERICIUM CHLORIDE SOLUTIONS BY MERCURY CATHODE ELECTROLYSIS. J. L. Holst and C. W. Barrick. RFP-183 (1960).

A process has been developed for the removal of Cr, Cu, Fe, Mn, Ni, Pb, Sn, and Zn impurities from an acid solution of AmCl_3 using a mercury cathode cell operating at 5 to 10 amperes and 16 to 18 volts. The Am is not affected.

G. Electrophoresis

100

ELECTROPHORESIS ON CELLULOSE ACETATE PAPER IN STRONG ELECTROLYTES AND CONCENTRATES. EQUIPMENT AND TECHNIQUES; DETERMINATION OF ELECTROPHORETIC MOBILITIES AND SEPARATION OF SOME TRANSURANIC ELEMENTS IN NITRIC MEDIA. F. Clanet, J. Clarence, and M. Verry. *J. Chromatog.*, 13, 440-50 (1964).

An apparatus for the electrophoresis of ions in strong electrolytes is described. Cellulose acetate membranes were used as the support. The electrophoretic mobilities of U(VI), Pu(IV), Am(III), and Cm(III) were determined in 6 N HNO_3 , 10 N HNO_3 , and 12 N HNO_3 . A separation was obtained.

H. Molten Salt Extraction

101

THE EXTRACTION OF PLUTONIUM FROM PLUTONIUM-ALUMINUM ALLOYS BY MOLTEN BISMUTH. D. E. McKenzie, J. W. Fletcher, and T. Bruce. CRC-639; AECL-314 (April 1956).
The distribution of Pu, Am, and certain fission products between neutron-irradiated Al-Pu alloys and molten Bi have been examined in small scale experiments. An equal volume of Bi extracts 78 percent of the Pu, 93 percent of the Am, the majority of the Ce, but essentially no Ru or Zr from the Al phase. A possible process is discussed.

102

SOLVENT EXTRACTION OF ACTINIDES AND LANTHANIDES FROM MOLTEN SALTS. N. M.

Isaac, P. R. Fields, and D. M. Gruen. *J. Inorg. Nucl. Chem.*, 21, 152-68 (1961).

Quantitative measurements were made of distribution coefficients of metal ions between a fused salt phase and an organic phase. These were made at 150°C using a $\text{LiNO}_3\text{-KNO}_3$ eutectic (m.p. = 120°C) and TBP as the active extractant with a mixture of polyphenols as the inert diluent. Distribution coefficients were determined for Co(II), Eu(III), Nd(III), Am(III), Cm(III), Np(V), Np(VI), and U(VI), and found to be higher by a factor of 10^2 to 10^3 as compared with concentrated aqueous nitrate solutions. The number of TBP molecules associated with the complexes $\text{M}(\text{NO}_3)_p$ and $(\text{TBP})_q$ in the organic phase were found to be the same [except for Co(II)] as those reported for aqueous nitrate systems. The effect of Cl addition to the nitrate melt was to lower the distribution coefficients. The separate factors, 3.2 for Am(III)/Cm(III), suggests a possible application to the separation of these two elements.

103

SEPARATION OF CURIUM AND AMERICIUM. P. R. Fields and N. M. Isaac. U.S. Patent 3,022,134 (February 20, 1962).

Curium and americium are contained in an anhydrous molten salt medium having a low melting point. Curium is preferentially extracted from the molten salt by a hot organic solvent containing preferably less than 10 percent alkyl phosphate.

104

HIGH TEMPERATURE ORGANIC EXTRACTION OF URANIUM, PLUTONIUM, AND AMERICIUM FUSED CHLORIDES. Z. Borkowska, M. Mielcarski, and M. Taube. *J. Inorg. Nucl. Chem.*, 26, 359-71 (1964).

The distribution of U, Pu, and Am between a KCl-CuCl eutectic melt and an organic phase (TBP, TOA, HDBP diluted by diphenyl) was investigated at 180°C. Distribution ratios were determined for U(IV), U(III), Pu(IV), Pu(III), and Am(III), and for the components of the salt phase Cu, K, and Cl. The distribution ratios obtained in order of ascending magnitude were

$$D_K^{\text{TOA}} \ll D_{\text{Cu}}^{\text{TOA}} < D_{\text{Pu(III)}}^{\text{TOA}} < D_{\text{Am(III)}}^{\text{TOA}} < D_{\text{U(III)}}^{\text{TOA}}$$

$$\ll D_{\text{U(IV)}}^{\text{TOA}} \text{ where } D_{\text{U(IV)}}^{\text{TOA}} = \sim 50 D_K^{\text{TBP}} < D_{\text{Cu}}^{\text{TBP}} < D_{\text{Am(III)}}^{\text{TBP}}$$

$$< D_{\text{U(III)}}^{\text{TBP}} < D_{\text{U(IV)}}^{\text{TBP}}$$

105

SEPARATION OF PLUTONIUM, URANIUM, AMERICIUM, AND FISSION PRODUCTS FROM EACH OTHER. J. B. Knighton and R. K. Steunenberg. U.S. Patent 3,147,109 (September 1, 1964).

A process was developed for separating Am from Cm. The Am-Cm mixture was contacted with halide containing at least 50 mole % of magnesium halide and at the same time with Mg-Zn or Mg-Cd alloys containing between 10 and 90 wt % Mg. The Am is taken up by the halide; the Cm by the alloy.

106

AMERICIUM-CURIUM SEPARATION. S. Lawroski, J. B. Knighton, and R. K. Steunenberg. U.S. Patent 3,152,887 (October 13, 1964).

A process was developed for the separation of Am from Cm. A molten salt containing magnesium halide and a magnesium-zinc alloy was added to the mixture containing the two actinides; the Cm was taken up by the alloy and the Am as the halide by the salt.

I. Carrier Precipitation Techniques

107

RADIOACTIVE PRODUCT AND METHOD OF PRODUCING THE SAME. L. B. Werner. U.S. Patent 2,551,476 (May 22, 1951).

Americium is removed from solution by mixing a carbonate solution of pentavalent Ta with a solution containing pentavalent americium and heated to precipitate tantalum as a hydrated oxide to carry americium from the solution.

108

OBSERVATIONS ON CURIUM VALENCE STATES; A RAPID SEPARATION OF AMERICIUM AND CURIUM. S. E. Stephanou and R. A. Penneman. AECD-3339; LADC-1114 (1952).

A rapid separation method based on the precipitation of AmF_3 from Am(VI) was developed. For macro amounts of Am, AmF_3 is precipitated without carrier, leaving Am(VI) in the supernatant; for amounts of Am where the solubility of AmF_3 is a limiting factor, LaF_3 carrier is used. Where La is used, it can be removed by a column elution using 13f HCl. The solubility of AmF_3 , in the absence of La, was found to be 12 $\mu\text{g/ml}$.

109

CALCIUM OXALATE CARRIER PRECIPITATION OF Pu. W. J. Maraman, A. J. Beaumont, E. L. Christensen,

- A. V. Mullins, and R. S. Winchester. LA-1692 (1954). A plant-scale procedure for concentrating Pu and Am in slag and crucible (metal reduction residues) and other recovery solutions by a calcium oxalate carrier precipitation is described. Conclusions from explanatory laboratory tests on the variables affecting the efficiency are included.
- 110
COPRECIPITATION OF Am(III) WITH LANTHANUM OXALATE. J. A. Hermann. LA-2013 (1956). The coprecipitation of Am with lanthanum oxalate is investigated. The separation and purification of Am from La and other cations by the fractional precipitation of lanthanum oxalate is demonstrated.
- 111
COPRECIPITATION OF LANTHANUM, CERIUM, AND AMERICIUM WITH POTASSIUM SULFATE. V. I. Grebenshchikova and V. N. Bobrova. *Zhur. Neorg. Khim.*, 3, 40-5 (1958). In the coprecipitation of La, Ce, and Am with K_2SO_4 it was shown that the ions not only coprecipitate but that they were also adsorbed by crystalline deposits. It was found that the quantity adsorbed increases with the concentration of the elements in the solution. The adsorption is not affected by the presence of foreign ions. It appears that La, Ce, and Am are carried in the interior of the K_2SO_4 crystal. It is concluded that these elements form anomalous mixed crystals not having a lower boundary of miscibility.
- 112
RECOVERY OF AMERICIUM. M. Ader and H. H. Hyman. U.S. Patent 2,934,403 (1960). A process is given for separating Am and Pu and recovering the Am. Pu is extracted with a water insoluble solvent and Am is precipitated from the aqueous phase by adding a ferric salt and an alkali metal hydroxide thereto. The precipitate is dissolved in HCl and the ferric salt extracted from the Am with an organic solvent.
- 113
COPRECIPITATION OF AMERICIUM AND EUROPIUM WITH LANTHANUM OXALATE. V. I. Grebenshchikova and R. V. Bryzgalova. *Radiokhimiya*, 2, 152-8 (1960). Coprecipitation of Am and Eu with lanthanum oxalate was studied in order to determine the mechanism of coprecipitation and crystallization coefficients of the components. The crystallization coefficients for Am ($D = 4.8$) and Eu ($D = 3.8$) indicate that separation by fractionation of lanthanum oxalate crystals is impossible.
- 114
COPRECIPITATION OF Pu AND Am WITH POTASSIUM SULFATE. V. I. Grebenshchikova and V. N. Bobrova. *Radiokhimiya*, 3, 544-50 (1960). Coprecipitation of Pu(IV) and Am(III) with K_2SO_4 was studied using Am-241 and Pu-239 isotopes and chemically pure twice recrystallized K_2SO_4 . It is shown that Pu(IV) and Am(III) form mixed crystals concentrations of 10^{-7} to 10^{-9} M and Am(III) concentrations of 10^{-7} to 10^{-9} M. A high crystallization factor for Pu(IV) and Am(III) makes K_2SO_4 a good carrier for transuranium elements.
- 115
ORGANIC COPRECIPITANTS: XV. COPRECIPITATION OF AMERICIUM. V. I. Kuznetsov and T. G. Akimova. *Radiokhimiya*, 3, 737-42 (1961). A quantitative precipitation of trivalent americium at pH 5 to 8 was achieved using arsenazobenzene-2 carboxy < 1 azo - 7> - 1.8 dioxynaphthalene-3, 6 disulfonic acid, eriochrome black T reacting with methyl violet, crystal violet, or methylene blue. A quantitative precipitation was observed with a dilution of 1.1×10^{12} (0.0002 γ Am in 200 ml). It is also shown that Am is coprecipitated with low-solubility oxalate formed by 1.8 diaminonaphthalene cation.
- J. Solvent Extraction Techniques**
- 116
SEPARATION OF AMERICIUM AND CURIUM FROM AQUEOUS SOLUTIONS. D. F. Peppard and P. R. Gray. U.S. Patent 2,683,655 (July 13, 1954). The process consists of contacting an aqueous concentrated HNO_3 medium and a water-immiscible alkyl phosphate, at least one of the media containing Am or Cm in solution, whereby the Cm values are preferentially held by the alkyl phosphate medium while the Am values go to the aqueous medium, and separating an alkyl phosphate phase from an aqueous phase.
- 117
CHELATION OF THE +3 IONS OF ELEMENTS 95 THROUGH 100 WITH THENOYLTRIFLUOROACETONE. L. B. Magnuson and M. L. Anderson. *J. Am. Chem. Soc.*, 76, 6207 (1954). Variations in the extraction equilibria of the thenoyl-trifluoroacetates of the trivalent actinides in toluene-aqueous systems were observed. Distribution ratios of Eu, Yb, Ac, Am, Cm, Bk, Cf, 99, and 100 are tabulated. With the exception of element 100, the dependence of the acid on acid concentration was found to be inversely proportional to the third power of the acid concentration.

118

CHEMISTRY DIVISION SECTION C-1: SUMMARY REPORT FOR JULY, AUGUST, AND SEPTEMBER 1950. D. W. Osborne. ANL-4545 (1950).

The extraction of Am and Cm into butyl phosphate solvents from various aqueous phases is discussed.

119

ANALYTICAL CHEMISTRY DIVISION QUARTERLY PROGRESS REPORT FOR PERIOD ENDING MARCH 26, 1951. ORNL-1088.

A method for the separation of Am and Cm from the rare earths is being studied which consists in extracting them from an aqueous phase of pH 5 with 0.5 M TTA-xylene and then "stripping" the organic phase with versene. The effect of pH on the selectivity of Am stripping is shown.

120

PLANT SCALE CONCENTRATION OF Am AND Pu(III) USING TRIBUTYL PHOSPHATE. W. J. Maraman, A. J. Beaumont, R. S. Day, and R. S. Winchester. LA-1699 (August 2, 1954).

Am³⁺ and Pu³⁺ have been recovered on a plant scale by extracting with TBP from slag and crucible and other recovery solutions. Process losses were 0.03 percent Am and 0.01 percent Pu. The product stream contained 0.08 g Am/liter and 0.15 g Pu/liter. Final cleanup to less than 10⁻⁴ g Pu/liter was accomplished by TBP extraction of Pu³⁺ under conditions of low acidity and high nitrate.

121

ACID AND ESTERS OF ORTHOPHOSPHORIC ACID AS SELECTIVE EXTRACTANTS FOR METALLIC CATIONS: TRACER STUDIES. D. F. Peppard, G. W. Mason, W. J. Driscoll, and R. J. Sirenén. *J. Inorg. Nucl. Chem.*, 7, 276-85 (1958).

The extraction of trivalent Sc, Y, La, Ac, Pm, Tm, and Am into solutions of (GO)PO(OH)₂ and (GO)₂PO(OH) in toluene as carrier solvent from aqueous mineral acid phases have been investigated as a function of solvent concentration in the organic phase, hydrogen ion concentration in the aqueous phase, the nature of G, and the position of M(III) in the periodic table, using radioactive tracer techniques.

122

CHEMICAL TECHNOLOGY DIVISION, CHEMICAL DEVELOPMENT, SECTION C, MONTHLY PROGRESS REPORT, AUGUST 1959. K. B. Brown, K. A. Allen, C. F. Coleman, D. J. Crouse, and A. D. Ryon. CF-59-8-45.

Plutonium was effectively freed from Am contamination

by extraction from 2 M HNO₃ with 0.1 M di(2-ethylhexyl) phosphoric acid.

123

SEPARATION PROCESS FOR ACTINIDE ELEMENTS AND COMPOUNDS THEREOF. L. B. Werner, I. Perlman, and M. Calvin. U.S. Patent 2,894,805 (1959).

This patent deals with the separation of Am and/or Am salts from La salts contained in an aqueous solution by contacting the latter at pH 2 to 4.8, with fluorinated β-diketone

wherein R is an alkyl, aryl, aralkyl, alkaryl, or heterocyclic radical and R¹ and R² are hydrogen or fluorine. The Am or Cm is selectively extracted as a chelate with the β-diketone. It can be chelated and extracted away from Am and Cm by adjusting the pH between 0.2 and 3.

124

TRI-n-BUTYL PHOSPHATE AS AN EXTRACTING AGENT FOR INORGANIC NITRATES. VII. THE TRIVALENT ACTINIDE NITRATES. G. F. Best, E. Hesford, and H. A. C. McKay. *J. Inorg. Nucl. Chem.*, 12, 136-40 (1959).

The trivalent actinide nitrates resemble the trivalent lanthanide nitrates in their extractability by tri-n-butyl phosphate (TBP). The resemblance is especially close for elements of the same ionic radius. In both series the element with a half filled f-shell (Gd or Cm) is less extractable than might have been expected from the behavior of its neighbors.

125

APPLICATION OF PHOSPHORIC ACID ESTERS TO THE ISOLATION OF CERTAIN TRANS-PLUTONIDES BY LIQUID-LIQUID EXTRACTION. D. F. Peppard, G. W. Mason, W. J. Driscoll, and S. McCarty. *J. Inorg. Nucl. Chem.*, 12, 141-8 (1959).

The use of (GO)₂PO(OH) and (GO)PO(OH)₂ as extractants in a carrier solvent against an opposing aqueous mineral acid phase in effecting certain mutual separations in the actinide(III) and lanthanide(III) series was investigated. The separation of Cf (and Es and Fm) from Cm (and Am) by use of a di-2-ethylhexyl phosphoric acid-HCl system was carried out on a laboratory scale. The separations of Am(III) from Pm(III) by use of mono-2-ethylhexylphosphoric acid-HCl system was demonstrated. No system readily applicable to the separation of Am and Cm was developed.

126

THE EXTRACTION OF ACTINIDE ELEMENTS FROM NITRIC ACID SOLUTIONS BY TRI-n-OCTYLAMINE.

W. E. Keder, J. C. Sheppard, and A. S. Wilson.

J. Inorg. Nucl. Chem., 12, 327-35 (1960).

The extraction of Th, Pa, U, Np, Pu, and Am from HNO_3 solutions by tri-n-octylamine in xylene was investigated and the effects of the amine concentrations were measured.

127

TRANSURANIUM STUDIES. ORNL-2993.

A solvent extraction flowsheet was developed on a laboratory scale for recovering Pu, Am, and Cm from highly irradiated Pu-Al alloy. A process for separating actinides from lanthanides by anion exchange based on selective chloride complexing was developed and tested on a laboratory scale. Am, Cm, and rare earths were sorbed on Dowex 1-10x resin from a solution of 8 M LiNO_3 . The rare earths were selectively eluted with 10 M LiCl and the Am-Cm with 1 M LiCl . This process gave greater than 99.5 percent recovery of Am, which contained no detectable amounts of rare earths. Am and Cm were concentrated by extraction into 100 percent TBP from concentrated LiCl_3 solution. AmCl_3 solutions, containing 170 g of Am, were converted to pure AmO_2 at the theoretical 88.3 percent.

128

SOLVENT EXTRACTION TECHNOLOGY. ORNL-2993.

Americium was extracted preferentially to the light rare earths from concentrated LiCl solutions by TBP, giving the most promising separation observed thus far for the transplutronics from fission-product rare earths. A 12-stage batch countercurrent extraction with 1 M TBP from 10 M LiCl -0.1 N HCl gave a separation factor of 310 between Am and Eu. Am was extracted between Ce and Eu by several amines.

129

SOLVENT EXTRACTION OF Eu(152)(154) AND Am(241) BY Di-n-BUTYL PHOSPHATE (DBP) IN DIFFERENT ORGANIC SOLVENTS. D. Dyrssen and L. D. Hay. *Acta Chem. Scand.*, 14, 110-1 (1960).

The distribution of Am-241, Eu-152 and 154 between aqueous nitric acid and solutions of di-n-butyl phosphate was studied in seven organic solvents. For separation of Eu and Am, n-hexane, CCl_4 , and CHCl_3 are the best solvents studied. For given concentrations, n-hexane and CCl_4 give the highest distribution ratio.

130

SEPARATION OF TRANSPLUTONIUM AND RARE EARTH ELEMENTS BY LIQUID-LIQUID EXTRACTION.

R. D. Baybarz and R. E. Leuze. CF-60-3-32 (1960).

A solvent extraction process for separating Am and Cm from major portions of rare earths was developed. Rare earth elements are extracted from 10 M LiCl solutions (with HCl varying from 0.5 to 1.0 M) into 0.5 M mono-2-ethylhexyl orthophosphoric acid in xylene carrier. The Am and Cm remain in the LiCl solution. Am is separated from all rare earths and Cm from all rare earths except La by countercurrent extraction.

131

CHEMICAL TECHNOLOGY DIVISION: CHEMICAL DEVELOPMENT SECTION C. PROGRESS REPORT FOR JUNE-JULY 1960. K. B. Brown. CF-60-7-108 (September 26, 1960).

In a study of relative extractabilities of americium and lanthanides from aqueous solutions by several reagents, the only preferential extractions of Am over the fission product rare earths were with phosphate TBP and phosphonate esters from concentrated LiCl solutions.

132

ANALYTICAL TECHNICAL MANUAL. R. A. Schneider and K. M. Harmon. HW-53368 (February 1, 1961).

Descriptions are given of alpha counting methods and the determination of Am-241 by TBP and TTA extraction.

133

INFLUENCE OF THE CHELATING AGENT ON THE SEPARATION OF Eu(III) AND Am(III) IONS BY SOLVENT EXTRACTION. D. Ryrssen, M. Haffez, and T. Sekine. *J. Inorg. Nucl. Chem.*, 16, 367-8 (1961).

The distribution ratios ($\text{CHCl}_3/\text{H}_2\text{O}$ with β -isopropyltropolone) is $q_{\text{Eu}} \approx q_{\text{Am}}$ and with 5,7-dichlorooxime $q_{\text{Eu}} < q_{\text{Am}}$. This gradual change of order seems to be parallel to the basicity of the ligand forming atoms in the complexing agents. Hence the oxygen atoms in β -isopropyltropolonate are less basic than the nitrogen and oxygen atoms in 5,7-dichlorooximate. Qualitatively an increase in the basicity and chelating power (stability constants) of the ligand will increase $q_{\text{Am}}/q_{\text{Eu}}$. This relationship may facilitate the choice of a suitable chelating agent for the separation of Eu(III) and Am(III).

134

EXTRACTION OF AMERICIUM WITH TRIBUTYL-PHOSPHATE. V. I. Zemlyanukhin and G. P. Savoskina. *Radiokhimiya*, 3, 411-6 (1961).

In the presence of non-extractable nitrate the americium distribution coefficient increases with increased nitrate concentrations and diminishes with increased concentrations of nitric acid. The salting-out equivalents are calculated for a certain group of nitrates. The extraction of Am improves with increased cation potential and Am activity coefficient. Complexes of $\text{Am}(\text{NO}_3)_3 \cdot$

nTBP·mHNO₃ in the organic phase formed during extraction from strong HNO₃ > 8 M solutions and the lack of stable complexes in aqueous solutions were observed.

135

SYNERGISM IN THE SOLVENT EXTRACTION OF DI-, TRI-, AND TETRA-VALENT METAL IONS. I. SYNERGIC EFFECTS OF DIFFERENT PHOSPHATE ESTERS. T. V. Healy. *J. Inorg. Nucl. Chem.*, 19, 314-27 (1961).

Synergic effects noted previously only in the solvent extraction of UO₂ ions are now shown to exist for other ions. Examples of this greatly enhanced extraction from aqueous solution are given for rare earths, actinides and alkaline earths, the extracted species being Ca(TTA)₂S₂, UO₂(TTA)₂S₁, UO₂(TTA)₂S₂, Pm(TTA)₃S₂, Tm(TTA)₃S₁, Tm(TTA)₃S₂, Am(TTA)₃S₂, Cm(TTA)₃S₂, and Th(TTA)₄S₁ where S is a neutral organophosphorous ester varying from trioctyl phosphine oxide with its highly polar phosphorous oxygen bond to the very weakly basic triphenylphosphate and TTA.

136

SYNERGIC EFFECTS IN THE SOLVENT EXTRACTION OF THE ACTINIDES. IV. TRI-VALENT PLUTONIUM, AMERICIUM, AND EUROPIUM. H. Irving and D. N. Edgington. *J. Inorg. Nucl. Chem.*, 21, 169-80 (1961). By using radioactive tracers the solvent extraction of Pu(III), Am(III), and Eu(III) from 0.01 N HCl, 0.001 N HNO₃, and an acetate buffer of pH 3.95, respectively, into mixtures of TTA and TBP in cyclohexane was studied. The extractible species has the composition MX_n·2TBP (where TTA is HX and M is Pu, Am, or Eu). This demonstrates the possibility of eight-fold coordination in these elements. When the TBP is replaced by tri-n-butyl phosphine oxide, a synergic enhancement of the extraction coefficient is again found. Here the TBPO replaces some of the chelating molecules and the species MX₂(NO₃)·2TBPO and MX₃ (M is Am or Eu) appears to be co-extracted. Some equilibrium constants are reported.

137

THE SOLVENT EXTRACTION OF PLUTONIUM AND AMERICIUM BY TRI-N-OCTYL PHOSPHINE OXIDE. B. Martin, D. W. Ockenden, and J. K. Foreman. *J. Inorg. Nucl. Chem.*, 21, 96-107 (1961).

The extraction of plutonium in the three valence states (III), (IV), and (VI) from nitric and hydrochloric acids of various strengths and the properties of the Pu(IV) and (VI) tri-n-octylphosphine oxide complexes extracted into the organic phase from nitric acid are described. The extraction of Am(III) from nitric acid is also

briefly described. Over the range of acidities examined, 0.1 M TOPO extracted at least 99.5 percent of the Pu(IV) nitrate and 99.5 percent of the Pu(VI) nitrate from 0.3 to 0.7 N nitric acid. The extraction of Pu(VI) and Pu(IV) chlorides was similar.

138

ANALYTICAL EXTRACTION OF NEPTUNIUM USING TRI-ISO-OCTYLAMINE AND THENOYLTRIFLUORO-ACETONE. R. A. Schneider. *Anal. Chem.*, 34, 522-5 (1962).

An analytical solvent extraction method for separation of Np from Pu, Am, Cm, U, Th, and fission products using tri-iso-octylamine and TTA is described. Np is separated from the bulk of the Pu, Am, Cm, and fission products by the extraction of Np(IV) into tri-iso-octylamine dissolved in xylene from an aqueous HNO₃ reducing solution. The Np bearing organic solution is then scrubbed with HNO₃ reducing solution to achieve further purification. Final purification is obtained by stripping the Np from the tri-iso-octylamine-xylene solution into dilute HCl and then extracting the Np(IV) into TTA dissolved in xylene. The method is used routinely to separate Np-237 from other alpha emitters and fission products in preparation for a quantitative Np-237 measurement by alpha counting.

139

SEPARATION OF TRANSURANIUM ELEMENTS BY PHOSPHATE EXTRACTION. R. D. Baybarz. *Trans. Am. Nucl. Soc.*, 5, No. 1, 18-9 (1962). Separation of Am from Bk, Cf, and Es.

140

SEPARATION OF TRANSPLUTONIUM ELEMENTS BY PHOSPHONATE EXTRACTION. R. D. Baybarz. ORNL-3273 (1962).

A process for separating transcurium elements from Am and Cm which consists of preferential solvent extraction of the transcurium elements with 2-ethylhexylphenyl phosphonic acid from dilute HCl solutions was developed and tested on a laboratory scale. Single stage separation factors of 100 were found between Cf and Cm. Extraction positions of Am, Cm, Bk, Cf, Es, and Fm were determined. Extraction varied with the inverse third power of the acid composition in the range 1 to 4 N and directly with the third power of the extractant concentration.

141

EXTRACTION OF MENDELEVIUM AND FERMIUM IN TBP - HNO₃. M. Taube, E. Gvuzd, K. A. Gavrilov, Ya. Maly, I. Brandshtet, and T'ung-seng Wang. JINR-P-1001 (1962).

The partition ratio of Md, Fm, Cf, Am, Cm, and Eu by TBP extraction from HNO_3 solutions was measured. The obtained results are: $D_{\text{Cf}} < D_{\text{Eu}} < D_{\text{Fm}} \leq D_{\text{Md}}$ when $4 < D_{\text{Md}} < 5.5$, $3.5 < D_{\text{Fm}} < 4.5$ for 13.1 M HNO_3 .

142

SYNERGISTIC EFFECTS IN THE EXTRACTION OF SELECTED METALLIC CATIONS BY MONO-(2-ETHYL HEXYL) PHOSPHORIC ACID. G. W. Mason, S. McCarty, and D. F. Peppard. TID-15271; UAC-5922 (1961); *J. Inorg. Nucl. Chem.*, 24, 967-77 (1962).

The effect of synergistic agents upon the extraction of M(III) lanthanides, Y(III), Am(III), Cm(III), Th(IV), and U(VI) by H_2MEHP , mono-2-ethylhexyl phosphoric acid, in a carrier diluent from aqueous HCl was investigated as a function of carrier diluent synergistic agent concentration of H_2MEHP and Z of M(III) lanthanides.

143

ON THE SYNERGISTIC EFFECT IN SOLVENT EXTRACTION. L. Newman. BNL-6188 (1962).

It is shown that the synergistic effect is the result of addition reactions as well as replacement reactions and is not a function of the metal being extracted. A completion of equilibrium constants describing the synergistic effect of TBP and TOPO on TTA extraction is given for the following metal ions: Th(IV), $\text{UO}_2(\text{II})$, Am(III), Cm(III), Pm(III), Tm(III), and Ca(II).

144

THE EXTRACTION OF AMERICIUM AND EUROPIUM NITRATE BY TRI-n-OCTYL PHOSPHINE OXIDE IN TOLUENE. T. Ishimori, C. T. Rhee, and T. Fujino. *Nippon Genshiryoku Gakkaishi*, 4, 837-44 (1962).

The extraction behavior of Am and Eu is studied in a TOPO- HNO_3 system. Only free TOPO extracts Am and/or Eu. From this conclusion the maximal K_d value and corresponding acidity are estimated.

145

STUDY OF THE COMPLEX FORMATION OF AMERICIUM WITH DI-ISOAMYL ESTER METHYLPHOSPHINIC ACID (DAMP). V. I. Zemlyanukhin, G. P. Savoskina, and M. F. Pushlenkov. *Radiokhimiya*, 4, 655-60 (1962).

In view of the good results obtained with DAMP in the extraction of Pu, the complex formation of Am and its extraction from HNO_3 , HClO_4 , HCl , H_2SO_4 , and CH_3COOH solutions with this agent were investigated. The distribution coefficient of Am was found to be quite high during the extraction from HNO_3 and HClO_4 solutions in which a trisolvate is formed. The element is not extracted well from the other three acids. The constant of complex formation of $\text{Am}(\text{NO}_3)_3 \cdot 3\text{DAMP}$ was found to be $k = 8.3$.

146

COMPLEXING OF AMERICIUM WITH NEUTRAL PHOSPHOROORGANIC COMPOUNDS (PART I).

V. I. Zemlyanukhin, G. P. Savoskina, and M. F. Pushlenkov. *Radiokhimiya*, 4, 570-5 (1962).

Studies of Am extraction by phosphoroorganic compounds (tri-n-butyl-phosphate, di-n-butylester of n-butyl-phosphonic acid, n-butylester of di-n-butylphosphinic acid, and tri-n-butylphosphine oxide) show that Am and neutral phosphoroorganic compounds form Am trisolvate: $\text{Am}(\text{NO}_3)_3 \cdot \text{TBP}$, $\text{Am}(\text{NO}_3)_3 \cdot 3\text{DBEBP}$, $\text{Am}(\text{NO}_3)_3 \cdot 3\text{BEDBP}$, and $\text{Am}(\text{NO}_3)_3 \cdot 3\text{TBPO}$. Complexing constants are $K_{\text{TBP}} = 0.4$, $K_{\text{DBEBP}} = 7.4$, $K_{\text{BEDBP}} = 112$, and $K_{\text{TBPO}} = 1780$.

147

BIDENTATE ORGANOPHOSPHOROUS COMPOUNDS IN EXTRACTANTS. I. EXTRACTION OF CERIUM, PROMETHIUM, AND AMERICIUM NITRATES.

T. H. Siddal. TID-16930 (1962).

It is shown that tetraalkyl methylenediphosphonates, dialkyl N , n-dialkylcarbamyldiphosphonates, and dialkyl N , n-dialkylcarbamyldimethylenephosphonates are powerful chelating extractants for Ce, Pm, and Am from HNO_3 solutions.

148

ORGANOPHOSPHOROUS COMPOUNDS OTHER THAN TBP FOR PROCESSING OF IRRADIATED FUELS AND BY PRODUCTS. T. H. Siddal. TID-18299 (1963).

Recovery of by-product elements such as Pm, Am, and Cm is discussed with particular emphasis on the possible use of bifunctional organophosphorous extractants.

149

SEPARATION OF TRANSURANIUM ELEMENTS BY SOLVENT EXTRACTION WITH ALKYLPHOSPHORIC ACIDS. V. N. Kosyakov, E. S. Gureev, and G. N. Yakovlev. CONF-72-2 (1963).

Mono- and di-alkylphosphoric acids were studied as extractants for transuranium elements at different valency (III, IV, V, VI). It was found that the mechanism of extraction of Me^{+3} , Me^{+4} , and MeO^{+2} has a cation exchange nature and that the distribution coefficients of these cations are affected differently by H^+ ion concentration, complexing ion concentration in aqueous phase, extractant concentration, and diluent nature. Several examples of separation techniques are described. The different ability of trivalent actinide and lanthanide elements, for complex formation with SCN^- anions, was used for developing an extraction method of separation of Am from lanthanide fission products.

150

HOT LABORATORY DIVISION. L. G. Stang, M. Hillman, *et al.*, BNL-782.
Hydrolysis of americium was found to limit the pH range over which Am can be extracted with TTA.

151

SOME ASPECTS OF SYNERGISM IN SOLVENT EXTRACTION. II. SOME DI-, TRI-, AND TETRA-VALENT METAL IONS. M. Zangen. *J. Inorg. Nucl. Chem.*, 25, 1051-63 (1963).

Synergistic extraction of trivalent lanthanides and actinides, alkaline earths, and Th from HCl solutions, was studied using a combination of a monoacidic phosphate or phosphonate ester with a neutral organophosphorous compound (the synergist) at varying concentrations in cyclohexane.

152

CHEMISTRY OF LANTHANIDE AND TRANSPLUTONIUM ELEMENTS. ORNL-3452, p 166-7 (1963).

The extraction of Am(III) was found to be greater than that of Am(VI) by factors greater than 10^4 with D2EHPA from dilute HNO_3 ; up to 100 with tri-octylphosphine oxide from LiNO_3 ; and up to 30 with TBP from NaNO_3 . Extractions by D2EHPA should be applicable to the separation of Cm from Am as Am(VI), since Cm(III) is usually still more extractable than Am(III).

153

TYPES OF ACIDIC ORGANOPHOSPHOROUS EXTRACTANTS AND THEIR APPLICATIONS TO TRANSURANIC SEPARATIONS. G. W. Mason and D. F. Peppard. *Nucl. Sci. Eng.*, 17, 247-51 (1963). Certain applications of acidic organophosphorous extractants to transuranic separations are described.

154

APPLICATION OF AMINE AND PHOSPHONATE EXTRACTANTS TO TRANSPLUTONIUM ELEMENT PRODUCTION. R. E. Leuze, R. D. Baybarz and B. S. Weaver. *Nucl. Sci. Eng.*, 17, 252-8 (1963).

The Tramex process, in which trivalent actinides are extracted into tertiary amine-HCl from concentrated LiCl solution, was developed for the isolation of transplutonium elements. Tests made in a laboratory scale mixer-settler gave Am losses of about 0.01 percent, and fission product decontamination factors of equal to or greater than 10^4 .

155

CHEMICAL TECHNOLOGY DIVISION, CHEMICAL DEVELOPMENT SECTION C, PROGRESS REPORT ON SEPARATIONS CHEMISTRY AND SEPARATIONS PROGRESS RESEARCH FOR JANUARY-JUNE (1963).

K. B. Brown. ORNL-3496 (1963).

Alamine 336 extracted Eu and Am about three times as well as Ce from carboxylic acids, while preference was in reverse order from concentrated $\text{Al}(\text{NO}_3)_3$. Aliquot 336 extracted Ce, Eu, and Am strongly and about equally from dilute KHCO_3 solutions. Am(III) was more extractable than Am(VI) in several extraction systems. Some of the systems seem to be suitable for the separation of Am from Cm.

156

ISOLATION OF TRANSPLUTONIUM ELEMENTS BY TERTIARY-AMINE EXTRACTION. R. D. Baybarz, B. S. Weaver, and H. B. Kinser. *Nucl. Sci. Eng.*, 17, 457-62 (1963).

A process based on tertiary-amine extraction of transplutonium elements from concentrated LiCl solutions was developed. Single stage separation factors between the transplutonium and lanthanide elements were found to be ≥ 100 . Extraction positions were found to be $\text{Cf} > \text{Fm} > \text{Es} > \text{Bk} > \text{Am} > \text{Cm} >> \text{lanthanides}$. Extraction coefficients were directly proportional to the square of the amine concentration in the solvent, directly proportional to the 17th power of the LiCl concentration, and inversely proportional to the 1.3 to 2.0 power of the acid concentration in the aqueous phase. Extraction coefficients were affected by the presence of various contaminant anions and were also dependent upon the solvent used to dilute the amine.

157

DEVELOPMENT OF CHEMICAL FLOWSHEETS FOR THE OVERALL PROCESS. K. B. Brown and R. E. Leuze. ORNL-3558.

Lithium chloride anion exchange was successfully used to recover and purify Am-Cm containing 22 mg of Cm-242 and to separate gram quantities of Am-241 from contaminant rare earths. Tracer level Am(VI) was usually less extractable than Am(III) in several extracting systems. Extraction by di(2-ethylhexyl) phosphoric acid from dilute HNO_3 showed a preference of 10^4 for Am(III) and indicated a possible method for the preferential extraction of Cm(III) from Am(VI).

158

COMPLEXING OF AMERICIUM WITH ACIDIC PHOSPHOROUS ORGANIC COMPOUNDS. V. I. Zemlyanukhin, G. P. Savoskina, and M. F. Pushlenkov. *Radiokhimiya*, 5, 674-9 (1963).

Studies of the extraction of Am from various media by dibutyl phosphate (DBP) indicated that the extraction mechanism varies with increased acid concentration in aqueous solution. At low acidity (to 1 M) of the solution, Am displaces H in DBP forming $\text{Am}(\text{HA}_2)_3$ complexes with complexing constants $K = 1.6 \pm 0.3$ for 30

percent solutions of DBP in CCl_4 . At high acid concentration, an addition reaction forms different complexes of the $\text{Am}(\text{NO}_3)\cdot n\text{H}_2\text{A}_2$ type. A synergistic effect was discovered in the extraction of Am by TBP and DPP mixtures.

159

SEPARATION OF Eu^{+3} AND Am^{+3} BY SOLVENT EXTRACTION OF THEIR METAL CHELATE COMPLEXES. T. Sekine and D. Dyrssen. *Talanta*, 11, 867-73 (1964).

The separation of Eu^{+3} and Am^{+3} by solvent extraction was studied. The distribution of chelate complexes of these metal ions between 0.1 M NaClO_4 and CHCl_3 or hexane with 19 chelating acids was determined. Among the acids it was found that some extract Eu^{+3} into the organic phase better than Am^{+3} , some extract Am^{+3} better, and some extract them equally well. It was found that dialkylhydrogenphosphates and 5,7-dichloroxine are the most suitable chelating acids for the separation of Eu^{+3} and Am^{+3} by solvent extraction.

160

THE EXTRACTION OF CURIUM AND AMERICIUM BY TRI-N-OCTYL PHOSPHINE OXIDE. K. Watanabe and R. Ono. *J. Nucl. Sci. Technol.*, 1, 75-6 (1964). The extraction of Cm by TOPO from HNO_3 solutions was studied together with the extraction of Cm, Am, and Eu from NH_4NO_3 solutions. The extraction of Am by 5 percent TOPO from HCl solution was also investigated.

161

TALSPEAK: A NEW METHOD OF SEPARATING AMERICIUM AND CURIUM FROM THE LANTHANIDES BY EXTRACTION FROM AN AQUEOUS SOLUTION OF AN AMINOPOLYACETIC ACID COMPLEX WITH MONOACIDIC ORGANOPHOSPHATE OR PHOSPHONATE. B. S. Weaver and F. A. Kappelmann. ORNL-3559 (1964).

Talspeak is a method for separating Am and Cm from the lanthanides. The process consists in highly preferential complexing of the trivalent actinides by an aminopolyacetic acid, so that the lanthanides are much more strongly extracted by a monoacidic organophosphate or phosphonate.

162

A RAPID RADIOCHEMICAL ANALYSIS FOR AMERICIUM-241. M. H. Campbell. *Anal. Chem.*, 36, 2065-7 (1964); HW-79770.

Am(III) is quantitatively separated from HNO_3 solutions by liquid-liquid extraction with di(2-ethylhexyl) orthophosphoric acid with no valence adjustment. Am recoveries are presented as a function of acid molarity and

extractant concentration. Decontamination factors for Pu, U, and Np are presented. The Am yield was 99.2 percent with a standard deviation of ± 0.8 percent.

163

NEW APPROACH TO THE SEPARATION OF TRIVALENT ACTINIDE ELEMENTS FROM LANTHANIDE ELEMENTS. SELECTIVE LIQUID-LIQUID EXTRACTION WITH TRICAPRYLMETHYLAMMONIUM THIOCYANATE. F. L. Moore. *Anal. Chem.*, 36, 2158-62 (1964); ORNL-P-37.

Preferential liquid-liquid extraction of the anionic thiocyanate complexes of trivalent actinide elements with tricaprylmethylammonium thiocyanate dissolved in xylene affords an improved method for their separation from the lanthanide elements. The order of decreasing extractability is

$\text{Cf} > \text{Bk} > \text{Am}, \text{Cm} > \text{Yb} > \text{Tm} > \text{Eu} > \text{Pm} > \text{Y} > \text{Ce} > \text{La}$.

K. Ion-Exchange Techniques

164

THE SEPARATION OF AMERICIUM AND CURIUM FROM THE RARE EARTH ELEMENTS. K. Street, Jr., and G. T. Seaborg. *J. Am. Chem. Soc.*, 72, 2790-2 (1950).

Elution of Am, Cm, Lu, and Pm with ammonium citrate, 2M ammonium nitrate and various concentrations of HCl, HBr, and HClO_4 in a resin ion-exchange column was performed. The concentration of the acid strongly effected the time of elution of Am and Cm with respect to the rare earths. Elution rates were determined.

165

STUDIES IN THE NUCLEAR CHEMISTRY OF PLUTONIUM, AMERICIUM AND CURIUM, AND THE MASSES OF THE HEAVIEST ELEMENTS. R. A. Glass (thesis). UCRL-2560 (1954).

Ion-exchange column elution methods for the separation of americium and curium using tartrate and lactate solutions have been developed which are superior to citrate elutions. Tartrate is suitable for slow elutions and lactate elutions are satisfactory for rapid separations. In the course of the Pu-239 bombardments a study of the decay scheme of Am-240 was undertaken.

166

CHELATING AGENTS APPLIED TO ION EXCHANGE SEPARATIONS OF AMERICIUM AND CURIUM. R. A. Glass. UCRL-2521 (1954).

The elution of trivalent Am and Cm from cation exchange columns with tartrate and lactate solutions is reported. The column elutions with 0.1 M tartrate

solution adjusted to a pH of 4.0 with NH_4OH gave a separation factor of 1.30 between Am and Cm at room temperature. The contamination was less than 0.2 percent. A 0.4 M lactic acid solution adjusted to a pH of 4.6 gave a separation factor of 1.19 with a contamination of about 2 percent. A study of the relative efficiencies of four related chelating acids was made.

167

CURIUM-AMERICIUM SEPARATION AND PURIFICATION PROCESSES. K. Street, Jr. U.S. Patent 2,711,362 (June 21, 1955).

A process is presented for separating transuranic elements from each other and from the elements of the lanthanide series. The cations to be separated are first adsorbed on a cation-exchange resin such as a sulfonated-polyvinyl aryl resin and then selectively eluted by strong 6 to 13.3 M HCl.

168

PURIFICATION OF GRAM AMOUNTS OF AMERICIUM. J. S. Coleman, D. E. Armstrong, L. B. Asprey, T. K. Keenan, L. E. LaMar and R. A. Penneman. LA-1975 (November 1955).

Ion-exchange, solvent-extraction, and precipitation methods for the purification of Am are discussed. Two new ion-exchange methods for the separation of Am from the rare earths are discussed. The first involves absorption of the rare earths and Am on a H-form cation exchanger, followed by elution with 0.1 percent ammonium citrate, pH 8. The second involves the tendency of strongly basic anion exchangers to absorb Am in preference to the rare earths from thiocyanate solution. Solvent extraction with TBP and oxidation-reduction methods are also described.

169

SEPARATION OF ACTINIDE ELEMENTS BY CATION EXCHANGE USING ALPHA HYDROXYISOBUTYRIC ACID. J. Milsted and A. B. Beadle. *J. Inorg. Nucl. Chem.*, 3, 248 (1956).

The separation factors for Am, Cm, and Cf by elution from Zeo-Karb 225 resin with alpha hydroxyisobutyric acid are determined.

170

AN ANION EXCHANGER PROCESS FOR GRAM-SCALE SEPARATION OF AMERICIUM FROM RARE EARTHS. J. S. Coleman, R. A. Penneman, T. K. Keenan, L. E. LaMar, D. E. Armstrong, and L. B. Asprey. *J. Inorg. Nucl. Chem.*, 3, 327-8 (1956).

A simple one-step process for the separation of gram amounts of Am from large quantities of light rare earths is presented. The separation utilizes the marked tendency of a strong base anion exchanger such as

Dowex 1 to absorb Am from concentrated ammonium thiocyanate solutions in preference to light rare earths.

171

THE ISOLATION AND PURIFICATION OF AMERICIUM. D. O. Campbell. ORNL-1855 (1956). Gram amounts of Am were separated quantitatively from kilogram quantities of La to yield an Am product approaching 90 percent purity. The remaining impurity was chiefly Y. Elution of Am from a Dowex-50 resin with 0.15 M citric acid - 0.10 M diammonium citrate - 0.3 M ammonium nitrate, pH 3.3, gave a product containing 99 percent of the Am with a La/Am ratio of 1/100 and with a 100 fold volume reduction. Elution with 12.8 M HCl gave a 90 percent Am product with a La/Am ratio of 1/4.

172

EQUILIBRIUM SORPTION OF LANTHANIDES, AMERICIUM, AND CURIUM ON DOWEX-50 RESIN. J. P. Surls, Jr. and G. R. Choppin. *J. Am. Chem. Soc.*, 79, 855-9 (1957).

The equilibrium sorption of the tripositive lanthanides and americium and curium from 0.110 HClO_4 solutions on Dowex-50 cation exchange resin has been studied at 25°C. The relative sorbability decreased from La to Dy. From Dy to Lu almost no change in sorbability was observed. Am and Cm sorbed with the same strength as lanthanides of comparable crystallographic radius. A correlation of ion-exchange sorbabilities and ionic conductance at infinite dilution has been made.

173

ION EXCHANGE SEPARATION OF GRAM QUANTITIES OF AMERICIUM FROM A KILOGRAM OF LANTHANUM. D. E. Armstrong, L. B. Asprey, J. S. Coleman, T. K. Keenan, L. E. LaMar, and R. A. Penneman. *A. I. Ch. E. Journal*, 3, 286-8 (1957).

The separation of 4.5 g of Am from 1 kg of light rare earths was achieved on a pilot-plant scale by chromatographic displacement of the mixture from Dowex-50 with 0.1 percent ammonium citrate. The Am was collected in a narrow band and was eluted free from La but contained an equal weight of Ce. No adverse effects were noted from 15 curies of alpha activity.

174

ION EXCHANGE BEHAVIOR AND DISSOCIATION CONSTANTS OF AMERICIUM, CURIUM, AND CALIFORNIUM COMPLEXES OF ETHYLENEDIAMINE-TETRAACETIC ACID. J. Fuger. *J. Inorg. Nucl. Chem.* 5, 332-8 (1958).

Separation factors between Cf, Cm, and Am anion exchange resin Dowex-50-x-12, in ammonium form, have been calculated from static equilibrations between

pH 2 and pH 3.3 in presence of EDTA 10^{-3} M. They are found to be 2.04 ± 0.05 between Am and Cm and 5.5 ± 0.1 between Am and Cf. In the experimental conditions, only 1:1 complexes are formed. The dissociation constants are found to be equal to Cf $10^{-19.09 \pm 0.2}$, Cm $10^{-18.45 \pm 0.1}$, and Am $10^{-18.16 \pm 0.1}$. Preliminary column experiments show that this complexing agent will be quite useful for separating actinide elements.

175

ANION-EXCHANGE BEHAVIOR OF SEVERAL METAL IONS IN HCl, HNO₃, AND H₂SO₄ SOLUTIONS WITH DOWEX-2. L. R. Bunney, N. E. Balloa, J. Pascual, and S. Foti. USNRDL-tr-228.

Distribution coefficients were measured for Am and other elements in the systems Dowex-2-HCl, Dowex-2-HNO₃, and Dowex-2-H₂SO₄. Acid concentrations ranged from 0.1 N to concentrated. Am did not show any significant adsorption in any of the systems studied.

176

SEPARATION OF AMERICIUM AND PROMETHIUM.

R. S. Pressey. ORNL-2202.

Ion-exchange methods of separating rare earths separate Pm and Am together. Small quantities may be separated effectively but larger quantities are better separated by precipitation method. The Pm and Am are coprecipitated as fluorides and then dissolved in boric acid and HNO₃ solution. The resultant solution is made 3.0 M in H₂SiF₆ which, upon heating and slow digestion, decomposes into HF and SiF₄. PmF₃ precipitates from solution and americium remains complexed.

177

SEQUENTIAL SEPARATION OF SOME ACTINIDE ELEMENTS BY ION EXCHANGE. F. P. Roberts and F. P. Brauer. HW-60552 (1959).

Methods are presented by which trace amounts of actinide elements are separated. Use is made of the large differences in distribution coefficients, so careful chromatographic techniques are not necessary. A method is described for Am, Pu, and Np. These elements are sequentially eluted from columns of Dowex-1 resin in that order by 8 M HNO₃, 0.02 M ferrous sulfamate in 4.5 M HNO₃, and 0.001 M ceric sulfate in 0.25 M HNO₃. Another method is used to separate Am, Th, Pu, and Np sequentially in that order by 8 M HNO₃, 12 M HCl, 12 M HCl - 0.1 M NH₄I, and 4 M HCl by elutriation. Pa and U follow Am in both methods.

178

SOLUBILITY AND ION EXCHANGE METHODS FOR DETERMINING THE COMPLEX FORMATION OF

PLUTONIUM AND AMERICIUM(III) IN AQUEOUS SOLUTIONS. A. I. Moskvina. *Radiokhimiya*, 1, 430-4 (1959).

Ion exchange was used in studies of tri- and pentavalent plutonium complex formation in oxalate and EDTA solutions. The distribution of small quantities of Pu and Am between the solutions and KU-2 ammonium resin was studied with and without a complexing agent in the pH range 1 to 5 at 20°C.

179

A METHOD OF PURIFICATION OF AMERICIUM.

K. Naito. UCRL-8748 (1959).

All impurities, except Al and Mn, were separated from Am using the anion exchange separation with 9 M HCl eluant and with 5 M NH₄SCN dissolution and 2 M NH₄SCN elution. Some interesting facts were observed during the process of elution with NH₄SCN from the cation and anion exchange columns.

180

PREPARATION OF PURE AMERICIUM. V. A. Ryan and J. W. Pringle. RFP-130 (1960).

Am may be recovered in good yield and high purity from a HNO₃ feed containing Am at 1 mg/l together with large amounts of La, Fe, Pu, Al, etc., by ion exchange. The Pu is removed by sorption on Dowex-1 from a 7 M HNO₃ system. The solution was loaded at proper ionic strength on cationic resin (Dowex-50) and eluted with 5 M NH₄SCN. The Am thiocyanate complex was loaded onto an anion exchange resin (Dowex-1) and washed free of impurities, including the rare earths, with 5 M NH₄SCN. Am was finally eluted with 0.1 M HCl. The eluate is added to strong base and Am, Pu, and Fe are precipitated. This is washed, dissolved in 7 M HCl, and the Pu and Fe are fixed on an anion exchange resin (Dowex-1) while pure Am is washed from column with additional 7 M HCl.

181

ANION EXCHANGE SEPARATION OF THE TRI-VALENT ACTINIDE AND LANTHANIDES.

M. H. Lloyd and R. E. Leuze. CF-60-3-23 (1960).

A process for the separation of Am and Cm from rare earths by anion exchange based on selective chloride complexing was developed and tested on a laboratory scale. The separation is accomplished by sorption of Am, Cm, and rare earths on Dowex 1-10x resin from a solution of 8 M LiNO₃ followed by selective elution of rare earths with 10 M LiCl and Am-Cm elution with 1 M LiCl. Better than 99.5 percent Am was recovered containing no detectable amounts of rare earths.

182

DETERMINATION OF THE COMPOSITION AND INSTABILITY CONSTANTS OF OXALATE, NITRATE, AND SULFATE COMPLEXES OF Am(III) AND Cm(III) BY ION EXCHANGE. I. A. Lebedev, S. V. Pirozhkov, and G. N. Yakovlev (Akademiya Nauk SSSR). AEC-tr-4275. *Ordena Lenina Institut Atomnoi Energii*.

The effect of various factors on the sorption of Am(III) and Cm(III) from oxalate, nitrate, and sulfate solutions onto KU-2 cation exchange resin were studied. The formation of Am(III) and Cm(III) complexes with oxalate, nitrate, and sulfate ion was studied by ion-exchange methods. The composition and instability constants of these compounds were determined.

183

BEHAVIOR OF MICROQUANTITIES OF RADIO-ELEMENTS IN DILUTE SOLUTIONS: BEHAVIOR OF Am IN ION EXCHANGE. I. E. Starik and F. L. Ginzburg. *Radiokhimiya*, 3, No. 1, 45-51 (1961).

The sorption of Am-241 on ion-exchange resins in nitric acid solution (1 to 18 M) was studied. Am(III) is predominant in the solutions up to 1 M. With pH 4 the positive charge is reduced due to hydrolysis. Anion sorption of colloidal Am reaches 80 percent, however, cation sorption of colloidal Am does not occur. Electromigration and sorption in HNO₃ solutions indicate the formation of positively charged complexes in 1 to 4 M solutions. Neutral Am complexes are predominant in 4 to 16 M solutions.

184

DETERMINATION OF THE COMPOSITION AND INSTABILITY CONSTANTS OF Am(III) AND Cm(III) LACTATE COMPLEXES BY ION EXCHANGE. I. A. Lebedev and G. N. Yakovlev. *Radiokhimiya*, 3, 455-7 (1961).

Sorption of Am(III) and Cm(III) on cation resin KU-2 as a function of lactate ion concentration was studied. The results show the presence of AmLact⁺, Am(Lact)₂⁺, CmLact⁺, and Cm(Lact)₂⁺. Instability constants were calculated.

185

RAPID AND EFFICIENT PURIFICATION OF AMERICIUM. T. K. Keenan. *J. Inorg. Nucl. Chem.*, 20, 185-8 (1961).

About 200 mg of Am-241 was brought to 99.8 percent purity by ion-exchange and precipitation operations. Dilute and concentrated ammonium thiocyanate solutions were used as eluting agents with cation and anion exchangers to achieve this purity. This method did not purify Cm-244. Even at comparable levels of total alpha activity, much more thiocyanate

decomposition was observed with Cm than with Am. The specific activity or density of alpha radiation is postulated as the controlling factor.

186

ION EXCHANGE STUDIES OF THE LANTHANIDES AND ACTINIDES IN CONCENTRATED MINERAL ACIDS. G. R. Choppin and R. H. Dinius. *Inorg. Chem.*, 1, 140-5 (1962).

The absorption of trivalent actinide and lanthanide ions by Dowex-50 ion-exchange resin was studied in concentrated solutions of HClO₄, HCl, HBr, and HI. An explanation of the very strong absorption in 12 M HClO₄ is offered in terms of extraction of metal ion-perchlorates ion-pairs into the resin phase. The order of complexing, Cl > Br > I > ClO₄, agreed with the normal order for covalent complexes.

187

ION EXCHANGE PURIFICATION OF Pm-147 AND ITS SEPARATION FROM Am-241 WITH DIETHYLENETRIAMINEPENTAACETIC ACID AS THE ELUANT. P. B. Orr. ORNL-3271 (July 6, 1962). Based on a half-life of 2.64 ± 0.02 yr, a calculated weight of 2.032 g of Pm₂O₃-147 in 9 g of fission produced rare earths and americium oxides that was separated in two runs by cation exchange. Dowex-50 W-X4 resin, 80 mesh, with diethylenetriaminepentaacetic acid as an eluant. Pm, as the element, was present to the extent of about 23.5 wt % in the starting mixture and was increased to 98 wt % in the first run and to 99 wt % in the second with yields of 58.2 and 61.8 wt % respectively. A decontamination factor of 2.7 × 10⁹ was realized in the removal of Am from the product. Procedures, a modified elution curve, methods of analysis, losses, material balances, and a description of equipment are given. In addition, a possible colorimetric analysis scheme (qual.) is given for determining the proportions of Nd and Pm in a solution.

188

ANION EXCHANGE OF METAL COMPLEXES. XIII. THE ACTINIDE(III) NITRATE SYSTEM. Y. Marcus and M. Givon. IA-783 (1962).

Anion exchange distribution data were obtained for a number of trivalent actinide ions (Pu, Am, Cm, Cf, and Es) in LiNO₃ solutions. The distribution coefficients are comparable with those of the lanthanide group so that no group separation is possible, but within the actinide group, an efficient separation of Am and Cm was found. Extraction behavior by long chain amines followed that of the lanthanide but in reverse Z order. A second power dependence of distribution coefficients on amine concentration was found.

189

ION EXCHANGE BEHAVIOR OF THE TRANSURANIUM ELEMENTS IN LiNO_3 SOLUTIONS. S. Adar, R. K. Sjöblom, R. F. Barnes, P. R. Fields, E. K. Hulet, and H. Wilson. TID-16595; UAC-6498 (1962).

The distribution coefficients of trivalent Pu, Am, Cm, and Cf between LiNO_3 solutions (0.005 M H+) and Dowex-1 anion resin were measured. A column separation of Am and Cm using this system was investigated at 22.5°C and 87°C. The separation factor was found to be higher than that obtained with an ammonium alpha-hydroxyisobutyrate cation column system.

190

PROCESS FOR SEPARATING AMERICIUM AND CURIUM FROM RARE EARTH ELEMENTS.

R. D. Baybarz and M. H. Lloyd. U.S. Patent 3,079,225 (1963).

This invention relates to the separation of Am and Cm from the lanthanides. Am, Cm, and rare earths are sorbed on an anion exchange resin. A major portion of the rare earths are stripped from the resin with concentrated LiCl solution then Am, Cm, and a minor portion of the rare earths are stripped with a dilute solution of LiCl . Am and Cm may be further purified by selectively extracting the rare earths with monoalkylphosphoric acid from 8 M LiCl .

191

THE SEPARATION OF Cm-242 FROM JRR-1 NEUTRON IRRADIATED AND Am-241 CATION EXCHANGE WITH ALPHA HYDROXYISOBUTYRATE. T. Fujino. *Nippon Genshiryoku Gakkaishi*, 5, 640-3 (1963).

The separation was carried out by elution with 0.5 M ammonium alpha hydroxyisobutyrate at pH 3.68 from 8 percent cross-linked Diaion SK#1. A flow rate of 1 drop/5 min was found to give a good separation of Cm-242 from Am-241. The separation factor was 1.49.

192

AN ANION EXCHANGE PROCESS FOR AMERICIUM-CURIUM RECOVERY FROM PLUTONIUM PROCESS WASTES. M. H. Lloyd. *Nucl. Sci. Eng.*, 17, 452-6 (1963).

An anion exchange process was developed for the recovery of Am, Cm, and lanthanides from Pu process wastes. The wastes, which contain Am, Cm, Al, and F.P.'s in HNO_3 , are concentrated by evaporation and adjusted to 2.34 M $\text{Al}(\text{NO}_3)_3$ by dilution. The Am, Cm, and R.E.'s are sorbed on Dowex-1-10X resin; Al is washed from the column with 8 M LiNO_3 and the Am, Cm, and R.E.'s are eluted with 0.65 M HNO_3 .

193

ANION EXCHANGE OF METAL COMPLEXES. XIV. THE EFFECT OF ACIDITY ON THE SORPTION OF

LANTHANIDES FROM LITHIUM NITRATE SOLUTIONS.

Y. Marcus and M. Givon. *J. Phys. Chem.*, 68, 2230-4 (1964).

The acidity dependence of the distribution of La, Eu, Yb, and Am between resin and a LiNO_3 solution was measured. Sorption of the species $\text{M}(\text{NO}_3)_5^{2-}$ for M = Eu, Yb, and possibly Am, and $\text{La}(\text{NO}_3)_7^{4-}$ was found to be consistent with experimental data.

194

RECOVERY AND PRELIMINARY PURIFICATION OF AMERICIUM OBTAINED FROM WASTE MATERIAL.

P. G. Hagen and H. W. Miller. RFP-442 (March 29, 1965).

Americium was recovered from various residues by leaching with HCl . The solution was filtered and oxalic acid was added. The oxalate was calcined to americium oxalate. The oxalate was purified from Pb, Ca, Ce, K, and Pu by both cation-anion ion-exchange techniques and precipitation methods. Ammonium thiocyanate was used as both an eluting and complexing agent. The AmO_2 content of the product was increased from approximately 42 percent to 99 percent.

X. ANALYTICAL

A. Absorption Spectroscopy

195

THE ABSORPTION SPECTRUM OF AMERICIUM.

B. J. Stover, J. G. Conway, and B. B. Cunningham. AECD-2915 (1950).

The absorption spectra of aqueous solutions and solid compounds of Am have been investigated. The relation of the spectrum to that of other actinides and rare earth compounds is discussed.

196

AMERICIUM AND ITS ANALYTIC PROPERTIES.

C. Ferradini. *Chim. Anal.*, 45, 647-52 (1963).

The chemical analytic properties of Am in its various valence states were studied, including the hydroxide, fluoride, phosphate, and oxalate. The possibility of extraction of acid solutions by organic solvents is reviewed as regards Am(III) and Am(V). The principal methods for determining Am, viz. absorption spectrometry of the tetra-, penta-, and hexavalent states and radiometry of Am-241, are reviewed.

B. Alpha-Gamma Spectroscopy

197

DETERMINATION OF AMERICIUM IN PLUTONIUM BY GAMMA COUNTING. J. Bubernak, M. S. Lew,

and G. M. Matlack. *Anal. Chem.*, 30, 1759-62 (1958). The gamma specific activity of Am-241 is 30,000 times greater than that of Pu when gamma-rays above 30 kev are counted. This is the basis of a procedure for determining as little as 5 ppm of Am in Pu. When counted in a well-type scintillation detector, Am-241 shows a specific activity of 2.2×10^6 cpm per gamma. The average error is 2 percent standard deviation for 5×10^{-4} gamma of Am or greater in the presence of up to 10 gamma of Pu.

198

STUDIES OF THE ACTINIDES. I. DETERMINATION OF Am-241 CONTENT IN PLUTONIUM BY SPECTROSCOPY OF THE ALPHA AND GAMMA RAYS. J. Maly, H. Kurzweilova, R. Lenk, and I. Peka. *Collection Czechoslov. Chem. Commun.*, 25, 1383-90 (1960).

The work indicates the possibility of determining Am-241 in Pu by alpha spectroscopy in a minimum quantity of 0.02 percent and gamma spectroscopy in quantities up to 0.001 percent.

199

RADIOCHEMICAL DETERMINATION OF PLUTONIUM ISOTOPES AND AMERICIUM-241 IN A PLUTONIUM SAMPLE. K. Watanabe, E. Saki, and K. Minami. *J. Nucl. Sci. Technol.*, 1, 197-202 (1964). Isotopic ratios of Pu-238, Pu-239, Pu-240, and Am-241 in a Pu sample were approximately determined by means of combined alpha and gamma spectrometry without chemical separation of Am from Pu.

C. Emission Spectroscopy

200

THE IMPURITY ANALYSIS OF AMERICIUM SOLUTIONS. A. J. Johnson and E. Vejvoda. RFP-194 (1960).

A solution d-c arc method was developed for the impurity analysis of Am solutions which are 3 M to 5 M in ammonium thiocyanate.

201

EMISSION SPECTROGRAPHIC ESTIMATION OF AMERICIUM IN PLUTONIUM. A. W. Wenzel and C. E. Pietri. NBL-204, p 65-9 (1964).

An emission spectrographic method for Am in Pu was developed. The method is quantitative in the 10 ppm to 120 ppm range and estimations may be made in the range 1 ppm to 200 ppm. Greater sensitivity was obtained when standards were processed in 1 N HNO₃ instead of 8 N HNO₃.

202

SEMIANNUAL PROGRESS REPORT FOR THE PERIOD JULY 1963 THROUGH DECEMBER 1963.

NBL-210 (1964).

A method for the emission spectrographic estimation of Am in Pu was improved and can now be used for quantitative Am determination. The sensitivity of the method is about 0.03 µg Am.

203

EMISSION SPECTROGRAPHIC DETERMINATION OF Am IN Pu. C. E. Pietri and A. W. Wenzel. *Anal. Chem.*, 36, 1937-9 (1964).

A method is described in which Am is determined simultaneously with other impurities by emission spectrography after separation from Pu by anion exchange in 8 N HNO₃. The lower limit of detection is 0.03 µg.

D. Mass Spectroscopy

204

ISOTOPIC ANALYSIS OF AMERICIUM AND CURIUM BY MASS SPECTROMETER. D. F. Dance. AERE-C/M-366 (1958).

Isotopic analyses of Am and Cm were carried out by mass spectrometer using about 10^{-8} g and 10^{-9} g of these elements, respectively. While satisfactory measurements of the main isotopic abundances were made, abundances of the order of 2 percent were measured with an accuracy of only ± 10 percent, due to small quantity of sample used.

205

DETERMINATION OF AMERICIUM-243 IN CURIUM-244. C. J. Banick, G. A. Caruthers, and W. T. Donaldson. *Anal. Chem.*, 35, 1312-13 (1963); TID-17393.

Dilution mass spectrometry was used for the precise determination of Am-243 in the presence of approximately equal quantity of Cm-244. The ionization efficiency of Am-243 is 50 times that of Cm-244, thus, the Cm would not cause errors greater than 1 percent unless present in Cm-244/Am-243 ratio greater than 1 to 2. The isotopic dilution technique may be applied to mixtures of Cm and Am without chemical separation.

E. Chromatography

206

PAPER CHROMATOGRAPHY OF TRANSURANIUM ELEMENTS VARIATIONS IN R_F OF PLUTONIUM AND AMERICIUM IN THE n-BUTANOL-HCl SYSTEM. F. Clanet. *J. Chromatog.*, 85-9 (1961).

The variation of the R_F values at 20 deg. was determined for U(IV), U(VI), Pu(III), Pu(IV), Pu(VI), and Am(III) as a function of the concentration of HCl in the n-butanol-HCl mixtures. The values obtained for HCl molarities from 1 to 10 are tabulated.

207

SEPARATION OF URANIUM, NEPTUNIUM, PLUTONIUM, AND AMERICIUM BY REVERSED PHASE CHROMATOGRAPHY. H. Eschrich.

Institut for Atomenergi, Kjeller, November 1961.

Reversed phase partition chromatography was applied to the separation of U, Np, Pu, and Am using TBP as the stationary phase and HNO_3 with and without reducing agents as the mobile phase. The general principle of the separation is described. Representative chromatograms are given for the separation of (Cr), U, Np, Pu, Am, and for the separation of U, Np, and Pu.

208

PAPER CHROMATOGRAPHY OF TRANSURANIC ELEMENTS: VARIATIONS OF R_F OF PLUTONIUM AND AMERICIUM IN MIXTURES OF n-BUTANOL· HNO_3 (1:1) COMPARISON WITH URANIUM, THORIUM AND SOME RARE EARTH ELEMENTS. F. Clanet.

J. Chromatog., 7, 373-9 (1962).

The R_F values of Pu(III), (IV), (VI), and Am(III) were determined by paper chromatography with mixtures of n-butanol· HNO_3 (1:1) in which the molarity of the HNO_3 was varied. These R_F values were compared with those of other elements, U(VI), Th(IV) and some rare earth elements. The results obtained show that there are possibilities for the analytical separation of various mixtures of the elements investigated. An example of the separation of Am(III) and Pu(VI) is given.

209

SEPARATION OF THE ELEMENTS ACTINIUM TO AMERICIUM BY PAPER CHROMATOGRAPHY.

C. Keller. *J. Chromatog.*, 7, 535-51 (1962).

A separation of the elements actinium to americium by paper chromatography is described. Alcohol-acid mixtures of various concentrations are used as eluents. In order to determine the position of the ions on the paper chromatograms, assay, autoradiographic, and colorimetric techniques are used. The valency of Pu and Np deposited on the paper chromatogram is determined after separation by coprecipitation reactions. The influence of the acidity of the eluents on the separation of the elements Ac-Th-Pu and Am is investigated more closely. With methanol-HCl as eluent the trivalent and tetravalent actinide elements show a minimum R_F value at a 2:1 methanol-HCl acid ratio. Pu-239 was detected by paper chromatography in a uranium solution that had been irradiated then stored. With Th as an example it is shown that a quantity of substance exceeding 10^{-10} g/paper chromatogram is necessary for obtaining a constant R_F value. With smaller amount of Th the R_F value decreases.

210

INVESTIGATION OF THE EXTRACTION CHROMATOGRAPHY OF Am(VI) AND Bk(IV).

E. K. Hulet. KR-56 (1963).

The extraction of Am(VI) and Bk(IV) tracers has been investigated by reverse-phase partition chromatography in an effort to improve the separation of normally tri-valent transplutonides. Simultaneous elution of Am(VI) and Am(III) tracers from 0.20 M bis (2-ethylhexyl) orthophosphoric acid (HDEHP) absorbed in a stationary bed of silica resulted in 90 percent to 92 percent Am extraction. A decontamination factor from Cm of 1000 was obtained. Attempts by the same method to extract anionic americyl sulfate complexes with triisooctylamine failed, though the existence of such complexes was demonstrated by adsorption in anion exchange resin.

F. Fluorescence

211

FLUORESCENCE STUDIES OF PLUTONIUM, NEPTUNIUM, AND AMERICIUM. G. R. Price.

CN-3545 (August 13, 1946).

A number of compounds of Pu, Np, and Am were tested for luminescence in the hope that a fluorescence method for analysis of Pu could be developed. In no case was conclusive evidence of luminescence found.

G. Radiochemical

212

SPECIAL RADIOISOTOPE METHODS, SECTION II.

S. A. Reynolds. CF-48-10-219 (September 20, 1948).

A method for the determination of Am is outlined.

213

THE QUANTITATIVE SEPARATION OF AMERICIUM FROM PLUTONIUM AND URANIUM. H. W. Miller.

HW-22267 (1951).

The procedure described for the separation and determination of Am and Pu in solutions containing Am, Pu, and U is based on the fact the ceric ion will oxidize Pu to the PuO_2^{++} ion and the subsequent addition of HF results in the partial precipitation of ceric fluoride which carries AmF_3 quantitatively. This precipitant is mounted for counting. Treatment of the supernate containing UO_2^{++} and PuO_2^{++} ion, with $\text{H}_2\text{NOH}\cdot\text{HCl}$ results in the reduction of both the ceric and the plutonyl ions and the subsequent entrainment of Pu with the very insoluble cerous fluoride. The uranyl ion remains in solution and is discarded while the precipitate obtained is mounted for the

determination of the Pu by counting methods. The theory and limitations of the procedure are discussed.

214

THE DETERMINATION OF AMERICIUM IN PLUTONIUM PRODUCT SOLUTIONS.

A. Chetham-Strode, Jr. HW-25205 (August 15, 1952).

The cerium fluoride method for the determination of Am in the presence of Pu and U has been extended with modifications to application of plant streams of very high Pu to Am ratios. The precision of the modified method has been determined to be ± 2.24 percent at the 99 percent limits.

215

THE ANALYTICAL CHEMISTRY OF AMERICIUM AND CURIUM. A. Chetham-Strode, Jr. AECD-3559; HW-28277 (1953).

The determination of Am and Cm may necessitate the use of a variety of analytical methods. The most widely used method is oxidation of Pu and Np to the (VI) state with $\text{Ce}(\text{SO}_4)_2$ and then the precipitation of Am(III) and Cm(III) with HF. The AmF_3 and CmF_3 are evaporated to dryness and counted for alpha activity. Modifications of this method include using $\text{Ce}(\text{ClO}_4)_4$ as the oxidant and dissolution of the precipitate with zirconyl ion and reprecipitation with fluoride. Cm may be determined alone by using $\text{H}_2\text{S}_2\text{O}_8$ as an oxidant. Americium may be separated from Pu by extraction of Pu with cupferron and CCl_4 .

216

A COMPARISON OF ANALYTICAL METHODS FOR AMERICIUM. W. W. Gift. HW-33486 (October 1954).

The ratio of TBP-TTA to CeF_3 recoveries was 1.05 with a standard deviation of ± 0.028 .

217

COLLECTED RADIOCHEMICAL PROCEDURES.

J. W. Barnes, N. A. Bonner, C. I. Browne, D. C. Hoffman, II. A. Potratz, H. L. Smith, B. Warren, and J. Kleinberg. AECD-3674.

An analytical procedure is presented for the determination of Am in fission-produced material.

218

ANALYTICAL CHEMISTRY OF THE ACTINIDES.

P. N. Palei. *Zhur. Anal. Khim.*, 12, 647-64 (1957).

An outline is presented of the properties and reactions used as a basis for the chemical methods of separating and determining the elements of the actinide group, mainly U, Th, Pu, Np, and Am.

219

COLLECTED RADIOCHEMICAL PROCEDURES.

J. Kleinberg. LA-1721 (2nd ed, 1958).

The properties of the chemical elements are discussed

on the basis of electronic configuration. A procedure for the separation of Am from fission product yields and its radiochemical determination is given.

220

THE DETERMINATION OF NITROGEN, Am, Np, AND U IN P.P.M. QUANTITIES IN PURE PLUTONIUM.

F. Buchanan, J. P. Hughes, J. J. Hines, and C. A. A. Bloomquist. *Talanta*, 6, 173-84 (1960).

A method was developed for the determination of as low as 25 ppm of Am in high purity plutonium. The Am content was calculated from the difference between the percent of 5.5 Mev alpha activity before and after the separation of Am from Pu. The activity of the alpha energy is determined by pulse-height analysis. The percent 5.5 Mev alpha activity before the separation indicates the sum of Am-241 and Pu-238. The Am was separated from the Pu in a 12 N HCl-0.1 HNO_3 by means of an anion-exchange resin. The Pu was eluted with 1 N HCl, and sample dried on a Pt disk for pulse-height analysis. About one man hour is required with precision and accuracy of 10 percent.

221

RAPID SIMULTANEOUS DETERMINATION OF Pu-IV AND Am-III IN NITRIC ACID SOLUTION. T. Bruce. CRDC-805.

A rapid method for the separation and determination of Am(III) and Pu(IV) was developed. Zirconium is added to the solution to be analyzed as a carrier for the plutonium, and phenyl arsonic acid is added as a precipitant. The zirconium, together with the plutonium, is precipitated leaving the americium in the supernatant phase. The americium and plutonium are then determined by alpha counting.

222

ANALYTICAL METHOD FOR THE DETERMINATION OF AMERICIUM-241 AND CURIUM-242 IN THE FEED SOLUTION TO THE PRIMARY SEPARATION PLANT.

United Kingdom Atomic Energy Authority, P. G. Report-280 (1960).

A portion of the feed solution is mixed with a solution of trioctylphosphine oxide in cyclohexane. Uranium and protactinium(IV) are extracted into the solvent phase. Am and Cm are not extracted. They are determined by counting the alpha activity of a diluted portion of the aqueous phase. The method is intended for the determination of the contribution by Am and Cm to the total alpha disintegration rate of the feed solution.

223

SEPARATION OF AMERICIUM FROM OTHER ELEMENTS: APPLICATION TO THE PURIFICATION AND RADIOCHEMICAL DETERMINATION OF AMERICIUM. F. L. Moore. *Anal. Chem.*, 35, 715-22 (1963).

A radiochemical method for the determination of Am tracer involves the Ag-catalyzed peroxydisulfate oxidation of Am(III) to AmO_2^{++} . Fluoride stabilizes the americyl ion during a series of LaF_3 scavenges. Excellent separation of Am tracer from Cm, Bk, Cf, Pu, U, Th, Cs, Sr, Zr, Nb, Ru, Fe, Al, and lanthanide elements is obtained.

XI. HIGHER VALENCE STATES

224

THE PENTAVALENT STATE OF AMERICIUM.

L. B. Werner and I. Perlman. AECD-2898 (1950).

Spectrophotometric and titration methods were used to establish the Am pentavalent state of americium. On addition of NaOCl to a K_2CO_3 -Am(III) solution at 95°C , the absorption peaks of Am(III) decreased to zero and a precipitate was formed. A reducing agent, $\text{Na}_2\text{S}_2\text{O}_4$, reversed this behavior. The corrected absorption spectrum is given as $5150\text{\AA}$ and $7200\text{\AA}$ for Am(V) in $0.1\text{ M H}_2\text{SO}_4$.

225

A NEW OXIDATION STATE OF AMERICIUM, Am(VI).

L. B. Asprey, S. E. Stephanou, and R. A. Penneman. AECU-927 (1950).

Am(VI) has been prepared by the oxidation of Am(III) and Am(V) in acid solutions. Various methods are described, including the disproportionation of Am(V). Sodium americyl acetate was prepared. It has been assigned the formula AmO_2^{++} . The absorption spectra of Am(VI) in HClO_4 solution has been increased. A narrow peak at $992\text{ m}\mu$, a minor peak at $666\text{ m}\mu$, and continuous ultraviolet absorption were observed. The potential of the Am(III)-Am(VI) couple is estimated to be -1.9 v .

226

A NEW VALENCE STATE OF AMERICIUM, Am(VI).

L. B. Asprey, S. E. Stephanou, and R. A. Penneman. AECD-2950; LADC-739 (1950).

Americium(III) was completely oxidized by americium peroxydisulfate in 0.2 M nitric and in 0.2 M perchloric acid to a nonfluoride precipitable state. The characteristic pink color of Am(III) changed to a strong yellow color. A yellow compound of tetrahedral structure was obtained which is isomorphous with the analogous NaMO_2Ac_3 compounds where M is U or Pu.

227

THE OXIDATION OF AMERICIUM TO THE HEXAVALENT STATE. M. Ward and G. A. Welch. *J. Chem. Soc.*, 4038-9 (1954).

The oxidation of trivalent Am to the hexavalent state in HNO_3 by ammonium persulfate with AgNO_3 at 85°C to 90°C is discussed briefly. Experimental procedures

and results are given. In addition, partial oxidation of tracer amounts was achieved by the addition of iodic acid and by the passage of O_3 into Am solutions in HNO_3 .

228

RECENT ADVANCES IN THE BASIC CHEMISTRY OF PLUTONIUM, AMERICIUM, AND CURIUM. S. W. Rabideau, L. B. Asprey, T. K. Keenan, and T. W. Newton. A/CONF. 15/P/2247.

Advances in the chemistry of Am and Cm include the discovery and isolation of new valence states and characterization of the metals and compounds. Solid phase studies of Am and Cm are also presented.

229

AMERICIUM AND CURIUM. T. K. Keenan. *J. Chem. Ed.*, 36, 27-31 (1959).

The chemistry of Am and Cm is discussed, and methods for the preparation of these elements are reviewed. Am shows reactions typical of a highly electropositive metal and is capable of existing in solution as a hydrated trivalent ion or as a doubly oxygenated (V) or (VI) ion. Tetravalent Am can exist in certain solid compounds but has never been found in acid solutions because of its ability to oxidize water or undergo disproportionation. The solution chemistry of the (V) and (VI) states of Am is complicated by self reduction. It has not been possible to attain any oxidation states of Cm other than (III) in solution although a (IV) state can exist in the solid. The use of Cm-244 ($T_{1/2} = 17.9\text{ yr}$) enabled certain new discoveries to be made which probably never would have been possible with the extremely active Cm-242.

230

ON NON-CONTINUOUS CHANGES OF CHEMICAL PROPERTIES OF PENTAVALENT ACTINIDE OXIDE IONS WITH INCREASING ATOMIC NUMBERS.

Yu. A. Zolotov. *Radiokhimiya*, 2, 192-6 (1960).

Correlations of the behavior of UO_2 - AmO_2 ion series indicated variable changes in certain properties with the increase of atomic number. A certain similarity was observed between pentavalent uranium and plutonium ions on one side and pentavalent neptunium and americium on the other side.

231

ALKALINE OXIDATION OF AMERICIUM; PREPARATION AND REACTIONS OF AMERICIUM(IV) HYDROXIDE. R. A. Penneman, J. S. Coleman, and T. K. Keenan. *J. Inorg. Nucl. Chem.*, 17, 138-45 (April 1961). A pink slurry of Am(OH)_3 is converted quantitatively into the black hydroxide of tetravalent americium by hypochlorite oxidation in dilute base. This material dissolves in nitric acid and perchloric acid and disproportionates according to the equation $2\text{Am(IV)} \rightarrow$

Am(V) + Am(III) with a minimum of half the Am(V) produced from the simple disproportionation of Am(IV) being consumed by a consecutive reaction: $\text{Am(IV)} + \text{Am(V)} \rightarrow \text{Am(VI)} + \text{Am(III)}$. Oxidation of Am(OH)_3 past Am(OH)_4 is observed with both ozone and peroxydisulfate. Details are given for a new and convenient method for producing AmO_2^{++} in dilute acid solution based on the ozone oxidation of Am(OH)_3 . Ozone oxidizes Am(OH)_3 in 0.1 M NaOH to a soluble yellow complex of Am(VI).

232

PREPARATION AND PROPERTIES OF AMERICIUM(VI) IN AQUEOUS CARBONATE SOLUTIONS. J. S. Coleman, T. K. Keenan, L. H. Jones, W. T. Carnall, and R. A. Penneman. *Inorg. Chem.*, 2, 58-61 (1963).

Hexavalent Am was prepared as a soluble, red-brown complex in aqueous Na_2CO_3 or NaHCO_3 by O_3 or $\text{S}_2\text{O}_8^{2-}$ oxidation of Am. The infrared spectra of solid sodium americyl carbonate established the presence of the O-Am-O group. Based on the properties of Am(VI) in carbonate solution, a new procedure for the preparation of Am(V) free from traces of Am(III) and a useful process for the separation of Am and Cm are reported.

233

INVESTIGATION OF THE CHEMISTRY OF PENTAVALENT NEPTUNIUM. Yu. A. Zolotov and I. P. Alimarin. *J. Inorg. Nucl. Chem.*, 25, 691-6 (1963).

The properties of NpO_2^+ were compared with those of the ions of other pentavalent actinides and an analogy between Np(V) and Am(V), and between U(V) and Pu(V), was noted.

234

NEPTUNIUM, PLUTONIUM, AND THE TRANS-URANIUM ELEMENTS. *Nature* (Paris), No. 3340, 336-7 (1963).

A review is given of the atomic, chemical, physical, and mechanical properties and oxidation resistance of Np, Am, and Cm. Application in nuclear reactors is also discussed.

XII. KINETICS AND DISPROPORTIONATION

A. Kinetics

235

THE VAPOR PHASE HYDROLYSIS OF THE TRICHLORIDES OF La, Pr, Sm, AND Am.

A. Broido. AECD-3012; UCRL-666 (1950).

Equilibrium constants at various temperatures in the range 350°C to 550°C have been determined for the

vapor-phase hydrolysis of the trichlorides of La, Pr, Sm, and Am.

236

ISOTOPIC EXCHANGE REACTIONS OF AMERICIUM.

T. K. Keenan, R. A. Penneman, and J. F. Suttle. *J. Phys. Chem.*, 59, 381 (1955).

The isotopic exchange reactions between Am(III), Am(V), and Am(VI) were measured in HClO_4 as a function of metal ion concentration, hydrogen ion concentration, and temperature. The results of the exchange reactions between Am(III) and Am(V) were inconclusive. A rapid exchange of Am(V) and Am(VI) was noted in 1.0 f HClO_4 .

237

KINETICS OF AMERICIUM(V) REDUCTION BY HYDROGEN PEROXIDE. A. A. Zaitsev, V. N. Kosyakov, A. G. Rykov, Yu. P. Sobolev, and G. N. Yakovlev. NP-7514.

The kinetics of Am(V) reduction by H_2O_2 in 0.1 M HCl was investigated. The reaction rate constant determined at 25°, 30°, and 35°C were 14.8 ± 1.5 , 21.6 ± 2.2 and 30.3 ± 3.0 moles/l/hr. The reaction activation energy (Arrhenius) and the activated complex enthalpy changes were $\Delta E = 13.3$ kcal/mole and $\Delta H^\ddagger = 12.7$ kcal/mole.

238

RADIOLYTIC REDUCTION OF Am(VI) AND Am(V). A. A. Zaitsev, V. N. Kosyakov, A. G. Rykov, Yu. P. Sobolev, and G. N. Yakovlev. NP-7515.

The rate constants for radiolytic reduction of AmO_2^{+2} in HCl, H_2SO_4 , and HNO_3 were determined by the yield of radiolytic products. The expression of the AmO_2^+ reduction rate is used for determining the yield of H_2O_2 and H^+ in the investigated solutions.

239

A COMPENSATORY EFFECT IN REACTION KINETICS OF THE ACTINIDES. V. P. Kazakov, B. I. Peshchevitskii, and A. M. Erenburg. *Radiokhimiya*, 6, 291-8 (1964).

A plot of the heat of activation $\Delta H^\ddagger$ versus the entropy $\Delta S^\ddagger$ for various actinide reactions showed that these two terms are not independent of each other. An increase in the heat of activation is always accompanied by an entropy increase, thus a smaller change in reaction rate constants than would be expected if this relationship did not exist. Values of $\Delta H^\ddagger$ were plotted against $\Delta S^\ddagger$ for various oxidation reduction reactions and complexing reactions for various ions of U, Np, Pu, and Am. These data lie on a straight line and may be used to estimate the values of ΔS° or ΔF° from the enthalpy value of a reaction. The reaction rate constants are nearly the same at room temperature; thus the coexistence of a number of oxidation states of the

actinide elements in aqueous solution. This behavior also makes it possible for a number of parallel reactions to take place simultaneously.

B. Disproportionation

240

THE DISPROPORTIONATION OF AMERICIUM(V).

S. E. Stephanou, L. B. Asprey, and R. A. Penneman. AECU-925.

Pure Am(V) was prepared in which Am(III) in alkaline solution was oxidized with NaOCl. A discussion of the absorption spectra is given.

241

THE DISPROPORTIONATION OF AMERICIUM(V) IN AQUEOUS SOLUTION. G. R. Hall and T. L. Markin. *J. Inorg. Nucl. Chem.*, 4, 296-303 (1957).

The kinetics of self reduction of Am(V) and Am(VI) have been studied in HClO₄. A mechanism has been postulated for the non-appearance of Am(III) during the reduction of Am(V) and Am(VI) in dilute acid solutions. The decrease in the value of the rate constant for the self reduction of Am(VI) with increasing H₂SO₄ concentration is shown to be due to the increase in the rate of disproportionation of Am(V).

242

DISPROPORTIONATION OF AMERICIUM(IV).

A. A. Zaitsev, V. N. Kosyakov, A. G. Rykov, Yu. P. Sobolev, and G. N. Yakovlev. NP-7517.

Qualitative studies were made of the americium(IV) disproportionation reaction in H₂SO₄ solutions. The total disproportionation reaction is $3\text{Am(IV)} \rightarrow 2\text{Am(III)} + \text{Am(VI)}$ following two parallel reactions: $2\text{Am}^{+4} + 2\text{H}_2\text{O} \rightarrow \text{Am}^{+3} + \text{AmO}_2^{+2} + 4\text{H}^+$ and $\text{Am}^{+4} + \text{AmO}_2 \rightarrow \text{Am}^{+3} + \text{AmO}_2^{+2}$.

243

DISPROPORTIONATION OF AMERICIUM(V).

A. A. Zaitsev, V. N. Kosyakov, A. G. Rykov, Yu. P. Sobolev, and G. N. Yakovlev. NP-7518.

The disproportionation of Am(V) in HCl, H₂SO₄, and HNO₃ followed two reactions: $2\text{Am(V)} \rightarrow \text{Am(VI)} + \text{Am(V)}$ and $\text{Am(IV)} + \text{Am(V)} \rightarrow \text{Am(VI)} + \text{Am(III)}$ with parallel radiolytic reduction of VI, V, and IV. The rate constant for $2\text{AmO}_2^{+2} + 4\text{H}^+ \rightarrow \text{AmO}_2^{+2} + \text{Am}^{+4} + 2\text{H}_2\text{O}$ in HCl is $1.45 \pm 0.10 \times 10^{-2}$ /mole/hr. For this reaction $\Delta E_{298} = 1.93 \pm 0.9$ kcal/mole; $\Delta H_{298} = 18.7 \pm 0.9$ kcal/mole; $\Delta S_{298} = 20.1 \pm 3.0$ kcal/mole, and $\Delta F_{298} = 12.7 \pm 0.9$ kcal/mole. The rate constant of Am(V) disproportionation in H₂SO₄ is proportional to the H ion concentration and is 0.45 ± 0.03 1/mole/hr. The system is much more complicated in HNO₃.

244

INVESTIGATION OF SOME OXIDATION-REDUCTION REACTIONS OF AMERICIUM. A. A. Zaitsev, V. N.

Kosyakov, A. G. Rykov, Yu. P. Sobolev, and G. N. Yakovlev. *Trudy Vsesoyuz. Nauch-Tekhn. Konf. po Primenen. Radioaktiv. i Stabil. Izotopov i Izlucheniya v Narod. Khoz. i Nauke.*, Moscow, *Izotopy i Izlucheniya v Khim.*, 1957-58, pp 326-38.

Investigations were made of the oxide-reduction reactions of americium in H₂SO₄ solutions. Am-241 was used to study disproportionation and auto-reduction at 20°C to 24°C. Disproportionation of Am(V) in moderately acid solutions was negligible and practically only auto-reduction of Am(V) to Am(III) took place. The auto-reduction of Am(V) was determined by the formation rate of the reducing products of radiolysis of water and by the reduction rate of Am(V) with these products. The reaction rate depended on the concentration of Am(V). In strongly acid solutions, the disproportionation of Am(V) took place along with the auto-reduction of Am(VI).

245

THE KINETICS OF THE DISPROPORTIONATION OF AMERICIUM(V). J. S. Coleman. *Inorg. Chem.*, 2, 53-7 (1963); LADC-3670.

Uses of the isotope Am-243 (T_{1/2} = 7951 yr) made possible the first observations of the disproportionation of Am(V), unobscured by the effects of radiolysis. At 75.7°, the rates in 2 N HNO₃, HCl, and H₂SO₄ are 4.0, 4.6, and 24 times as great as that in 2 N HClO₄. Observations of the oxidation of Am(III) by Am(VI), the reverse of the disproportionation reaction, is also reported.

246

RECENT DEVELOPMENTS IN THE CHEMISTRY OF AMERICIUM AND CURIUM. T. K. Keenan. LADC-5913 (1963).

A brief summary is given of recent developments in the chemistry of Am and Cm. The topics discussed include disproportionation of Am(V), behavior of Am(VI) in carbonate and bicarbonate solutions, complexes of Am and Cm with common inorganic ligands, and preparation of Am(IV) and Cm(IV) in solution.

XIII. COMPLEXES

247

THE CHLORIDE COMPLEXES OF TRIVALENT PLUTONIUM, AMERICIUM, AND CURIUM. M. Ward and G. A. Welch. *J. Inorg. Nucl. Chem.*, 2, 395-402 (1956).

In concentrated HCl solutions the relative complexing

power has been shown to be $\text{Pu} \gg \text{Am} > \text{Cm}$. This result has been discussed with reference to a theory of f-orbital hybridization in the actinides.

248

STABILITY CONSTANTS OF ALPHA-HYDROXYISOBUTYRIC ACID COMPLEXES WITH ACTINIDE ELEMENTS. B. G. Odenheimer and G. R. Choppin. UCRL-3515 (1956).

The first stability constant was determined to be $K_1 = 527$, $\text{pK} = 2.72$ for americium alpha-hydroxyisobutyrate.

249

INVESTIGATION OF OXALATE AND EDTA COMPLEXES OF TRIVALENT AMERICIUM BY ION EXCHANGE. A. I. Moskvina, G. V. Khalturin, and A. D. Gelman. *Radiokhimiya*, 1, 141-6 (1959).

The distribution of trace amounts of Am^{+3} between cation exchanger KU-2 and 1 M NH_4Cl at various pH values with and without a complexing agent show formation of the complexes $[\text{Am}(\text{C}_2\text{O}_4)_2]^-$, $[\text{Am}(\text{HC}_2\text{O}_4)_3]^\circ$, and $[\text{Am}(\text{HC}_2\text{O}_4)_4]^-$ with respective instability constants of $(1 \text{ to } 2) \times 10^{-10}$, 2.3×10^{-19} , and 1.0×10^{-11} . Similarly at pH of 1.0 to 2.2, and complexes $(\text{AmY})^-$ and $(\text{AmHY})^\circ$ are formed in EDTA solution with corresponding instability constants $(9.7 \pm 2.8) \times 10^{-19}$ and $(2.0 \pm 0.5) \times 10^{-10}$. The calculations used in determining the compositions and instability constants of the oxalate and EDTA complexes of Am^{+3} are similar to those applied in determining the analogs of Pu^{+3} complexes.

250

THE COORDINATION CHEMISTRY OF THE ACTINIDES. A. E. Comyns. *Chem. Rev.*, 60, 115-46 (1960).

A comprehensive survey is given of coordination compounds formed by the actinides with organic ligands, both in solid state and in solution. The review includes discussions of the complexes of Th, U, Pa, Np, and Pu individually, and Am and heavier actinides together. There are 584 references cited.

251

ON THE COMPLEX FORMATION OF Am^{+3} WITH ION OXALATES. I. A. Lebedev, S. V. Pirozhkov, V. M. Razbitnoi, and G. N. Yakovlev. *Radiokhimiya*, 2, 351-6 (1960).

The formation of Am^{+3} oxalate complexes was studied by solubility methods. Am-241 with $T_{1/2} \approx 457.7$ yr was used. The formula of americium oxalate at 20°C to 90°C is $\text{Am}_2(\text{C}_2\text{O}_4)_3 \cdot 9\text{H}_2\text{O}$. The solubility in HClO_4 at 25°C is 2.2×10^{-3} . Analysis of the solubility curve indicated the presence of $\text{Am}(\text{C}_2\text{O}_4)_2^+$, $\text{Am}(\text{C}_2\text{O}_4)_2^-$, and $\text{Am}(\text{C}_2\text{O}_4)_3^{-3}$ with instability constants 5.0×10^{-8} , 6.9×10^{-5} , and 1.6×10^{-1} .

252

STUDY OF AMERICIUM AND CURIUM COMPLEXES WITH ALPHA-HYDROXYISOBUTYRIC ACID.

V. B. Dedov, M. N. Ryzhov, P. S. Trukhlyaev, and G. N. Yakovlev. AEC-tr-4238 (1960).

Separation and behavior of Am and Cm complexes with alpha-hydroxyisobutyrate were studied. Ion exchange was used in the investigation since this method lends itself to the use of tracers. Results and conclusions are included.

253

COMPLEX FORMATION OF AMERICIUM AND CURIUM WITH α -OXYISOBUTYRIC ACID.

V. B. Dedov, I. A. Lebedev, M. N. Ryzhov, P. S. Trukhlyaev, and G. N. Yakovlev. *Radiokhimiya*, 3, 701-5 (1961).

Ion exchange chromatograph was used in studies of trivalent actinide separations. The formation of complex $\text{Am}(\text{o-But})^{+2}$, $\text{Am}(\text{o-But})_2^+$, $\text{Am}(\text{o-But})_3$, $\text{Cm}(\text{o-But})^{+2}$, $\text{Cm}(\text{o-But})_2^+$, and $\text{Cm}(\text{o-But})_3$ was observed during Am(III) and Cm(III) sorption on KU-2 cation of ammonium α -oxyisobutyrate. The concentration of α -oxyisobutyrate ions varied from 6×10^{-4} to $> 10^{-1}$ M at a constant ion strength of 0.5. The stability constants of the complex ions were determined at 0.5 and zero ion strength.

254

STABILITY CONSTANTS OF CERTAIN LANTHANIDE (III) AND ACTINIDE (III) CHLORIDE AND NITRATE COMPLEXES. D. F. Peppard, G. W. Mason, and I. Hucher. TID-14716; UAC-5777 (1961).

Extraction of trivalent lanthanides and actinides from mixed perchlorate-chloride and perchlorate-nitrate aqueous phases was used to determine the stability constant for trivalent lanthanide and actinide chlorides and nitrates. A monoacidic ester of orthophosphoric acid in toluene as a carrier diluent was used to extract the metal ions from the aqueous phase.

255

DETERMINATION OF THE COMPOSITION AND STABILITY CONSTANTS OF Am CITRATE AND TARTRATE COMPLEXES BY ION EXCHANGE.

A. I. Moskvina, G. V. Khalturin, and A. D. Gelman. *Radiokhimiya*, 4, 162-6 (1962).

In citrate solutions Am(III) forms complex ions $[\text{Am}(\text{H}_2\text{Cit})_3]^\circ$, $[\text{Am}(\text{Cit})]^\circ$, and $[\text{Am}(\text{Cit})_2]^{-3}$ with instability constants (at $\mu = 1$) of 5.1×10^{-9} , 7.7×10^{-8} , and 1.0×10^{-14} , respectively. In tartrate solutions it forms complex ions of $[\text{Am}(\text{tart})_2]^-$ and $[\text{Am}(\text{tart})(\text{H tart})]^\circ$ with instability constants of 1.9×10^{-11} and 2.1×10^{-6} . The composition of Am(III) complexes depends on the concentration of anions and hydrogen ions.

256

DETERMINATION OF COMPOSITION AND STABILITY CONSTANTS OF Am(III), Cm(III), AND Ce(III) RHODANIDE COMPLEXES BY ION EXCHANGE.

I. A. Lebedev and G. N. Yakovlev. *Radiokhimiya*, 4, 304-8 (1962).

Sorption of Am(III), Cm(III), and Ce(III) on cation resin at ionic strengths from 0.5 to 5.0 was studied. AmSCN^{+2} , $\text{Am}(\text{SCN})_3$, CmSCN^{+2} , and $\text{Ce}(\text{SCN})_3$ were prepared and their stability constants calculated. The feasibility of a group separation of trivalent lanthanides and actinides on anionite is discussed.

257

ON THE STABILITY OF THE ACETATE, GLYCOLATE, AND THIOGLYCOLATE COMPLEXES OF TERVALENT EUROPIUM AND AMERICIUM.

I. Grenthe. *Acta Chem. Scand.*, 16, 1695-1712 (1962). Stability constants for the acetate, glycolate, and thioglycolate complexes of trivalent Eu and Am were determined in a perchlorate medium of the ionic strength $I = 0.5 \text{ M}$ and at a temperature of 20.0°C . The Am complexes were stronger than the Eu complexes. The difference was greatest for the glycolate systems. For both Eu and Am the stability constants of the complexes decreased in the following order: glycolate, acetate, and thioglycolate.

258

CHLORIDE, NITRATE, AND SULFATE COMPLEXES OF EUROPIUM(III) AND AMERICIUM(III). B. M. L. Bansal, S. K. Patil, and H. D. Sharma. *J. Inorg. Nucl. Chem.*, 26, 993-1000 (1964).

The stability constant for Cl^- , NO_3^- , and SO_4^{2-} ions with Eu^{+3} and Am^{+3} was determined at ionic strength of 1 by the ion exchange method. The value of β_1 for Am in 1 M acid for chloride and nitrate complexes is 0.9 and 1.4, respectively. The values of stability constants for Eu^{+3} and Am^{+3} for all of these liquids are almost the same, even though their ionic radii differ.

259

THE CHEMISTRY OF TRIVALENT NEPTUNIUM, PLUTONIUM, AND AMERICIUM IN HALIDE SOLUTIONS. M. Shiloh and Y. Marcus. IA-924 (1964). The species $\text{Np}(\text{III})$, $\text{Pu}(\text{III})$, and $\text{Am}(\text{III})$ in concentrated halide solutions were characterized by spectrophotometry and ion exchange. The americium chloride complex absorbed strongly at $2350\text{\AA}$. Only small changes due to complex formation are evident at other wave lengths.

260

COMPLEX FORMATION OF La(III), Eu(III), Lu(III), AND Am(III) WITH OXALATE, SULFATE, CHLORIDE, AND THIOCYANATE IONS. T. Sekine.

J. Inorg. Nucl. Chem., 26, 1463-5 (1964).

The complex formation of Am(III) with oxalate, sulfate, chloride, and thiocyanate ions was studied by a distribution method at 25°C . The complexes of Am(III) were similar to Eu(III) except for thiocyanate complexes. The stability of the complexes with different ligands, decreased in the order oxalate>sulfate>thiocyanate>chloride.

XIV. COMPOUNDS

261

THE CHEMISTRY OF AMERICIUM COMPOUNDS.

S. Fried. ANL-JJK-14B-91 (December 1947).

The following reactions were studied:

1. $\text{Am}(\text{OH})_3 \xrightarrow[900^\circ]{\text{air}} \text{AmO}_2$
2. $\text{AmO}_2 + \text{H}_2 \xrightarrow{600-750^\circ} \text{AmO}$
3. $\text{AmO}_2 + \text{HF}-\text{O}_2 \xrightarrow{600-750^\circ} \text{AmF}_3$
4. $\text{AmO}_2 + \text{CCl}_4 \xrightarrow{850^\circ} \text{AmCl}_3$
5. $\text{AmO}_2 + \text{AlBr}_3 \xrightarrow{500^\circ} \text{AmBr}_3$
6. $\text{AmO}_2 + \text{AlI}_3 \xrightarrow{500^\circ} \text{AmI}_3$

262

THE PREPARATION OF ANHYDROUS AMERICIUM COMPOUNDS. S. Fried. *J. Am. Chem. Soc.*, 73, 416-8 (1951).

The following compounds were prepared and identified: AmO_2 , AmF_3 , AmCl_3 , AmBr_3 , AmI_3 , and Am_2S_3 . A detailed description of the techniques and a qualitative discussion of the properties of americium are presented.

263

NEW COMPOUNDS OF QUADRIVALENT AMERICIUM AmF_4 , KAmF_5 . L. B. Asprey. *J. Am. Chem. Soc.*, 76, 2019-20 (1954).

Two new compounds, KAmF_5 and AmF_4 , were prepared by reaction of fluorine gas with Am(III), Am(IV), or Am(V) compounds. The fluorination proceeds readily at 500°C and one atmosphere of fluorine.

264

ALKALI CARBONATES OF Np(V), Pu(V), AND Am(V). J. P. Nigon, R. A. Penneman, E. Staritzky, T. K. Keenan, and L. B. Asprey. *J. Phys. Chem.*, 58, 403-4 (1954).

The existence of the XO_2^+ ion in crystalline, double alkali carbonates containing Am(V) is established. $(\text{NH}_4)\text{AmO}_2\text{CO}_3$ is hexagonal. The existence of the compound $\text{RbAmO}_2\text{CO}_3$ has been established.

265

EQUILIBRIA IN THE OXIDE SYSTEMS OF PRASEODYMIUM AND AMERICIUM. L. B. Asprey and B. B. Cunningham. UCRL-329 (1955).

The decomposition of AmO_2 was carried out to $\text{AmO}_{1.85}$. The composition of the higher oxide was shown to be $\text{AmO}_{1.98 \pm 0.02}$.

266

THE THERMAL DECOMPOSITION OF Am(III) OXALATE. T. L. Markin. *J. Inorg. Nucl. Chem.*, 7, 290-1 (1958).

Hydrated americium oxalate was precipitated from a nitrate solution and dried in a vacuum (1μ) at room temperature. The thermal decomposition of americium oxalate in air and *in vacuo* was studied with the aid of a thermogravimetric balance. The oxalate was heated at the rate of 3°C per minute and readings were taken at 5°C intervals.

267

PREPARATION OF AmO_2 BY THERMAL DECOMPOSITION OF AMERICIUM OXALATE IN AIR.

R. D. Baybarz. ORNL-3003 (December 20, 1960).

A hydrochloric acid solution containing 175 g of americium, varying from 1 to 7 N , was converted to AmO_2 . Americium oxalate was precipitated from 0.1 N HCl with 100 percent excess of oxalic acid and was converted to AmO_2 by calcination at 800°C in air. The solubility losses in oxalate precipitate filtrate averaged approximately 7 mg/liter of solution with total loss of 0.09 percent.

268

ALKALINE OXIDATION OF AMERICIUM; PREPARATIONS AND REACTIONS OF Am(IV) HYDROXIDE.

R. A. Penneman, J. S. Coleman, and T. K. Keenan. *J. Inorg. Nucl. Chem.*, 17, 138-45 (April 1961).

A pink slurry of Am(OH)_3 is converted quantitatively into the black hydroxide (or hydrous oxide) of tetravalent Am by hypochlorite oxidation in dilute base. This material dissolves in HNO_3 or HClO_4 and disproportionates according to the equation:

It dissolves in H_2SO_4 giving Am^{+6} and Am^{+3} with a minimum of half of the Am^{+5} produced from simple disproportionation of Am^{+4} being consumed by a consecutive reaction:

Revision from +0.4 to at least -0.5 is suggested for the value of the standard potential of the Am(OH)_3 - Am(OH)_4 couple. Oxidation of Am(OH)_3 past Am(OH)_4 is observed with both ozone and peroxydisulfate.

Details are given for a new and convenient method for producing AmO_2^{++} in dilute acid solution based on the ozone oxidation of Am(OH)_3 . Ozone oxidizes Am(OH)_3 in 0.1 M NaOH to a soluble yellow complex of Am^{+6} .

269

THE FIRST OBSERVATION OF AQUEOUS TETRAVALENT AMERICIUM. L. B. Asprey and R. A.

Penneman. *J. Am. Chem. Soc.*, 83, 2200 (May 5, 1961).

A solution of pure Am(IV) was prepared in saturated NH_4F . Black Am(OH)_4 was freshly prepared by heating Am(OH)_3 with 0.2 M NaOCl -0.2 M NaOH . It was treated with saturated aqueous NH_4F . The slurry of Am(OH)_4 completely dissolves in 15 M NH_4F to give an Am concentration of 0.01 M . The resulting clear (pink-red) solution shows absorption peaks of Am(IV) . The peak at $4500\text{\AA}$ ($\epsilon = 25$) is sharp and well separated. Heating the solution in 15 M NH_4F to 90°C does not cause disproportionation of Am(IV) or its chemical reduction by water. Oxidation and reduction tests are also discussed.

270

THE FLUORIDES OF THE ACTINIDE ELEMENTS.

N. Hodge, p 183. *Advances in Fluorine Chemistry*, Vol 2, M. Stacey, J. C. Tatlow, and A. G. Sharpe, London, Butterworths, 1961.

Both horizontal and vertical relationships between the actinide fluorides are described. The horizontal relationship is expressed in the classification of the elements (Ac, Am, Cm, Pu, Pr, Np, Th, and U) in terms of valency and in ability of a small anion to polarize to bring out the highest oxidation state of a particular element. The vertical treatment of each actinide fluoride is discussed separately.

271

PREPARATION AND PROPERTIES OF AQUEOUS TETRAVALENT AMERICIUM. L. B. Asprey and R. A. Penneman. *Inorg. Chem.*, 1, 134-6 (1962).

Stable aqueous solutions of Am(IV) were prepared readily by reaction of Am(OH)_4 with saturated ammonium fluoride. Heating to 90°C did not cause disproportionation of Am(IV) nor its chemical reduction by water. Slow reduction of Am(IV) to Am(III) occurred due to Am-241 alpha radiation. At 25°C the solubility of Am(IV) in 13 M NH_4F was 0.02 M and the solid phase in equilibrium was $(\text{NH}_4)_4\text{AmF}_8$. Concentrated solutions of KF , RbF , and CsF also reacted with Am(OH)_4 yielding sparingly soluble salts of Am(IV) -fluoride complexes. In 13 M NH_4F 0.02 M Am(IV) has a rose color and a characteristic absorption spectrum which is different from those of Am(III) , Am(IV) , and Am(VI) . The narrow Am(IV) peak at $4560\text{\AA}$ ($\epsilon = 30$) is separated from peaks of other Am valence states and can be used to determine Am(IV) quantitatively. Iodide ion reduces Am(IV) to Am(III) . Ozone oxidizes Am(IV) in 13 M NH_4F to Am(VI) .

- 272 A CRYSTALLINE FLUORIDE OF TETRAVALENT AMERICIUM. F. H. Kruse and L. B. Asprey. *Inorg. Chem.*, 1, 137-9 (1962).
A stable crystalline complex of Am(IV), Rb_2AmF_6 was obtained from an aqueous fluoride solution. It is isostructural with the analogous compound of tetravalent Am prepared from aqueous solution hitherto were unknown. Both compounds are orthorhombic, probable space group $\text{Cmc}2$, four molecules per unit cell, dimensions: Rb_2AmF_6 : $a_0 = 6.98\text{\AA}$, $b_0 = 12.09\text{\AA}$, $c_0 = 7.56\text{\AA}$; Rb_2UF_6 : $a_0 = 6.958\text{\AA}$, $b_0 = 12.042\text{\AA}$, $c_0 = 7.605\text{\AA}$.
- 273 THE EFFECTS OF ALPHA DECAY ON THE CHEMICAL DECOMPOSITION OF AMERICIUM OXALATE. I. A. Lebedev, S. V. Pirozhkov, V. M. Razbitnoi, and G. N. Yakovlev. *Radiokhimiya*, 4, 308-12 (1962).
After 50 to 60 days the precipitate from radioactive americium oxalate is americium carbonate. It is shown that the decomposition is a first rate reaction with a rate constant of 0.22 to 0.04 day. The gas separated during the reaction contains a mixture of CO_2 and CO with a prevalence of CO.
- 274 THE ATTEMPTED PREPARATION OF AmF_6 . S. Tsujimura, D. Cohen, C. Chernick, and B. Weinstock. TID-16645; UAC-6548 (1962).
Experiments in which unsuccessful attempts were made to prepare AmF_6 are described.
- 275 INVESTIGATIONS OF THE GERMANATES AND SILICATES IN THE ABO_4 TYPE OF THE TETRAVALENT ELEMENTS FROM THORIUM TO AMERICIUM. C. Keller. *Nukleonik*, 5, 41-8 (1963).
The reactions of the dioxides of elements from Th to Am with GeO_2 and SiO_2 were investigated by thermal and hydrothermal methods. AmO_2 reacts both thermally and hydrothermally with GeO_2 with the formation of $\alpha\text{-MeGeO}_4$. AmO_2 reacts hydrothermally with SiO_2 to form $\alpha\text{-MeSiO}_4$ (zircon structure).
- 276 CHEMISTRY AND METALLURGY OF THE TRANS-URANIC ELEMENTS. G. T. Seaborg. NNES Vol 14A, Chapter I. (December 1947).
A survey of present knowledge concerning chemical and physical properties of the transuranic elements.
- 277 ISOLATION AND CHEMISTRY OF AMERICIUM. B. B. Cunningham. ANL-JJK-124 (February 1948).
The properties of Am as determined by experiments with microgram quantities are summarized:
- the specific α -activity and $T_{1/2}$ (498 yr)
 - the absorption spectrum of Am(III)
 - evidence for various oxidation states
 - solubility of Am compounds in various solutions.
- 278 SOLUTIONS OF EUROPIUM AND YTTERBIUM METALS IN LIQUID AMMONIA. J. C. Warf and W. L. Korst. *J. Phys. Chem.*, 60, 1590-1 (1956).
The solubility of Am in liquid ammonia is discussed.
- 279 THE STATE OF MICROQUANTITIES OF RADIO-ELEMENTS IN SOLUTIONS. XIV. INVESTIGATION OF AMERICIUM IN AQUEOUS SOLUTIONS. I. E. Starik, ed., and F. L. Ginzburg. *Radiokhimiya*, 1, 435-8 (1959).
The adsorption of Am by quartz glass was studied as a function of pH. The maximum adsorption from HNO_3 with Am concentration 10^{-9} M is found at pH 6.5 to 7.0. Microquantities of colloidal Am were determined by ultrafiltration. An increase of pH tends to enhance hydrolysis, and with $\text{pH} > 7$ leads to colloidal particle formation.
- 280 ON THE MOLECULAR STATE OF ULTRA-SMALL QUANTITIES OF RADIOELEMENTS IN SOLUTIONS. I. E. Starik, N. I. Ampelogova, F. L. Ginzburg, M. S. Lambet, I. A. Sculskii, and V. N. Schebetkovskii. *Radiokhimiya*, 1, 370-8 (1959).
Investigations of Am from aqueous solutions by non-exchangeable ion hydrophobic adsorbents indicates that the adsorption behavior of the radioelements is determined by their molecular state in the solution.
- 281 DISTRIBUTION OF THE ACTINIDE ELEMENTS IN THE MOLTEN SYSTEM: $\text{KCl-AlCl}_3\text{-Al}$. R. H. Moore and W. L. Lyon. HW-59147 (October 20, 1959).
Data are reported for the distributions of the elements 90 through 96 between molten salt solutions of their chlorides and molten Al (or alloy) at 725°C . The molten salt solutions were mixtures of AlCl_3 and KCl containing the actinide metal chloride. In all cases, the distributions were found to be strongly dependent upon the stoichiometry of the system and exhibited a maximum when the mole ratio of AlCl_3 to KCl was approximately 1.0. This behavior was interpreted from the

XV. GENERAL CHEMISTRY

standpoint of the Lewis acid-base theory. The distributions for Th, Pu, Am, and Cm were of the same order of magnitude, ranging from about 0.02 to 0.5. Those for Np were approximately a factor of ten larger than this while those for U and Pa were respectively a factor of 100 and 200 to 300 larger.

282

THE RADIOCHEMISTRY OF AMERICIUM AND CURIUM. R. A. Penneman and T. K. Keenan. NAS-NS-3006 (1960).

A review of the nuclear and chemical features of particular interest to the radiochemist, a discussion of problems of dissolution of a sample and counting techniques, and a collection of radiochemical procedures for the elements as found in the literature are given.

283

DIFFUSION OF LANTHANIDES AND ACTINIDES FROM GRAPHITE AT HIGH TEMPERATURES.

C. J. Orth. *Nucl. Sci. Eng.*, 9, 417-20 (1961).

Measurements were made of the diffusion losses of lanthanide and actinide elements from graphite at temperatures from 1600°C to 2600°C. A close correlation is observed between the diffusion rates from graphite and the boiling points of the metals. The most volatile of the elements are those with easily attained lower oxidation states, (Sm, Eu, Yb) and possibly Am. Those elements with oxidation states greater than III show high temperature stability in graphite. The possible significance of these measurements to high temperature reactor design is discussed.

284

ON THE NATURE OF COLLOIDAL BEHAVIOR OF AMERICIUM. I. E. Starik and F. L. Ginzburg.

Radiokhimiya, 3, 685-9 (1961).

It is postulated that the colloidal behavior of Am at pH 6 to 8 is determined by sorption on negatively charged silicic acid particles in the solution. Centrifuge and electromigration methods were used for determining the fine dispersion phase of true Am colloid concentrations in solutions with pH>9. It is shown that paramagnetic resonance of Am(OH)₃ is not reached at pH 6 to 7, which corresponds to the sorption curve maximum, but at higher pH values.

285

THE TRANSURANIUM ELEMENTS. K. W. Bagnall. *Sci. Progr.*, 52, 66-83 (1964).

The transuranium element place in the periodic classification is described as are their various valence states. Oxides and other compounds are listed.

XVI. ELECTROCHEMISTRY

286

THE FORMAL POTENTIAL OF THE Am(V)-Am(VI) COUPLE. R. A. Penneman and L. B. Asprey. AECU-936 (1950).

The value of the Am(V)-Am(VI) couple is taken as -1.600 ± 0.005 v in 1 M HClO₄.

287

ELECTRODEPOSITION OF THE ACTINIDE

ELEMENTS. R. Ko. HW-41025 (January 23, 1956).

Americium has been deposited at metal cathodes by the electrolytic formation of base. Quantitative precipitation of the metal hydroxides at the cathode has been made possible by the addition of formate to various acid solutions.

288

AMERICIUM ELECTRODEPOSITION. R. Ko.

Nucleonics, 14, No. 7, 74 (1956).

The electrodeposition was performed at room temperature using Am-241. Americium was electrodeposited from a formic acid-ammonium formate solution on stainless steel, Pt, and Cu using a cathodic current density between 50 and 65 ma/cm².

289

THE PREPARATION OF THIN FILMS OF PLUTONIUM, AMERICIUM, AND CURIUM BY AN ELECTROLYTIC METHOD.

G. N. Yakovlev, P. M. Chialkov, V. B. Dedov, V. N. Kosyakov, and Y. P. Saholev. *J. Nucl. Energy*, 5, No. 1, 159-61 (1957).

Methods for the quantitative deposition of Pu, Am, and Cm on metallic surfaces were developed. The elements were deposited as hydroxides from neutral and weakly acidic alcoholic solutions of the chlorides.

290

ELECTRODEPOSITION OF SMALL AMOUNTS OF URANIUM, NEPTUNIUM, AND PLUTONIUM.

A. G. Samartseva and T. Vsesayuz. *Nauch-Tekh. Konf. po Primenen Radioaktiv, i Stabil. Izotopov i Izluchenu v Khim*, 318-25 Nauke, Moscow 1957 (*Izotopy i Izlucheniya v Khim*, 318-25).

A method was developed for the quantitative electrodeposition of Th, U, Pu, and Am from solutions of HNO₃, H₂SO₄, HCl, HClO₄, and H₂C₂O₄ at 10⁻³ M hydrogen ion concentration in the electrolytes. It was found that the hydrogen ion concentration and not the nature of the electrolyte anion is the determining factor in the electrodeposition of U, Np, and Pu. The dependency of the U, Np, and Pu yields on the cathodic current density and the electrolyte pH was investigated.

- 291
ELECTROLYTIC DEPOSITION OF STRONG LAYERS OF U, Np, Pu, AND Am. G. I. Khlebnikov and E. P. Dergunov. *Atomnaya Energ.*, 4, 376-7 (1958). Methods and practical conditions of electrolytic preparation of strong, fine layers (0.4 mg/cm²) of U, Np, Pu, and Am are described.
- 292
OBTAINING OF SOLID LAYERS OF URANIUM, NEPTUNIUM, PLUTONIUM, AND AMERICIUM BY ELECTROLYTIC DEPOSITION. G. I. Khlebnikov and E. O. Dergunov. *Atomnaya Energ.*, 4, 376-7 (1958); AEC-tr-3497. The technique for the preparation of thin tough layers of U, Pu, Np, and Am is presented. Conditions of electrolysis are described as well as the preparation of the electrolyte and treatment of the target.
- 293
ELECTRODEPOSITION OF ACTINIDE ELEMENTS OF TRACER CONCENTRATIONS. R. F. Mitchell. *Anal. Chem.*, 32, 326-8 (1960). The electrodeposition of the actinides from an electrolyte of NH₄Cl-HCl is a rapid method for recovering trace concentrations of these elements in high yields. The procedure produces adherent, uniform deposits. The effects of current density, pH, salt concentration, volume, and plating time are discussed.
- 294
PRODUCTION OF THICK LAYERS OF THORIUM, NEPTUNIUM, PLUTONIUM, AND AMERICIUM. G. I. Khlebnikov and E. P. Dergunov. *Atomnaya Energ.*, 9, 406-8 (November 1960). Preparation of thick layers of Th, U, Np, Pu, and Am by electrolytic precipitation, mechanical deposition with admixtures of various organic substances, electrochemical replacement, and deposition from suspensions are studied.
- 295
PREPARATION OF THIN ELECTRODEPOSITS OF ACTINIDES FROM AQUEOUS SOLUTIONS OF EDTA. J. Fuger. *Bull. soc. chim., Belges*, 71, 134-41 (1962). The cathodic electrodeposition of several actinides from aqueous solutions of EDTA partially neutralized with ammonia is studied. On Pt cathodes, the deposited films are thin adherent, and reasonably uniform. A yield of 90 percent to 95 percent can be achieved. The rate of deposition is the same for tripositive transplutonium elements, but Pu deposits preferentially at the beginning of the electrolysis; on the other hand, the uranyl ion has a deposition rate lower than the transplutonium elements. For Pu, deposits up to 300 micrograms/cm² were obtained but with a yield of 70 percent.
- 296
ELECTROLYTIC PRECIPITATION OF AMERICIUM AND CURIUM FROM THEIR AQUEOUS SOLUTIONS ONTO A PLATING CATHODE. A. G. Samartseva. *Radiokhimiya*, 4, 696-700 (1962). The problem of electrolytic separation of Am and Cm from their aqueous solutions was investigated; the study developed into a quantitative electrolytic separation method of the two elements.
- 297
CARRIER TECHNIQUE FOR QUANTITATIVE ELECTRODEPOSITION OF ACTINIDES. M. Y. Donnan and E. K. Dukes. *Anal. Chem.*, 36, 392-4 (1964); TID-19034. A carrier method was developed for the rapid quantitative electrodeposition of actinides from aqueous solutions. Incremental addition of natural U as the carrier was necessary for quantitative electrodeposition. The excellent quality of the deposits permitted alpha counting with a relative standard deviation of ± 0.2 percent.

XVII. SOURCE PREPARATION

- 298
AMERICIUM-241 AS A PHOTON SOURCE FOR THE GAMMA ABSORPTOMETRIC TECHNIQUE. D. G. Miller. HW-39971 (November 1955). The use of Am-241 as a photon source in the gamma absorptometric technique for the determination of U or Pu in aqueous solutions at concentrations <100 g/l is discussed.
- 299
THE PREPARATION OF AN AMERICIUM GAMMA SOURCE. R. C. Milham. DP-173 (1956). Americium-241 was separated from La, Pu, and common metallic elements by ion exchange methods. The purified Am was embedded in plastic and mounted in a holder for use as a gamma ray source.
- 300
GAMMA RAY ABSORPTOMETER FOR DETERMINATION OF CHROMIUM IN AQUEOUS AND ORGANIC SOLVENT SOLUTIONS. S. J. Broderick. *Anal. Chem.*, 34, 295-6 (1962). A gamma ray spectrum of Am-241 was prepared, and the influence of slit widths of 1/2 to 1/8 in. were found to show no appreciable effect upon the shape of the diagrams, also, the slight change in cell length with the 1/2-in. slit does not affect the absorption. With a 1/2-in. wide slit, the current generated in the ionization chamber by the Am-241 source is decreased to 2.2×10^{-8} amp.

XVIII. PROCESSING AND PRODUCTION

301

SUMMARY REPORT OF AMERICIUM PROCESSING TO BE PERFORMED BY THE MARTIN COMPANY. MND-P-2333.

Features of the proposed Heavy Element Processing Facility to be constructed near Middle River, Maryland, are discussed. The physical, chemical, nuclear, and radiobiological properties of Am-241 are given. The pre-process preparation of Am including receiving, storage, and charging of the process is outlined. Chemical, metallurgical, and decontamination procedures are discussed.

302

TRANSURANIUM DEVELOPMENT FACILITY.

B. B. Klima. Proceedings of the Ninth Conference on Hot Laboratories and Equipment, Chicago American Nuclear Society, 1961, pp 27-34.

An alpha tight transuranium development facility was designed and is being installed in a cell with the immediate objective of studying the recovery of Am and Cm from rare earths and fission products by ion exchange techniques. In addition, it is to provide a facility in which may be tested design concepts and equipment for use in a larger transuranium facility now in the preliminary stages of design.

303

SNAP PROGRAMS: TASK 6 FUEL TECHNOLOGY DEVELOPMENT PROGRAM. QUARTERLY PROGRESS REPORT No. 7, APRIL 1 - JUNE 30, 1961.

MND-P-3015-111.

Progress made in the development of isotope power sources for thermoelectric and thermionic conversion to electric energy is reported. The Heavy Element Processing Facility for processing Am and fabricating Am capsules for irradiation was opened. Experimental work on the purification of Cm was continued. A safety analysis was conducted which verified the integrity of the Am capsules during all stages of the irradiation program.

304

AMERICIUM-241 AND CURIUM-242 FUEL PROCESSING HAZARDS. MND-P-1972 (1962).

The processing of Am-241 preparatory to its encapsulation for irradiation, the extraction of Cm-242 from the irradiated material, and the subsequent processing of Am-242 into suitable fuel forms is described. The radiological hazards involved are discussed.

305

AMERICIUM CAPABILITY AT ROCKY FLATS.

A. K. Williams. RFP-349 (1964).

Am-241 appears in Rocky Flats recovery streams as a decay product of Pu-241. The Am is recovered only from a precipitation stream where it follows in the filtrate. The filtrate is concentrated by evaporation and most of the Pu is separated by anion exchange. Capacity of the facility is 360 g/year. The Pu recovery facility now under construction will include an Am processing line with a capacity of 3600 g/yr on a 5-day three-shift schedule and 5000 g/yr when the schedule is expanded to 7 days.

SECTION 2

PHYSICS

REFERENCES

XIX. NUCLEAR SPECTROSCOPY

A. Decay Schemes

306

THE RADIOACTIVITY OF Am-242. G. D. O'Kelley, G. W. Barton, Jr., W. W. T. Crane, and I. Perlman. AECD-2916 (1950).

Two isomers of Am-242 were found. Am-242m with $T_{1/2} = 16$ hr by β^- decay and a long lived β^- active ground state. Am-242m appears to decay about 60 percent by β^- emission, 20 percent by L-electron capture, and 20 percent by isomeric transition.

307

THE SPECTROMETRIC DETERMINATION OF SOME BETA PARTICLES AND CONVERSION ELECTRON ENERGIES. G. D. O'Kelley (thesis). UCRL-1243 (1951).

The decay of Am-242 has been investigated using a β -spectrometer, and a decay scheme is postulated. Schemes are also proposed for the decay of Am-241, Cm-242, Np-236, and Pb-203.

308

HEAVY ELEMENT DECAY SCHEMES WITH ALPHA-GAMMA AND ALPHA-ELECTRON COINCIDENCE COUNTING. C. A. Prohaska (thesis). UCRL-1395 (1951).

A detailed description is given of a coincidence apparatus for measuring both α - γ and α -electron coincidences. Decay schemes are postulated for Am-241, Cm-242, Th-230, Pa-231, and U-233. Internal conversion coefficients of these elements calculated from coincidence data are tabulated.

309

THE DECAY OF Am-241. J. K. Beling, J. O. Newton, and B. Rose. *Phys. Rev.*, 87, 670-1 (1952).

Studies of the low-energy gamma rays and L-rays from the decay of Am-241 have been made. Coincidence measurements using a resolving time of 2 μ sec between the 59.7 keV gamma rays detected and the other radiation detected in a proportional counter, showed that 6 ± 0.8 percent of the radiation in the three low-energy groups was coincident and that an upper limit of 3.6 percent could be set to the amount of coincident 26.3 keV radiation. A decay scheme for Am-241 is proposed.

310

ANGULAR CORRELATION AND COINCIDENCE STUDIES OF ALPHA-GAMMA CASCADES FROM PROTACTINIUM-231, CURIUM-242, AND AMERICIUM-241. R. L. Moore (thesis). AECU-2757 (1953).

The decay schemes and the spins and parities of some excited state of the daughter nuclei of the alpha emitters Pa-231, Cm-242, and Am-241 were studied. Spins of the states, properties of the radiations, and angular correlations between alpha particles and gamma rays emitted in cascade were obtained with the aid of the coincidence circuits and the appropriate mechanical apparatus for rotating one of the detectors about the source.

311

CHEMISTRY DIVISION QUARTERLY REPORT, DECEMBER 1953, JANUARY, FEBRUARY 1954. UCRL-2531.

Isotope shifts of Am are tabulated. A decay scheme is proposed for Am-238.

312

DECAY SCHEMES AND NUCLEAR SPECTROSCOPIC STATES IN THE HEAVY-ELEMENT REGION.

F. S. Stephens, Jr. (thesis). UCRL-2970.

Using a coincidence circuit coupled to a 50-channel pulse-height analyzer, a study of the radiations from Am-239, 243, and many other isotopes was made. In most cases decay schemes were suggested.

313

ENERGY LEVELS OF U-237 NUCLEUS AND DECAY OF Am-242m. S. A. Baranov and K. N. Shlyagin.

Meeting of the Division of Physical-Mathematical Sciences Session of the Academy of Sciences of the USSR on the Peaceful Use of Atomic Energy July 1-5, 1955. Moscow Publishing House of the Academy of Sciences of the USSR.

The radiations of Am-241 and Am-242m have been studied using a magnetic double-focusing β -ray spectrometer and other instruments. Two β -components were established for Am-242m $\rightarrow$ Am-242 with end points energies equal to $E_{\beta 1} = 625 \pm 5$ keV (49 percent) and $E_{\beta 2} = 667 \pm 5$ keV (33 percent), respectively. Measurement with a proportional counter has shown that one mode of decay of Am-242 is electron capture. This mode of decay (Am-242m electron capture to Pu-242; gamma ray Pu-242, $E_{\gamma} = 44$ keV) is equal to about 18 percent. The beta-transition energy of Am-242 to the

excited level of Cm-242 has been calculated. The energy is $E_0 = 580$ kev. A decay scheme for Am-242m has been plotted with Am-242m having a 0^- spin. The spin of the ground state of Am-242 is equal to 4 or 5.

314

THE DECAY CHAIN Pu-245-Am-245-Cm-245.

C. I. Browne, D. C. Hoffman, W. W. T. Crane, J. P. Balagna, G. H. Higgins, and M. E. Bunker. *Inorg. and Nucl. Chem.*, 1, 254-61 (1955).

Pu-245 and Am-245 have been produced by neutron irradiation methods. The study of the radiations of these nuclides is described and a preliminary decay scheme for Am-245 is presented.

315

CHEMISTRY DIVISION QUARTERLY REPORT.

UCRL-3157 (September 1955).

A metastable state of Am-243 was investigated.

316

BRANCHING RATIO OF Am-242m DECAY.

R. W. Hoff, E. K. Hulet, and M. C. Michel.

J. Nucl. Energy, 8, 224-8 (1959).

The branching ratio, β^- ($EC = 5.1 \pm 0.1$ for Am-242m) decay was measured by determining the relative amounts of the decay products, Cm-242 and Pu-242 formed. The 16-hr Am-242m was produced by neutron irradiation of Am-241 in the MTR. A pile neutron cross section of $620 \pm 65b$ for the reaction Am-241 (n, γ) Am-242m was measured.

317

PHYSICS DIVISION ANNUAL PROGRESS REPORT FOR PERIOD ENDING MARCH 10, 1959. J. L.

Fowler and E. O. Wollan. ORNL-2718 (1959).

Fast chopper time-of-flight spectrometer studies were made on samples of Am-241.

318

NEW DATA ON Am-241 DECAY. P. S. Samoilov.

Izvest. Akad. Nauk. S. S. S. R., Ser. Fiz., 23, 1416-30 (1959).

The electron spectra of Am-241 from 1 to 400 kev were measured in order to verify the data on excitation levels and gamma transitions in Np-237. Conversion electrons for gamma transitions 42.8, 76, and 103 kev were observed and transitions 127, 159, 166, 208, and 268 kev are confirmed. Observations on certain conversion electrons suggest the existence of gamma transitions 27, 67, 70, 123, 164.7, 234, 304.4, 333, and 369 kev. The decay scheme of Am-241 to Np-237 is included.

319

RADIOACTIVE DECAY PROPERTIES OF Am-238,

Am-239, Am-240, Cm-240, AND Cm-241. R. A. Glass,

R. J. Carr, and W. M. Gibson. *J. Inorg. Nucl. Chem.*, 13, 181-91 (1960).

Some electron capture and alpha-decay properties of neutron deficient Am and Cm isotopes were investigated. The results for Am-238 include a new half-life of 1.86 hr and identification of gamma rays of ~370 kev (~12 percent), 580 kev (~29 percent), ~950 kev (~2 percent), 980 kev (~76 percent), and 1350 kev (17 percent). The data on Am-239 $T_{1/2} = 12.1$ hr, indicate gamma rays of 225 kev (30 percent) and 275 kev (~20 percent) with a new alpha particle energy of 5.77 Mev and abundances of 5.0×10^{-3} percent. For Am-240 ($T_{1/2} = 51.0$ hr) gamma rays of 900 kev (~23 percent) and 1000 kev (~77 percent) and a negatron branching limit of $\leq 6 \times 10^{-6}$ percent were established.

320

ISOMERS OF Am-241. F. Asaro, I. Perlman, J. O. Rasmussen, and S. G. Thompson. *Phys. Rev.*, 120, 934-43 (1960).

New measurements on the Am-241 isomers show that the 16-hr activity is the ground state and the 152-yr activity is the upper isomer, contrary to earlier evidence. The experimental information on these isomers is given a detailed analysis in terms of the Bohr-Mottelson model. The most surprising conclusion of this analysis is that the spin in the ground state has a K quantum number of zero, and hence a negative spectroscopic quadrupole moment.

321

THE DECAY SCHEME OF 10.1-HOUR Am-244.

S. E. Vandenbosch and P. O. Day. *Nucl. Phys.*, 30, 177-90 (1962).

A 10.1-hr beta-emitter produced by neutron irradiation of enriched (99.97 percent) Am-243 was chemically identified as an isotope of Am and is assigned to an isomer of Am-244. The decay scheme was studied using a beta spectrometer in addition to gamma-gamma and gamma-beta coincidence scintillation counting techniques. A single beta group with an end point energy of 387 ± 1 kev populates a 1042 kev level in Am-244. The 26-min isomer of Am-244 decays by beta emission principally to the ground state of Am-244 with an energy 1498 ± 10 kev.

B. Alpha Decay

322

ON THE α -, β -, AND α -K BRANCHING OF THE HEAVIEST NATURAL AND ARTIFICIAL RADIOACTIVE SUBSTANCES. W. Jentschke. *Phys. Rev.*, 77, 98-101 (1950).

Based on empirical regularities in α -decay of the heavy elements, the following substances which show β emission or K capture should also be α -radioactive with α -,

β -, or α -K branching ratios of at least 10^{-10} : MsTh₂, MsTh₁, AcK, Ra-225, Pa-233, Np-234, Np-235, Np-236, Np-238, Np-239, Pu-241, and Am-242.

323

COMPLEX ALPHA STRUCTURE OF THE HEAVY ELEMENTS. F. Asaro, F. L. Reynolds, and I. Perlman. UCRL-1533 (1951).

A study of complex alpha-energy spectra was undertaken in the hope that a correlation with alpha-systematic might promote a better understanding of nuclear states and their influence on alpha-decay process. The complex alpha-particle energy spectrum of Am-241 comprises six groups: 5.544 Mev, 0.23 ± 0.06 percent abundant; 5.533 Mev, 0.34 ± 0.06 percent abundant; 5.433 Mev, 13.6 ± 1.4 percent abundant; 5.378 Mev, 1.4 ± 0.2 percent abundant.

324

THE COMPLEX ALPHA SPECTRA OF Am-241 AND Cm-242. F. Asaro, F. L. Reynolds, and I. Perlman. UCRL-1681 (1952).

The alpha-particle spectra of Am-241 and Cm-242 was studied in detail. Six alpha-particle groups were found in Am-241 and their energies and abundances are: 5.546 Mev, 0.23 percent; 5.535 Mev, 0.34 percent; 5.503 Mev, 0.21 percent; 5.476 Mev, 84.2 percent; 5.433 Mev, 13.6 percent; and 5.379 Mev, 1.47 percent. The alpha-decay scheme is correlated with gamma rays and conversion electrons observed for both Am-241 and Cm-242.

325

DECAY PROPERTIES OF Am-243 AND POSSIBLE ROTATIONAL BANDS IN THE ALPHA SPECTRA OF ODD-EVEN NUCLEI. F. Asaro and I. Perlman. UCRL-2450 (1954).

A close similarity is shown in the alpha spectra of Am-243 and Am-241 insofar as comparison is possible, and an interpretation of some of the observed levels is made. Rotational bands in the alpha spectra of odd-even nuclei are discussed.

326

ALPHA SPECTRA OF HEAVY ELEMENTS.

L. L. Gol'din, E. F. Tret'yakov, and G. I. Novikova. Meeting of the Division of Physical-Mathematical Sciences Sessions of the Academy of Sciences of the USSR on the Peaceful Use of Atomic Energy July 1-5, 1955, Moscow, Publishing House of the Academy of Sciences of the USSR, 1955, pp 226-50.

The alpha-particle spectra were studied, utilizing a 50-cm radius precision double-focusing magnetic alpha spectrometer with 2×10^{-4} of 4π transmission and 7.5 kev resolution, determined as half-maximum width. The alpha spectra of Am-241 was studied. New level schemes for Am-241 are presented.

327

ALPHA DECAY PROPERTIES OF Am-239. F. Asaro, F. S. Stephens, Jr., W. M. Gibson, R. A. Glass, and I. Perlman. *Phys. Rev.*, 100, 1541-2 (1955).

A study was made of the Am-239 decay in order to determine whether the favored alpha-transition led to a state of Np-235 which was de-excited by an El transition. The alpha-gamma coincidence spectrum and the Am-239 decay scheme are shown. Results show that every alpha disintegration of Am-239 goes through a 48-kev state to Np-235, and the transition is identified as El.

328

ENERGY LEVELS OF Np-237 POPULATED BY ALPHA DECAY OF Am-241. J. M. Hollander, W. G. Smith, and J. O. Rasmussen. *Phys. Rev.*, 102, 1372-7 (1956).

The conversion electron spectrum following alpha decay of Am-241 has been re-investigated. Energy level spacings and relative transition probabilities are compared and discussed in terms of the Bohr-Mottelson model.

329

CHEMISTRY DIVISION, SECTION C-II SUMMARY REPORT FOR APRIL, MAY, AND JUNE, 1952.

J. R. Gilbreath and O. C. Simpson. ANL-4888 (1953). Progress is reported on the study of the half-life of the metastable state in Np-237 arising from the alpha decay of Am-241.

330

ALPHA DECAY OF Np-237. L. N. Kondratév, G. I. Novikova, A. Vorob'ev, and L. L. Gol'din. *Izvest. Akad. Nauk, SSSR, Ser. Fiz.*, 20, 875-6 (1956).

Alpha spectra of Np-237 were studied and compared to the spectra of Am-241. The measurements were carried out with a magnetic alpha spectrometer. A diagram is given for the Np-237 α -spectra in the range of 4.8 Mev and the results obtained are tabulated.

331

HIGH LEVEL ROTATION STATE OF SOME NUCLEI. THE ALPHA DECAY INTENSITY OF VARIOUS ROTATION EXCITATION LEVELS. L. L. Gol'din, G. I. Novikova, and E. F. Tret'yakov. *Izvest. Akad. Nauk, SSSR, Ser. Fiz.*, 20, 868-74 (1956).

Detailed studies were made of alpha spectra of the Am-241, Pu-240, and U-233. The results obtained permitted the first comparison of the experimentally obtained formulas with the theoretical formulas. The Landau formula described well the intensity of alpha decay at various levels for even-even parity nuclei. For odd-parity nuclei, the picture is not yet clear.

332

ALPHA DECAY STUDIES IN THE HEAVY ELEMENT REGION. J. P. Hummel (thesis). UCRL-3456 (1956). A study of the complexity of the alpha spectra of Am-243 and other isotopes was made. An investigation of the associated gamma radiation was also made. Decay schemes have been suggested for most of the isotopes included in this study. Those for the even-even isotopes were found to conform well with the previously existing systematics for that group of nuclides.

333

ON THE TRANSMUTATION AM-241 $\xrightarrow{\alpha}$ Np-237. S. Rosenblum, M. Valadares, and J. Milsted.

J. Phys. Radium, 18, 609-18 (1957).

Several papers on alpha fine structure and conversion electrons of Am-241 $\xrightarrow{\alpha}$ Np-237 have been published since 1948. An up-to-date survey of all known contributions, including the authors latest results, is given.

334

NUCLEAR SPECTROSCOPY. I. Perlman. *Proc. Natl. Acad. Sci. U. S.*, 45, 461-70 (1959).

Nuclear states in the heavy element region were investigated, and methods for obtaining information from the study of alpha-radioactive substances are discussed. The alpha-emission process is analyzed. Spectra, decay schemes, and energy levels are shown graphically for several heavy isotopes.

335

ALPHA DECAY AMPLITUDES AND THEIR PHASES.

B. A. Jacobson and L. W. Miller. Proceedings on the International Congress on Nuclear Physics, pp 900-4. A method is sketched for predicting the real and imaginary parts of the odd-A amplitudes, and numerical results are presented for U-233 and Am-241.

336

ON THE ALPHA DECAY OF STRONGLY DEFORMED ODD-A-NUCLEI. O. Prior. *Arkiv Fysik*, 16, 15-8 (1959).

The hindrance factor is correlated with changes in the so-called asymptotic quantum numbers characterizing the single particle orbital of deformed nuclei for neptunium through californium. With F^{-1} to 4, alpha transitions are favored in most cases.

337

ALPHA-DECAY BARRIER PENETRABILITIES WITH AN EXPONENTIAL NUCLEAR POTENTIAL: ODD MASS NUCLEI. J. O. Rasmussen. *Phys. Rev.*, 115, 1675-9 (1959).

Calculations of barrier penetrabilities, reduced widths, and hindrance factors for odd-mass alpha-particle emitters are made by using the diffuse exponential nuclear

potential derived from the optical model analysis of alpha elastic-scattering data. The calculations are made on the same basis as for even-even alpha emitters.

338

IMPROVED ALPHA SPECTROSCOPY USING A MODIFIED FRISCH GRID IONIZATION CHAMBER.

T. B. Crockett, T. T. McMillan, and J. W. Crowe. NAA-SR-443 (1960).

Adaptation of a Frisch grid alpha-ionization chamber and its preamplifier to an Argonne type 256-channel pulse-height analyzer for alpha spectroscopy is described. Circuit modifications to the commercial preamplifier are given, and a procedure for electro-deposition of thin samples is described.

339

PERTURBATION OF ALPHA-GAMMA ANGULAR CORRELATIONS IN TRANSURANIUM ISOTOPES.

E. Flamm. UCRL-9325 (1960).

The perturbation of alpha-gamma angular correlations was studied in Am-241, Am-243, and Cm-243 by observing alpha particles in coincidence with gamma rays from daughter nuclei recoiling into vacuum, air, aluminum, silver, iron, Mylar, water, and benzene. The magnetic and electric moments of the intermediate nuclear states in the alpha-gamma cascades are estimated, and the configuration of the electron shell following alpha decay is considered.

340

ENERGIES OF ALPHA PARTICLES. A. H. Wapstra. *Nucl. Phys.*, 18, 587-95 (1960).

Energies of alpha particles emitted in ground state transitions between nuclei with mass <200 were computed from experimental data obtained with magnetic spectrometers using the newest calibration results.

341

EQUATIONS FOR ALPHA DISINTEGRATION

ENERGIES. Y. P. Varshni and R. N. Bhargava.

Nuovo cimento, 22, No. 10 (1961).

For nuclei with $Z \geq 84$ and $N \geq 128$, it is shown that $(Q - 0.6252)$ is a smooth function of the mass number A , where Q is the alpha disintegration energy. This relation is utilized to develop two equations for Q . Results by these two equations are compared by those given by Roger's equation.

342

THE ALPHA DECAY SCHEME OF 152 YEAR Am(242m).

F. Asaro, M. C. Michel, S. G. Thompson, and I. Perlman. Proceedings of the Rutherford Jubilee International Conference, Manchester, 1961, New York, Academic Press, Inc., 1961, pp 311-2; UCRL-9758.

Detailed nuclear spectroscopy studies on the alpha decay of Am-242m showed many low-lying energy levels

which were interpreted in terms of a few rotational bands. The predominant alpha decay is of the unhindered type. Observed bands can be interpreted in terms of the Nilsson orbitals associated with odd-mass nuclides as can the moments of inertia, and the inter-band alpha and gamma transitions probabilities. There is also evidence of an appreciable Corioles interaction between different rotational bands having the same Nilsson orbital assignment (one of which is $K = 1/2$).

343

THE ALPHA-GAMMA ANGULAR CORRELATION FOR FAVORED ALPHA TRANSITIONS. M. Iosifescu.

Rev. phys., Acad. rep. populaire Roumaine, 6, 589-607 (1961).

After some comments on the comparison of the formalism of wave functions and the formalism of radiation parameters, numerical calculations of the alpha-gamma angular correlations are made for the case of deformed odd nuclei having favored alpha transitions and pure gamma transitions. The explicit formula of the alpha-gamma directional correlation for gamma transitions of the M1+E2 type between two successive rotational levels of the nucleus was derived. This formula shows that, in the absence of polarization of the gamma radiation, the alpha-gamma angular correlation depends only on the square of the internal quadrupole moment and the square of the difference of the gyromagnetic factors. The formulas obtained were applied to U-233, Am-241, and Am-243, and the values obtained are tabulated.

344

ALPHA-GAMMA ANGULAR CORRELATION MEASUREMENTS WITH LIQUID SOURCES. E. S. Murphy, Jr.

Colo. State University Dissertation Abstr., 22, 3236 (March 1962).

Alpha-gamma angular correlation measurements were made with solid sources of Am-243 and with liquid sources containing either Am-243 or an even-even alpha emitter in dilute perchloric acid solutions. Even-even alpha emitters studied were U-232, Th-230, and Ra-226. Thickness of the solid sources were controlled so that the Np recoils from the other sources were stopped in the Al, Au, or mica backing on which the sources were vaporized. The liquid sources were films consisting of 3 microliters of solution placed between a rubber HCl membrane and a microscope cover glass 1 cm² in circular cross section. The HClO₄ concentration of the liquid sources ranged from 0.5 to 3.0 molar.

345

NEW EVALUATION OF LOW GEOMETRY ALPHA COUNTING. R. F. Overman. DP-780 (1962).

Low-geometry alpha counters and alpha-gamma coincidence counters were used to count Am-241 sources.

Comparisons of these methods showed results only 0.5 percent higher by coincidence counting.

346

INVESTIGATION OF α -DECAY OF Am-241.

S. A. Baranov, V. M. Kulakov, V. G. Zelenkov, and V. M. Shatinskii. *Zh. Eksperim. i. Teor. Fiz.*, 43, 795-9 (1962).

Alpha decay of Am-241 was studied with a double-focusing magnetic alpha spectrograph. Analysis of the alpha spectra revealed the existence of more than 18 fine structure alpha-ray groups, most of which have been observed for the first time. An energy level scheme for the Np-237 nucleus is constructed on the basis of the experimental data. The existence of a new rotational band in the indicated scheme is established.

347

MAGNETIC FIELD DEPENDENCE OF Am-243 ALPHA-GAMMA ANGULAR CORRELATIONS.

K. Siegbahn and F. Asaro. *Phys. Letters*, 2, 323-5 (1962); UCRL-10419.

The anisotropy of the Am-243 alpha-gamma angular correlation with alpha-decay recoils traveling into a vacuum or into Ag was investigated as a function of applied magnetic field. Experimental and theoretical values of the angular correlation and attenuation factors are compared for a vacuum environment.

348

DETERMINATION OF THE ENERGIES OF INTENSE ALPHA GROUPS EMITTED BY THE NUCLEI OF PLUTONIUM-238, -239, -240, AND NUCLEI OF AMERICIUM-241. C. Leang. *Compt. Rend.*, 255, 3155-7 (1962).

The energies of the intense alpha rays of Pu-238, Pu-239, Pu-240, and Am-241 were determined by magnetic spectroscopy with respect to Bi-212 with a precision of 1/7000.

349

PERTURBATION OF ALPHA PARTICLE-GAMMA RAY ANGULAR CORRELATIONS IN Am-241, Am-243, AND Cm-243. E. Flamm and F. Asaro. *Phys. Rev.*, 129, 290-6 (1963); UCRL-10199.

By utilizing the recoil properties associated with the alpha-decay process, perturbations of the alpha-gamma angular correlations in Am-241, Am-243, and Cm-243 were observed in a variety of media.

350

ALPHA GAMMA ANGULAR CORRELATION MEASUREMENTS WITH LIQUID SOURCE. E. S. Murphy, Jr. ANL-6685 (1963).

Alpha-gamma angular correlation measurements were made with solid sources of Am-243 and with liquid

sources containing either Am-243 or an even-even alpha emitter in dilute HClO_4 solutions.

351

α -DECAY OF Am-241. S. A. Baranov, V. M. Kulakov, V. G. Zelenkov, and V. M. Shatinskii. *Nucl. Phys.*, 43, 547-52 (1963).

The alpha decay of Am-241 was studied with a magnetic double-focusing alpha spectrograph. Analysis of the spectrum revealed more than 18 fine structure groups of the alpha radiation. A scheme of the energy levels of the Np-237 nucleus is constructed on the basis of the experimental data. A new rotational band is established in the scheme.

352

THE STRUCTURE OF HEAVY NUCLEI: A STUDY OF VERY WEAK ALPHA BRANCHING. C. M. Lederer (thesis). UCRL-11028 (1963).

Very weak alpha branching in heavy elements was studied by a recently developed coincidence technique. This technique makes it possible to measure the energies and intensities of both alpha-particle groups and de-exciting radiation, even when the transition intensities are as low as 10^{-8} relative to the most intense alpha group. Twenty alpha-particle emitters from Po-214 to Fm-254 were examined.

353

NEW DATA ON ALPHA DECAY OF AMERICIUM ISOTOPES. S. A. Baranov, V. M. Kulakov, and V. M. Shatinskii. *Zh. Eksperim. i. Theor. Fiz.*, 45, 1811-8 (1963).

Results of the investigation of radioactive decay of Am-243 and Am-241 are presented. The existence of new fine structure alpha groups has been established.

354

A RUGGED NUCLEAR PARTICLE DETECTOR WITH IMPROVED STABILITY. R. L. Williams and C. D. Wilburn. *Nucl. Instr. Methods*, 29, 175-6 (1964).

An Am-241 alpha spectrum obtained with this equipment is included in this paper.

355

NEW DATA ON Am-243 AND Am-241 α -DECAYS. S. A. Baranov, V. M. Kulakov, and V. M. Shatinskii. *Nucl. Phys.*, 56, 252-8 (1964).

The alpha decays of Am-243 and Am-241 were investigated. The alpha spectra of these nuclei reveal new fine structure alpha groups, some of which belong to Am-243. The proposed interpretation of new Np-239 and Np-237 levels seems to indicate new rotational bands corresponding to the orbitals $3^{-}/2$ (521) $3^{+}/2$ (651) and made possible the classification as some levels as collective.

C. Beta Decay

356

DETERMINATION OF THE MAXIMUM ENERGY OF THE β -RAYS FROM 16-HOUR Am-242. J. M. Grunlund, B. G. Harvey, N. Moss, and L. Yaffe. *Phys. Rev.*, 78, 69-70 (1950).

The maximum energy of the betas emitted by Am-242 was found to be 0.63 ± 0.01 Mev.

357

CHEMISTRY DIVISION QUARTERLY REPORT, MARCH, APRIL, AND MAY, 1950. UCRL-769 (1950). Progress has been reported on studies concerned with the beta spectra of americium isotopes.

358

ELECTRON CAPTURE STUDIES IN SHIELDED NUCLEI. H. Jaffe (thesis). UCRL-2537 (1954).

A search for electron capture in shielded nuclei has been undertaken. Electron capture decay has been confirmed in Am-242m.

359

ON THE SPECTRUM OF CONVERSION ELECTRONS EMITTED BY Am-241 AND Np-237. J. Milsted, S. Rosenblum, and M. Valadares. *Compt. Rend.*, 239, 259-61 (1954).

Numerical values for the electron conversion spectra associated with the energy levels of Np-237 are given.

360

I. NEUTRON-DEFICIENT ISOTOPES IN THE NOBLE METAL REGION. II. CONVERSION ELECTRON SPECTRA OF SOME HEAVY ELEMENTS. W. G. Smith (thesis). UCRL-2974 (1955).

The low-energy conversion electrons emitted in the alpha decay of Am-241 were investigated and some transition multipolarities are discussed.

361

THE INTERNAL CONVERSION ELECTRON SPECTRUM OF Am-241. J. F. Turner. *Phil. Mag.*, 46, No. 7, 687-700 (1955).

Observations of the internal conversion electron spectrum of Am-241 and of $e^{-}e^{-}$ coincidences, using a pair of magnetic lens spectrometers, afforded evidence of the level scheme in Np-237 derived from Asaro's alpha-particle observation except that no indications of transitions to the ground state is found.

362

BETA DECAY AND ELECTRON CAPTURE BRANCHING TO THE LEVELS OF Pu-239. J. M. Hollander. *Phys. Rev.*, 105, 1518-20 (1957).

The experimental log-ft values of the Np-239 β^{-} decay

and Am-239 electron capture are analyzed according to the asymptotic selection rules proposed by Alaga for deformed nuclei. The case of an "allowed" transition with $\log-ft > 8$ is discussed.

363

ELECTRON CAPTURE DECAY OF Am-239 AND Am-240. W. G. Smith, W. M. Gibson, and J. M. Hollander. *Phys. Rev.*, 105, 1514-7 (1957).

The conversion electron spectra arising from electron capture decay of Am-239 and Am-240 have been studied with a 180° photographic spectrograph at 0.1 percent resolution. The energies of the first two excited states of Pu-240 are accurately measured, and from these values (42.87 ± 0.04 and 141.77 ± 0.2 kev) the constants in the Bohr-Mottelsen two-term rotational formula are evaluated: $A = 7.16 \pm 0.01$ kev, $B = 0.005 \pm 0.002$ kev.

D. Gamma Decay

364

PART A: AN X-RAY SPECTROMETER FOR USE IN RADIOACTIVE MEASUREMENTS: THE L X-RAYS OF Np AND Pu. G. W. Barton. AECD-3010; UCRL-670 (1950).

The neptunium L x rays from Am-241 were measured.

365

L X-RAYS AND LOW ENERGY GAMMA RADIATION IN THE DECAY OF Am-241. C. I. Browne and I. Perlman. UCRL-1516 (1951).

The L x rays and low-energy gamma rays given off following the alpha decay of Am-241 have been studied. Eight gamma rays have been observed in the spectral region 12 kev to 85 kev with energies ranging from 14.23 ± 0.06 kev to 59.78 ± 0.02 kev. The ratio of vacancies produced in the L shell by internal conversion is $L_I:L_{II}:L_{III} = 6:5:2$. A partial decay scheme is suggested and a number of the α -ray transitions are shown to be in good agreement with known spacings from alpha-particle complex structure.

366

PRECISION MEASUREMENTS OF X-RAYS AND GAMMA RAYS IN RADIOACTIVE DECAY. C. I. Browne, Jr. (thesis). AECD-3404; UCRL-1764 (1952).

A 10-in. bent crystal spectrometer was used to examine the spectra of radiation emitted in the decay of Am-241. It was observed that the beta decay of U-237 and the alpha decay of Am-241 apparently lead to the same excited state in the daughter Np-237.

367

SOFT RADIATIONS FROM AM-241. J. K. Beling, J. O. Newton, and B. Rose. *Phys. Rev.*, 86,

797-8 (1952).

The gamma and x radiation produced in the decay of the alpha-particle emitter Am-241 have been examined over the energy range of 5 kev to 120 kev by the proportional counter technique. Lines attributable to Am-241 were observed at 59.7 ± 0.3 , 26.3 ± 0.2 , 20.9 ± 0.2 , 17.3 ± 0.2 , and 13.5 ± 2 kev of intensity roughly 1/2 percent of that of the 60-kev line. The absolute intensity of the 59.7-kev gamma was found by coincidence measurements to be 0.40 ± 0.015 per alpha particle.

368

THE BETA-SPECTRA OF Pu-239, Pu-240, AND Pu-241. M. S. Freedman, F. Wagner, Jr., and D. W. Engelkemeir. *Phys. Rev.*, 88, 1155-8 (1952). The existence of 264- and 59-kev gammas in Am-241 alpha decay is confirmed. A conversion line corresponding to a highly converted 41-kev gamma in Am-241 was found. The influence of the orbital-electronic-rearrangement energy on the beta decay is discussed.

369

THE GAMMA RADIATION FROM Am-241. J. O. Newton and B. Rose. *Phys. Rev.*, 89, 1157 (1953).

The spectrum of Am-241 was re-examined in the 26-total kev energy region using proportional counters filled with Kr and Xe. A typical spectrum using a carrier-free Am-241 source is shown and an upper limit of 0.1 percent/59.7-kev gamma ray is set for the intensity of gamma rays at 33.4 kev and 38.0 kev. Another spectrum obtained from an Am-241 source containing La shows strong lines present at 33.4 kev and 38.0 kev having a relative intensity ($\sim 5:1$). It is suggested that these are K_α and K_β radiations of La excited by the 59.7 kev γ -ray, rather than gamma rays as reported by Browne (UCRL-1764).

370

GAMMA RAY SPECTROSCOPY USING A GAS FILLED PROPORTIONAL COUNTER. D. G. Miller. HW-30638 (1954).

Spectrometer scans of the photon energies emitted by Pu-239 and Am-241 are presented as well as scans of the x-ray energies emitted by the K-capture calibration sources. Scans of the x-ray energies excited in copper and zirconium by the 60-kev photons from Am-241 are also shown.

371

INTERNAL CONVERSION OF GAMMA RADIATION IN THE L SUBSHELLS. T. O. Passell (thesis). UCRL-2528 (1954).

Electron spectra from conversion of low-energy nuclear gamma radiation (up to 350 kev) in several isotopes

of the heavier elements have been investigated. Both Am-241 and Am-242m have been studied.

372

GAMMA AND X-RADIATION IN THE DECAY OF Am-241. J. Jaffee, T. O. Passell, C. I. Browne, and I. Perlman. *Phys. Rev.*, 97, 142-50 (1955).
The decay scheme of Am-241 is discussed in terms of new information on the conversion electrons, gamma rays, and L series alpha rays accompanying its alpha decay. The photons were measured with a scintillation spectrometer and a bent-crystal spectrometer and the conversion electron spectrum was determined with a double-focusing beta-ray spectrometer.

373

ELECTROMAGNETIC SPECTRUM OF Am-241. P. O. Day. *Phys. Rev.*, 97, 689-700 (1955).
The electromagnetic spectrum of Am-241 has been studied with a 10-in. bent-crystal spectrometer and a NaI scintillation counter. Twelve gamma rays, sixteen Np L x rays and eight Am L x rays have been measured.

374

L X-RAY ENERGIES OF Np, Pu, AND Am. G. L. Rogosa and W. F. Reed. *Phys. Rev.*, 101, 591-3 (1956).
Five Am, L x-ray transitions have been observed in conventional x-ray fluorescence using a Cauchois type curved crystal transmission spectrometer. The energies of these transitions have been determined.

375

A MEASUREMENT OF THE HALF-LIFE OF Pu-241. B. Rose and J. Milsted. *J. Nucl. Energy*, 2, 264-76 (1956).
By studying the growth of the gamma activity of the daughter Am-241 in a xenon filled proportional counter, a value of 12.95 ± 0.28 yr was found to be the half-life of Pu-241.

376

PHYSICS DIVISION SUPPLEMENT TO QUARTERLY REPORT FOR SEPTEMBER, OCTOBER, AND NOVEMBER. ANL-5175 (1955).
An investigation of the isomeric transition associated with Am-242m failed to reveal any L-conversion lines for either E3 or M1 transitions.

377

INTENSITIES OF X-RAYS AND GAMMA-RAYS IN Am-241 ALPHA DECAY. L. B. Magnuson. *Phys. Rev.*, 107, 161-70 (1957).
Electromagnetic radiation intensities from levels of Np-237 were remeasured with NaI scintillation detectors and an argon proportional chamber. By absolute and coincidence counting the photon intensities per

alpha particle are 0.376, 0.025, 0.00073, and 0.359 for the L x rays and the 26.4-, 43.4-, and 59.6-keV gamma rays, respectively. Gamma rays with 99- and 103-keV energy were found by alpha-gamma coincidence. The 99-keV gamma ray is emitted from the 159-keV level with an intensity of 2.3×10^{-4} . The 103-keV gamma ray, of intensity 1.9×10^{-4} per alpha particle, is a de-excitation of the 103-keV level. The intensity of L x rays from levels above 59.6 keV is 0.064. Coincidence intensities of 26-keV gamma rays with L x rays from conversion of the 33.2-keV gamma ray and of the 33.2-keV gamma ray and of L x rays from these transitions are 0.01 and 0.031 per alpha particle, respectively.

378

NUCLEAR EFFECTS OBSERVED IN X-RAY SPECTRA. J. J. Merrill and J. W. M. DuMond. *Proceedings of the International Conference on Nuclear Structure*, pp 637-9 (1960).
Measurements of the L x-ray spectra of heavy elements, W, Pt, Bi, Th, U, Np, Pu, and Am with a precision two-crystal spectrometer are described.

379

PRECISION MEASUREMENT OF L X-RAY WAVELENGTHS AND LINE WIDTHS FOR $14 \leq Z \leq 95$ AND THEIR INTERPRETATION IN TERMS OF NUCLEAR PERTURBATIONS. J. J. Merrill and J. W. M. DuMond. *Ann. Phys.*, 14, 166-228 (1961).
Techniques for the precision measurement of x-ray lines using the two-crystal spectrometer are discussed, and then applied to the measurement of the L x-ray spectra of the transuranic elements U, Np, Pu, and Am. In all, 52 emission lines and 41 L_{111} absorption edges were measured, all of them with higher precision than has before been obtained and many of them for the first time. Binding energies of the electrons and the L_{111} L_{111} level splitting were computed and compared to theory.

XX. HALF-LIFE - SPECIFIC ACTIVITY

380

PREPARATION AND PROPERTIES OF Am-242. L. B. Asprey and W. M. Manning. AECD-2505 (December 1948).
It was found that Am-242 has a $T_{1/2} \approx 16$ hours. The 150 day found was assigned to Am-242. The maximum β energy for Am-242 is approximately 1.0 ± 0.3 MeV.

381

THE ISOTOPES OF AMERICIUM. K. Street, Jr., A. Ghiorso, and G. T. Seaborg. *Phys. Rev.*, 79, 530-1 (1950).
The preparation, decay characteristics, and half lives of Am-238, -239, -240, -241, -242, and -243 are given.

382

SUMMARY OF THE RESEARCH PROGRESS MEETING OF APRIL 19, 1951. B. E. Cushman. UCRL-1250 (1951).

The heavy metal energy cycle of Am-240-Cm-240 transition is 0.16 Mev. There must be K capture by the Am-240 with energy equal to 0.16 Mev and a half-life limit of >50 yr and with a β limit of >500 years.

383

THE ALPHA HALF-LIFE OF Am-241. B. G. Harvey. *Phys. Rev.*, 85, 482 (1952).

The specific alpha activity of a purified sample of AmO₂ has been determined to be 470^{+5}_{-10} yr for the alpha half-life of Am-241.

384

AN INVESTIGATION OF THE ISOTOPES OF AMERICIUM AND CURIUM. G. H. Higgins (thesis). UCRL-1796 (1952).

The partial alpha half-life of Am-239 was measured. Evidence for the discovery of Am-237 (-1 hr electron capture activity) has been presented. An appendix indicating the conditions for separation of the trivalent actinide by selective elution from ion-exchange resin with citric acid has been included.

385

THE HALF-LIFE OF Am-242m FOR NEGATIVE BETA PARTICLE EMISSION. T. K. Keenan, R. A. Penneman, and B. B. McInteer. AECD-3399; LADC-1132.

The half-life of Am-242m has been redetermined to yield a value of 16.01 ± 0.02 hours. Mathematical treatment of the decay data shows for counting time of 20 min,

$$\frac{\Delta N}{\Delta t} = \frac{dN}{dt} \text{ at mean time } \frac{\Delta t}{2}$$

to within 10^{-3} percent. For larger counting times, the exact time "t" at which

$$\frac{\Delta N}{\Delta t} = \frac{dN}{dt}$$

is

$$t = \frac{1}{\lambda} \ln (\lambda \Delta t / 1 - e^{-\lambda \Delta t})$$

For counting times of the order of an entire half-life, the relationship between the number of counts collected (ζN_1 and ζN_2) in two identical counting times is $\lambda = 1/t_2 \ln (\zeta N_1 / \zeta N_2)$ where t_2 is the elapsed time between the first and second counting period.

386

THE HALF-LIFE OF Am-243. H. Diamond, P. R. Fields, J. F. Mech, M. G. Inghram, and D. C. Hess. AECD-3543; ANL-WMM-1109 (1953).

A sample of Am-243 formed by pile irradiation of Pu was chemically purified and the mass ratio of Am-243 to Am-241 was determined. The ratio of the alpha activity of the Am isotopes was measured. From these data and the known Am-241 half-life (470^{+5}_{-10} yr) the alpha half-life of Am-243 was found to be $8.8 \pm 0.6 \times 10^3$ years.

387

A NEW DETERMINATION OF THE HALF-LIFE OF Am-242m. THE PROBLEM OF COUNTING SHORT-LEVEL ACTIVITIES. T. K. Keenan, R. A. Penneman, and B. B. McInteer. *J. Chem. Phys.*, 21, 1802-3 (1953). The half-life of Am-242m has been redetermined to yield a value of 16.01 ± 0.02 hours.

388

CHEMISTRY DIVISION QUARTERLY REPORT. UCRL-3068 (July 6, 1955).

The half-life of Am-243 was determined at 7.6×10^3 years.

389

PRODUCTION OF Pu-245 AND Am-245 BY NEUTRON IRRADIATION OF Pu-244. P. R. Fields, M. H. Studier, A. M. Friedman, H. Diamond, R. K. Sjoblom, and P. A. Sellers. *J. Inorg. Nucl. Chem.*, 1, 262-6 (1955).

Pu-245 and Am-245 were prepared by neutron irradiation of Pu-244. The beta-decay half-life of Am-245 was found to be 119 ± 1 minutes. The β -decay energy of Am-245 was found to be 0.86 Mev by absorption methods and gamma rays of 260, 121, and 70 kev, were resolved with a sodium iodide crystal spectrometer.

390

THE NEW ISOTOPES Pu-246 AND Am-246. D. W. Engelkemeir, P. R. Fields, S. Fried, J. L. Pyle, and C. M. Stevens. *J. Inorg. Nucl. Chem.*, 1, 345-51 (1955).

The half-life of Am-246 was estimated to be 25 ± 0.2 minutes. The total disintegration energy of Am-246 was determined to be 2.29 Mev.

391

THE ALPHA HALF-LIFE OF Am-241. G. R. Hall and T. L. Markin. *J. Inorg. Nucl. Chem.*, 2, 202-3 (1956). A mean value of 461.3 ± 1.7 yr was obtained for the alpha half-life of Am-241.

392

THE ALPHA HALF-LIFE OF AMERICIUM-241. G. R. Hall and T. L. Markin. *J. Inorg. Nucl. Chem.*,

4, No. 3 and No. 4m 137-42 (1957).

The preparation of AmO_2 , $\text{Am}_2(\text{SO}_4)_3$, and anhydrous AmCl_3 is described. These compounds have been used in the determination of the alpha half-life of Am-241. A value of $7.187 \pm 0.007 \times 10^6$ alpha/min/ μg was obtained for the specific activity from which the half-life is calculated to be 458.1 ± 0.5 years.

393

CHEMISTRY DIVISION, SECTION C-1 QUARTERLY REPORT FOR OCTOBER, NOVEMBER, AND DECEMBER. D. W. Osborne, ed. ANL-5054 (1953). Progress is reported on the determination of the half-life of Am-243.

394

THE SPECIFIC ACTIVITIES AND HALF LIVES OF AMERICIUM-241 AND AMERICIUM-243. J. C. Wallmann, P. Graf, and L. Goda. *J. Inorg. Nucl. Chem.*, 7, 199-200 (1958).

The specific activities of one sample of Am-241 metal and two samples of Am-243 metal have been measured. Half-lives of 457.7 ± 1.8 yr and 7951 ± 48 yr, respectively, have been obtained.

395

THE ALPHA AND ELECTRON CAPTURE PARTIAL HALF-LIVES OF Am-242. R. F. Barnes, D. J. Henderson, A. K. Harkness, and H. Diamond. *J. Inorg. Nucl. Chem.*, 9, 105-7 (1959).

The partial alpha half-life and partial electron capture half-life of the ground state of Am-242 were measured at $32,000 \pm 1600$ yr and 960 ± 50 yr, respectively. The alpha half-life of Am-242 was found to be 7720 ± 160 years.

396

SPECIFIC ACTIVITIES OF NUCLIDES, $Z > 87$.

N. M. Isaac and J. W. Wilkins. ANL-6042 (1959).

The specific activity of an isotope is expressed as the product of its decay constant and the number of atoms per unit weight. The specific activities of the elements with $Z > 87$ are calculated in units of disintegration per microgram.

397

THE HALF-LIFE OF AMERICIUM-243. A. B. Beadle, D. F. Dance, K. M. Glover, and J. Milstead. *J. Inorg. Nucl. Chem.*, 12, 359-61 (1960).

The half-life of Am-243 was determined by isotopic dilution with Am-241 and mass spectrometric and alpha pulse analysis of mixtures in the range (Am-243/Am-241) = 2.5 to 5.5. The mean half-life ratio was found to be 16.70 ± 0.10 corresponding to a half-life of 7650 ± 50 yr for Am-243.

398

ANNUAL PROGRESS REPORT FOR THE PERIOD JULY 1961 - JUNE 1962. NBL-188 (1962).

The absolute disintegration rate of an Am-241 alpha source, for use in calibration of alpha-counting equipment, was determined by means of the alpha-gamma coincidence method with a precision of 0.6 percent and a probably accuracy of 1 percent to 2 percent.

399

ABSOLUTE MEASUREMENTS OF THE DISINTEGRATION RATES OF AMERICIUM-241 SOURCES BY USING SEMICONDUCTOR DETECTORS. E. Saki, H. Tamura, and Y. Sakurai. *J. Nucl. Sci. Technol.*, 1, 101-9 (1964).

Low-geometry alpha counting and alpha-particle/gamma-ray coincidence counting were made to determine the absolute disintegration rate of an Am-241 source.

Alpha particles were counted by silicon junction detectors and gamma rays by a NaI(Tl) crystal photomultiplier system. The mean value of the absolute disintegration rate of a typical Am-241 source measured by coincidence counting was 1.696×10^4 dps. Accurate absolute measurements by low-geometry alpha-particle counting are very difficult because of the difficulty of measuring the geometries accurately.

XXI. NUCLEAR SPIN - MAGNETIC MOMENTS

400

NUCLEAR SPIN OF $^{241}_{95}\text{Am}$. M. Fred and F. S. Tomkins. AECD-3462; ANL-OCS-288.

The spectrum of Am-241 has been photographed and found to contain many lines with wide hyperfine structure in the form of flag patterns all apparently with six components. Since the J values are expected to be high, the number of components is presumably spin-limited, with $I = 5/2$. The existence of an appreciable quadrupole moment is indicated by a departure from the internal rule for some lines.

401

NUCLEAR SPIN OF Am-243 AND ISOTOPE SHIFT IN THE AMERICIUM SPECTRUM. J. G. Conway and R. D. McLaughlin. *Phys. Rev.*, 94, 498 (1954).

The hyperfine structure of Am-243 was found to be a flag pattern of six lines indicating a nuclear spin of $5/2$. Within 2 percent the patterns of Am-243 and Am-241 have the same overall width showing that their nuclear magnetic moments are equal. A table is presented of the isotope shifts between Am-241 and Am-243.

- 402
SPINS OF EXCITED STATES OF SOME ODD A NUCLEI ACCORDING TO THE COLLECTIVE MODEL. R. L. Moore. AECU-2912 (1954).
The energy level spacing of some heavy isotopes of odd A have been examined from the point of view of the collective model of the nucleus to obtain predictions about the level spins. Levels, spins, and rotational energies are estimated for Am-241.
- 403
NUCLEAR MOMENTS OF Am-241 AND Am-243. W. M. Manning, M. Fred, and F. S. Tomkins. *Phys. Rev.*, 102, 1108 (1956).
The following values have been derived from measurements of hyperfine structure in the spectrum of americium
 $\mu_{241} = +1.4\text{nm}$, $Q_{241} = +4.9 \times 10^{-24} \text{ cm}^2$, $\mu_{241}/\mu_{243} = +1.00 \pm 0.01$
 $Q_{241}/Q_{243} = +1.00 \pm 0.01$.
- 404
NUCLEAR SPIN OF AMERICIUM-241. R. P. Thorne. *Nature*, 178, 484-5 (1956).
The americium was excited in a hollow cathode cooled with liquid nitrogen. The hyperfine separations show a marked divergence from the interval rule. Thus, a relatively large quadrupole moment is expected for Am. It would appear that the nuclei of Am-241 and Np-237 have a ground state of f5/2.
- 405
CHEMISTRY DIVISION SEMI-ANNUAL REPORT (FOR) DECEMBER 1957 THROUGH MAY 1958. UCRL-8369 (1958).
Nuclear spins and magnetic moments are presented for Am-241 and other isotopes. Electronic ground states are also presented. Fluorescent studies of Am and Cm in LaCl_3 matrix are described.
- 406
ATOMIC BEAM RESEARCH ON RADIOACTIVE ATOMS. W. A. Nierenberg. UCRL-8553 (1958).
Spins of isotopes of americium are given.
- 407
SOME NUCLEAR AND ELECTRONIC GROUND STATE PROPERTIES OF Pa-233, Am-241, AND 16-HR Am-242. J. Winocur (thesis). UCRL-9174 (1960).
The atomic beam, magnetic-resonance method was used to study some properties of the nuclear ground state and the low lying electronic states of three radioactive actinides isotopes; Am-241, Am-242, and Pa-233. From the ratios of the hfs constants of the two Am isotopes, together with the optically measured nuclear moments of Am-241, it follows that $\mu(\text{Am-242}) = \pm 0.33\text{nm}$ and
- $Q(\text{Am-242}) = \pm 2.76$ barns. A description of the experimental technique and an analysis of the results are presented.
- 408
HYPERFINE STRUCTURE OF AMERICIUM-241. R. Marrus, W. A. Nierenberg, and J. Winocur. *Phys. Rev.*, 120, 1429-35 (1960).
Atomic beam measurements on Am-241 confirmed that the nuclear spin is $I = 5/2$ and established that the angular momentum $J = 7/2$ and a Lande splitting factor $g = 1.9371$ (10).
- 409
PROPERTIES OF DEFORMED ODD-ODD NUCLEI WITH $K = 0$. D. H. Varshalovich and L. K. Peker. *Izvest. Akad. Nauk, SSSR, Ser. Fiz*, 25, 287-96 (1961).
The electric quadrupole and magnetic dipole moments of odd-odd nuclei with $K = 0$ and $I = 1$ (Lu-176, Ta-180, and Am-242) are tabulated.
- 410
THE FINE AND HYPERFINE STRUCTURE OF AMERICIUM-I. K. Krebs and R. Winkler. *Z. Physik*, 162, 235-44 (1961).
It was previously shown that hfs splitting constants can easily be obtained from experimental data by means of a graphical representation. Here it is shown that this method is also capable of determining the J values of terms from hfs data. By application of this method on known hfs measurements of Am-241, the undetermined J value of one Am-I term could be obtained. In four other cases J values were found which differ from the values known so far. Consequences on the term analysis of the Am arc discussed.
- 411
HYPERFINE STRUCTURE AND NUCLEAR MOMENTS OF Am-242. R. Marrus and J. Winocur. *Phys. Rev.*, 124, 1904-6 (1961).
The hyperfine structure of Am-242 ($T_{1/2} = 16$ hr) in the $J = 7/2$ electronic ground state was studied by the atomic beam technique using radioactive detection. The nuclear spin is found to be $I = 1$. The measured values of the magnetic dipole interaction constant A and the electronic quadrupole interaction constant B are $A = \pm 10.124$ (10) Mc/sec and $B = \pm 69.639$ (40) Mc/sec, respectively. Combining these measurements with optical spectroscopic and atomic beam data for Am-241, the nuclear magnetic dipole moment is inferred to be $\mu_1 = \pm 0.33\text{nm}$ and the nuclear quadrupole moment $Q = \pm 2.76$ barns. These results are discussed in terms of the Bohr-Mottelson nuclear model.
- 412
MAGNETIC OCTUPOLE MOMENTS OF AXIALLY SYMMETRIC DEFORMED NUCLEI. S. A. Williams.

Phys. Rev., 125, 340-6 (1962).

The magnetic octupole moments of 20 odd-A nuclei whose energy levels are described by the axially symmetric collective model in strong coupling were calculated. With but two exceptions, the predicted moments are of the same magnitudes as or larger than the moments measured for seven nuclei. With but one exception, the spin gyromagnetic ratio, g_s , was found to have a value between the free particle and the pure Dirac particle value.

413

FEATURES EXPECTED OF THE DECAY OF 6-QUASIPARTICLE ISOMERIC STATES IN ODD-ODD NUCLEI HAVING A MASS NUMBER A $\sim$ 240.

L. K. Peker. *Izvest. Akad. Nauk, SSSR, Ser. Fiz*, 28, 298-301 (1964).

The isomeric state of the odd-odd nucleus Am-242 is the first example of a 6-quasiparticle state with a very large spin $K = I = 24$. This explains the existence of an excited long-lived isomeric state in Am-242. The probability of spontaneous fission in such nuclei is very high compared to the probabilities of β and α decay.

XXII. NUCLEAR CROSS SECTION

A. Cross Section

414

CHEMISTRY DIVISION QUARTERLY REPORT DECEMBER 1954, JANUARY, FEBRUARY, 1955. UCRL-2932 (1955).

Cross sections and excitation functions are given for reactions of Am-241 with alpha particles. Spectroscopic studies of the low-energy conversion spectra in Am-241 are outlined. A correlation of alpha decay energies with alpha half-lives by means of a generalized Gamow relationship has been obtained.

415

NUCLEAR DATA SERIES. PART II (1954).

J. S. Story. AERE-T/M-97; NRDC-33.

Neutron cross sections for heavy isotopes are tabulated and the methods by which the measurements were made are discussed.

416

PHYSICS AND MATHEMATICS: VOLUME 2; PROGRESS IN NUCLEAR ENERGY SERIES I.

D. J. Hughes, J. E. Sanders, and J. Horowitz, eds. New York, Pergamon Press, 1958.

Neutron cross-section data for isotopes of Th, U, Np, Pu, and Am are reviewed.

417

EFFECTIVE CROSS SECTION VALUES FOR WELL-MODERATED THERMAL REACTOR SPECTRA.

C. H. Westcott. AECL-670 (1958).

Formulas used in the calculations are presented and some of their limitations are discussed. Tables of g- and s-factors and effective cross sections are included for Am-241, Am-243, and other isotopes.

418

REPORT TO THE AEC NUCLEAR CROSS SECTIONS ADVISORY GROUP. OAK RIDGE NATIONAL LABORATORY, OAK RIDGE, TENNESSEE, NOVEMBER 13-14, 1958. V. L. Sailor.

WASH-1013 (1958).

The cross-section measurements program at ANL, BNL, Columbia Univ., HAPO, LASL, ORNL, Phillips Pet. Co., Rensselaer Poly Inst., Rice Inst., and UCRL are reviewed. Informal statements of recent developments, changes in emphasis, and preliminary cross-section data, are included.

419

REPORT TO THE AEC NUCLEAR CROSS SECTIONS ADVISORY GROUP. RICE INSTITUTE, HOUSTON, TEXAS, MARCH 4-5, 1959. V. L. Sailor.

WASH-1018 (1959).

Cross-section measurement programs at ANL, BNL, Columbia Univ., Duke Univ., HAPO, LASL, ORNL, Phillips Petroleum Co., Rensselaer Poly Inst., Rice Inst., and UCRL are reviewed. Informal statements of recent developments, changes in emphasis, and preliminary cross-section data are included.

420

SUPPLEMENT TO "EFFECTIVE CROSS SECTION VALUES FOR WELL-MODERATED THERMAL REACTOR SPECTRA." C. H. Westcott and D. A. Roy. CRRP-862; AECL-869 (1959).

The compilation of effective cross sections (CRRP-787) included neutron temperatures up to 760°C. Values are presented up to 1280°C. The validity of the low-energy cut-off of the epithermal neutron spectrum assumed in CRRP-787 was also examined. Calculations are repeated for some of the more important elements for cut-off functions of 1 and 3 kt.

B. Capture Cross Section

421

CURIUM ISOTOPES 246 AND 247 FROM PILE-IRRADIATED PLUTONIUM. C. M. Stevens, M. H. Studier, P. R. Fields, J. F. Mech, P. A. Sellers, A. M. Friedman, H. Diamond, and J. R. Huizenga.

Phys. Rev., 94, 974 (1954).

The pile neutron capture cross section of Am-243 is 115 ± 20 barns.

422

PHYSICS DIVISION SEMI-ANNUAL PROGRESS REPORT FOR PERIOD ENDING MARCH 20, 1955. J. L. Fowler and E. O. Wollan. ORNL-1879 (1955). Neutron absorption cross sections were measured for Am-241.

423

DETERMINATION OF THE NEUTRON CAPTURE CROSS SECTIONS OF Pu-242, Pu-238, AND Am-243. J. P. Butler, M. Lounsbury, and J. S. Merritt. CRC-628 (1956).

Neutron capture cross sections of Am-243 were determined for pile and thermal neutrons. The pile and thermal values for Am-243 are 131.8 ± 1.7 and 81.6 ± 1.8 . Resonance integrals are included.

424

THE NEUTRON CAPTURE CROSS SECTIONS OF Pu-238, Pu-242, AND Am-243 IN THE THERMAL AND EPICADMIUM REGIONS. J. P. Butler, M. Lounsbury, and J. S. Merritt. *Can. J. Phys.*, 35, 147-54 (1957). Thermal neutron capture cross sections of $403 \pm 8b$ for Pu-238, $18.6 \pm 0.8b$ for Pu-242, and $73.6 \pm 1.8b$ for Am-243 were measured by the activation method assuming $36.4b$ for the thermal neutron cross section of Co-59. Samples of Pu were irradiated for 1 to 5 months in the NRX reactor. The growth of Pu-239, Am-243, and Cm-244 was determined by mass analysis, by alpha spectrum analysis, and by total alpha counting. A resonance capture integral of $2290 \pm 50b$ was found for Am-243.

425

CROSS SECTION PROGRAM AT ORNL. J. A. Harvey and J. L. Fowler. CF-59-2-83 (1959). The ORNL pulsed Van de Graaff was used with a large liquid scintillator to study neutron capture cross sections as a function of neutron flight time. Transmission measurements on Am-241 were analyzed to yield resonance parameters.

C. Fission Cross Section

426

THERMAL NEUTRON FISSION OF Am-241. B. B. Cunningham and A. Ghiorso. AECD-3075; UCRL-1060 (1950). The mean value of the thermal neutron cross section (fission) of Am-241, as computed on purified $1/2$ to $1 \mu g$ samples of Am irradiated in the Argonne heavy water pile, was 3.0 ± 0.2 barns.

427

SLOW NEUTRON FISSION OF Am-242, Am-242m, AND Am-243. K. Street, Jr., A. Ghiorso, and S. G. Thompson. AECD-3268; UCRL-1185 (1951). A sample of Am-241 was irradiated with pile neutron. Mass spectrometry analysis showed 99 percent Am-241, 0.5 percent Am-242, and 0.5 percent Am-243. From these data the following approximate cross sections were calculated: cross section for formation of Am-242, ~ 50 barns; neutron capture cross section of Am-242 to form Am-243, ~ 2000 barns; total cross section for destruction of Am-242, ~ 8000 barns; fission cross section of Am-242, ~ 6000 barns. The fission cross section of Am-242m was calculated to be about 2000 barns.

428

THERMAL NEUTRON FISSION CROSS SECTION OF Am-242m. G. H. Higgins and W. W. T. Crane. *Phys. Rev.*, 94, 735 (1954). A value of 2950 barns was obtained for the fission cross section of Am-242m.

429

CHEMISTRY DIVISION QUARTERLY REPORT. UCRL-3240 (December 20, 1955). Fission and spallation cross sections for Am-241 are presented.

430

THERMAL-NEUTRON FISSION CROSS SECTIONS FOR ISOTOPES OF PLUTONIUM, AMERICIUM, AND CURIUM. E. K. Hulet, R. W. Hoff, H. R. Bowman, and M. C. Michel. *Phys. Rev.*, 107, 1294-6 (1957). The following thermal-neutron fission cross sections have been measured in the thermal column of the MTR at Idaho Falls, Idaho: Pu-238, $18.4 \pm 0.9b$; Am-241, $3.13 \pm 0.15b$; Am-242, $6390 \pm 500b$; Am-243, $< 0.072b$; Cm-243, $690 \pm 50b$; Cm-245, $1880 \pm 150b$. In addition, a pile neutron capture cross section of $520 \pm 40b$ has been measured for Pu-238.

431

PHOTOFISSION IN HEAVY ELEMENTS. L. Katz, A. P. Baerg, and F. Brown. A/CONF. 15/P/200. Measurements of photofission cross section for a number of heavy element nuclides were made by counting, in an ionization chamber, the fission fragments from foils irradiated in a bremsstrahlung beam of a betatron. Parameters describing the giant resonance fission cross-section curves were obtained for Th-232, U-233, U-238, Np-237, Pu-239, and Am-241. Am-241 was found to give an isotropic distribution.

432

2.5 AND 14.6 MEV NEUTRON CROSS SECTIONS OF Th-230, Pu-240, Pu-241, AND Am-241.

M. I. Kazarinova, Yu. S. Zamyatin, and V. M. Gorbachev. *Atomnaya Energ.*, 8, 139-41 (1960).
Cross sections for Am-241 fission by 2.5- and 14.6-Mev neutrons were measured in order to determine and verify the dependence of the neutron energy band f on A (at constant Z) and $f(A)$.

433

NUCLEAR PHYSICS RESEARCH QUARTERLY REPORT (FOR) APRIL, MAY, AND JUNE, 1958. HW-56919 (1958).

Fission cross sections for Am-241 at 0.1 to 5 ev were measured using a crystal spectrometer.

434

NUCLEAR PHYSICS RESEARCH QUARTERLY REPORT (FOR) JULY, AUGUST, SEPTEMBER, 1958. HW-57861 (1958).

Errors in previous measurements of the slow neutron fission cross section of Am-241 made new measurements on a new sample necessary. The new results are given.

435

THE FISSION CROSS SECTION OF Am-241 FOR 14.6 MEV NEUTRONS. A. N. Protopopov, Yu. A. Selitskii, and S. M. Solov'ev. *Atomnaya Energ.*, 6, 67-8 (1959).

The cross section for Am-241 fission by 14.6-Mev neutrons is $\sigma = 2.35 \pm 0.15$ barns.

436

FAST-NEUTRON INDUCED FISSION CROSS SECTIONS OF Pu-241 AND Am-243. D. K. Butler and R. K. Sjolom. *Phys. Rev.*, 124, 1129-31 (1961).
The cross section for neutron induced fission of Pu-241 for neutrons of energies from 0.02 to 1.80 Mev and of Am-243 for neutrons of energies from 0.3 to 1.7 Mev were determined by measuring the ratio of each cross section to that of U-235 using a back to back gas scintillation counter.

437

THE THERMAL NEUTRON FISSION CROSS SECTION OF 10.1 HR Am-244. S. E. Vandenbosch and J. Gray, Jr. *J. Inorg. Nucl. Chem.*, 23, 187-9 (1961).

The thermal neutron fission cross section of the 10.1-hr isomer of Am-244 was determined by counting fissions induced by neutrons in the thermal column of the Argonne reactor CP-5. A decrease in fissionability with the characteristic 10.1-hr half-life was observed. The fission cross section of 2300 ± 300 barns was obtained by comparing the fission counting rate of Am-244 with that of a U-233 standard.

D. Total Cross Section

438

THE NEUTRON CAPTURE CROSS SECTION OF Am-241. G. C. Hanna, B. G. Harvey, and N. Moss. *Phys. Rev.*, 81, 486-7 (1951).

A mean value of the partial cross section of Am-241 of 568 barns was obtained. The total cross section for Am-241 transformation was determined as 887 barns.

439

THE TOTAL NEUTRON CROSS SECTIONS OF Pu-240, Pu-242, AND Am-243. R. E. Coté, L. M. Bolinger, R. F. Barnes, and H. Diamond. The International Conference on the Neutron Interactions with the Nucleus, held at Columbia University, September 9-13, 1957. TID-7547, pp 117-8.

The total cross sections of Pu-242 and Am-243 were measured. Total cross sections and resonance parameters are included.

440

SLOW NEUTRON CROSS SECTIONS OF Pu-240, Pu-242, AND Am-243. R. E. Coté, L. M. Bolinger, R. F. Barnes, and H. Diamond. A/CONF. 15/P/685 (1958).

Measurement of the total cross section of Am-243 was carried out. No measure of the off-resonance cross section was made except in the thermal region. Measurements in the thermal region show the cross section does not vary as $1/v$.

XXIII. FISSION

A. Induced Fission

441

FISSION IN Am-242. G. C. Hanna, B. G. Harvey, N. Moss, and P. R. Tunncliffe. *Phys. Rev.*, 81, 893-4 (1951).

Slow neutron irradiation of Am-241 produces a nuclide with a large slow neutron fission cross section. Chemical separation shows this fission to be in the americium fraction, and the growth of fission rate with pile irradiation shows that Am-242, the long-lived ground state, is responsible. The fission cross section of the latter is reported as 2500 barns and the capture cross section as 5500 barns.

442

THE MASS YIELD CURVE FOR FISSION OF Am-241 BY NEUTRONS. J. G. Cunningham. *J. Inorg. Nucl.*

Chem., 4, 1-7 (1957).

Relative yields for the fission of Am-241 by pile neutrons have been measured for mass number 89, 91, 95, 97, 99, 111, 113, 115, 121, 131, 132, 136 (shielded), 137, 139, 140, 141, 143, 144, 147, and 153. The peak to trough ratio is ~ 160 and ν is 3 ± 0.5 . The light peak has moved two mass units towards the heavy peak when compared with the Pu-239 thermal fission curve.

443

MEAN NUMBER OF NEUTRONS EMITTED IN Am-241 FISSION BY THERMAL NEUTRONS. I. A. Lebedev and V. I. Kalashnikova. *Atomnaya Energ.*, 5, 176-7 (1958).

The mean number of neutrons emitted in a single Am-241 fission (ν) by thermal neutrons was determined in relation to the magnitude of ν for U-235. The ratio $\nu(\text{Am-241})/\nu(\text{U-235}) = 1.27 \pm 0.01$ was obtained on the basis of the universally accepted value $\nu(\text{U-235}) = 2.47 \pm 0.03$.

444

NUCLEAR PHYSICS RESEARCH QUARTERLY REPORT (FOR) OCTOBER, NOVEMBER, DECEMBER 1958. HW-59126 (1959).

The experimental program to study the neutron induced fission in low-energy resonance of nuclides with well-defined fast-neutron thresholds for fission in Pu-240, Np-237, and Am-241 is summarized.

445

DERIVATION OF THE MEAN NUMBER OF SECONDARY NEUTRONS PER FISSION FROM THE MASS DISTRIBUTION OF THE PRODUCTS. Yu. A. Zysin, A. A. Lbov, and L. I. Sel'chenkov. *Atomnaya Energ.*, 8, 409-12 (1960).

An evaluation is made of the order of error in the method for calculating the mean number of secondary neutrons ν by fission product mass distribution curves. Calculations are made of ν for Am-241 and other actinides. The data are analyzed and correlated with data obtained by other methods.

446

THE EXPERIMENTAL STUDIES OF FISSION PROPERTIES UTILIZED IN REACTOR DESIGN. D. Butler, S. Cox, J. Meadows, J. Roberts, A. Smith, and J. Whalen. *Physics of Fast and Intermediate Reactors*, Vol I, Vienna International Atomic Energy Agency, 1962, pp 125-37.

Experimental studies of fission parameters useful in reactor design are described. The periods and yields of delayed neutron groups emitted following the neutron-induced fission of Pu-241 are measured. Evidence for systematic isotopic dependence of delayed-neutron yields is presented. An experimental investigation of the relation between the time behavior of delayed-

neutron emission and energy of the incident neutron fission is described. The cross section for the inducing of fissions in Am-243, Pu-242, and Pu-241 using neutrons at 0.030 to 1.8 Mev is measured. Techniques and methods of measuring prompt fission-neutron spectra are described.

447

CALCULATIONS OF THE CONCENTRATIONS AND FISSIONS OF HEAVY ISOTOPES IN TIME-VARYING IRRADIATIONS OF URANIUM AND PLUTONIUM.

J. C. Connor. WAPD-TM-331 (May 1962).

Expressions for the concentrations and the number of fissions of 14 heavy isotopes produced in U and Pu irradiations were derived in the form of recursive relations which include the decay of unstable isotopes assuming a constant flux and arbitrary initial concentrations. The expression may be used to treat time-varying irradiation histories specified by a sequence of constant flux steps.

448

NUCLEAR FISSION AND ANGULAR ANISOTROPY OF FISSION FRAGMENTS. V. M. Strutinskii.

Fizika Deleniya Atomnykh Yoder, Moscow, Gosatomizdat, 1962, pp 54-60.

Radiochemical analysis was made of the ratio of asymmetric to symmetric events in Am-241 fission by thermal, fast, and 0.31, 0.58, and 1.27 eV resonance neutrons. The Am-241 nucleus with 5/2 spin forming a compound nucleus in 2⁺ and 3⁺ states and having a sub-barrier are of interest because of the two spin states with different thresholds. The relative yield of Mo-99 in Am-241 fission at various neutron energies were tabulated. The table indicates an increase in the ratio of symmetric-asymmetric fission events in transition from slow to fast neutrons.

449

AN EMPIRICAL FORMULA FOR THE AVERAGE NUMBER OF FISSION NEUTRONS. L. D. Gordeeva and G. N. Smirenkin. *At. Energ. (USSR)*, 14, 530-4 (1963).

Experimental data on the thermal neutron fission of the six odd nuclei Th-229, U-233, U-235, Pu-239, Pu-241, and Am-241 were used to derive an empirical relation. Values of $\bar{\nu}_T$ were computed for the isotopes of Th, Pa, U, Np, Pu, Am, and Cm, and agree within 3 percent of the known experimental values.

B. Spontaneous Fission

450

SPONTANEOUS FISSION. E. Segré. AECD-3149; LADC-975 (1951).

Apparatus and experimental techniques which were

used to measure the SF decay constants and the number of neutrons emitted per fission of Am-241 and other elements are described in detail. Results of these measurements are tabulated.

451

ELECTRON CAPTURE DECAY OF Am-244 AND THE SPONTANEOUS FISSION HALF-LIFE OF Pu-244.

P. R. Fields, J. E. Gindler, A. K. Harkness, M. H. Studier, J. R. Huizenga, and A. M. Friedman. *Phys. Rev.*, 100, 172-3 (1955).

The branching ratio (electron captures/beta particles) of Am-244 was determined as 0.039 ± 0.003 percent.

452

SPONTANEOUS FISSION OF Am-241. V. L. Mikheev, N. K. Skobelev, V. A. Dryin, and G. N. Flerov. *Zhur. Eksptl. i Theoret. Fiz.*, 37, 859-61 (1959).

Measurements on Am-241 were carried out during 160 hr with discrimination threshold of 4 v. Pulses were recorded for spontaneous fission of Am-241, $T_{1/2} = 2 \times 10^{14}$ years. A $T_{1/2}$ value -15 fold higher than that of previous experiments was obtained. The value is $\sim 10^5$ higher than could have been expected for even-even nucleus with given parameter Z^2/A .

453

SPONTANEOUS FISSION OF Am-241. V. A. Druin, V. L. Mikheev, and N. K. Skobelev. *Zhur. Eksptl. i Theoret. Fiz.*, 40, 1261-2 (1961).

A gas scintillation counter filled with Xe was used to measure the spontaneous fission period of Am-241. A value of $(2.3 \pm 0.8) \times 10^{14}$ yr was found to contrast to the previously accepted value of 1.4×10^{13} years.

454

THE FORMATION OF A SPONTANEOUSLY FISSIONING ISOMER IN REACTIONS WITH ALPHA PARTICLES AND DEUTERONS. G. N. Flerov, S. M. Polikanov, K. A. Gavrilov, V. L. Mikheev, V. P. Pereygin, and A. A. Pleve. JINR-P-1299.

The formation of a spontaneously fissioning isomer previously discovered in heavy ion (O, Ne) reactions was observed while bombarding Pu and Am targets by He^4 and deuterium ions. It is concluded that the spontaneously fissioning nucleus has $Z \leq 95$ and mass number ≤ 242 .

455

A SPONTANEOUSLY FISSIONING ISOMER PRODUCED IN REACTIONS WITH CHARGED PARTICLES.

G. N. Flerov, S. M. Polikanov, V. L. Mikheev, V. P. Pereygin, and A. A. Pleve. Proceedings of the Third Conference on Reactions Between Complex Nuclei, U. California Press, 1963, pp 219-22.

A spontaneously fissioning isomer with a 0.014 ± 0.02 sec half-life was produced in alpha-particle reactions with Am-241 and Am-243. Experimental data indicate

an isomeric state of Am-242 whose spontaneous fission probability is greatly increased.

456

THE FORMATION OF SPONTANEOUSLY FISSIONING ISOMER IN THE CAPTURE OF NEUTRONS BY Am.

A. F. Linev, B. N. Markov, A. A. Pleve, and S. M. Polikanov. JINR-D-1963 (1964).

The formation of a spontaneously fissioning isomer ($T_{1/2} = 13.1 \pm 1.0$ msec) was observed during the irradiation of Am-243 with 14 Mev neutrons. The cross section for the reaction is about 1.5×10^{-28} cm². It is believed that an isotope of Am-242 in an isomeric state was spontaneously fissioning.

C. Instruments

457

FISSION AND SPALLATION COMPETITION FROM THE INTERMEDIATE NUCLEI Am-241 AND Np-235. W. M. Gibson (thesis). UCRL-3493 (1956).

This paper contains a discussion of the determination of nucleometer (windowless methane flow proportional counter) counting efficiencies for the electron capture isotopes Am-239, Am-240, and Np-234.

458

SCINTILLATION GAS DETECTOR FOR RECORDING FISSION PRODUCTS. V. F. Gerasimov. *Priborg i Tekh. Eksptl.*, 6, No. 1, 61-4 (1961).

Descriptions are given of the design and characteristics of a scintillation gas detector for recording fission product activities against a 3×10^8 alpha-particle background. The detector was used in determining the cross section of Am-241 fission by mono-energetic neutrons of 0.004 to 0.04 ev.

XXIV. SOURCE PREPARATION

459

NEUTRON YIELDS FROM AMERICIUM-BERYLLIUM ALLOYS. O. J. C. Runnalls and R. R. Boucher. *Nature*, 176, 1019-20 (1955).

Two Am-Be alloys were prepared having atom ratios of 1:263 and 1:14. The respective neutron yields were $2.13 \pm 0.02 \times 10^5$ and $1.57 \pm 0.02 \times 10^5$ n/sec. Methods of alloy preparation and counting techniques are described.

460

NEUTRON YIELDS FROM ACTINIDE-BERYLLIUM ALLOYS. O. J. C. Runnalls and R. R. Boucher. *Can. J. Phys.*, 34, 949-58 (1956).

The neutron yield from the reaction $\text{Be}^3(\alpha, n)\text{C}^{12}$ have been measured for several actinide-beryllium alloys.

Values derived from the measurements on alloys containing Pu-239, Am-241, and Cm-242, are 60 ± 2 , 74 ± 2 , and 112 ± 3 neutrons per 10^6 alphas, respectively, when based on the Chalk River standard Ra-226 - α -Be source. The dependence of the thick target yield, n_{max} , on the alpha-particle energy E , is described by the empirical formula

$$n_{max} = 0.152E^{3.65}$$

neutrons per 10^6 alphas.

461

SNAP PROGRAMS. QUARTERLY PROGRESS REPORT No. 3. APRIL-JUNE (1960). MND-P-3011.

An analysis to determine the helium pressure buildup in Al-Am capsules was conducted. Dose rates were determined for Am slugs before irradiation at distances from slug surface up to one meter. Equations are presented concerning the reaction kinetics involved in the neutron irradiation of Am-241 with the subsequent production of Am-242.

462

THE PREPARATION, PROPERTIES, AND USES OF Am-241, ALPHA, GAMMA, AND NEUTRON SOURCES. J. E. Strain and G. W. Leddicotte. ORNL-3335 (September 6, 1962).

A study was made of the preparation of alpha, gamma, and neutron sources using the long-lived radioisotopes of Am-241. Am-241 decays to Np-237 by alpha emission followed by low-energy gamma emission. The high specific activity of Am-241 (7×10^9 d/m/mg combined with its reasonably long $T_{1/2}$ makes it ideally suited for the preparation of radioactive sources. The chemical and physical properties of Am-241 and physical manipulations involved in fabricating alpha, gamma, and neutron sources are described.

463

AMERICIUM-241 SOURCES FOR ANALYTICAL APPLICATIONS. *Nucleonics*, 20, No. 11, 90 (1962). Am-241 with a $T_{1/2} = 462 \pm 10$ yr and a specific activity of 7.0×10^9 d/m/mg is valuable as a radiation source. The emitted radiations are 5.49-Mev alpha and 0.0597-Mev gamma. Am-241 can be used as high-intensity alpha source, low-energy gamma source, and low-intensity neutron sources using (α, n) reactions of Be or B.

464

NEUTRON SPECTRUM OF AN Am-241 Be(α, n) SOURCE. K. W. Geiger and A. C. K. Hargrove. *Nucl. Phys.*, 53, 204-8 (1964). The neutron energy spectrum of an alloyed Am-241 Be(α, n) source was determined. The spectrum showed

fairly broad maxima at 3.5 and 5 Mev and extends up to 11.5 Mev. The average neutron energy was calculated to be 4.4 Mev.

XXV. ISOTOPE PRODUCTION

465

ISOTOPES OF THE NEW ELEMENT AMERICIUM. L. O. Morgan. AECD-2040 (June 1948).

Am-241 has been produced by action of helium ions on U-238 to form Pu-241 which decays by β^- emission to Am-241. This emits 5.45 Mev α and 60 kev γ . L x-radiation characteristics of Np, $T_{1/2} = 510 \pm 10$ years. Am-242 consists of a 17-hr β^- emitting isomer and a long-lived α emitting isomer. Deuteron bombardment of Pu-239 and helium bombardment of Np-237 produce 12-hr and 50-hr half-lives which are tentatively assigned to Am-239 and Am-238.

466

THE NEW ELEMENT AMERICIUM (AT. No. 95). G. T. Seaborg, R. A. James, and L. O. Morgan. AECD-2185 (January 1948).

The production and characterization of the radiation of several isotopes of the new element 95 are discussed

1. ${}_{94}\text{Pu}^{241} \xrightarrow{\beta^-} {}_{95}\text{Am}^{241}$ $\alpha - 5.45$ Mev $T_{1/2} = 510 \pm 20$ years
2. ${}_{95}\text{Am}^{241} (n, \gamma) {}_{95}\text{Am}^{242}$ $\beta^- - T_{1/2} = 17$ hours α, β
3. ${}_{94}\text{Pu}^{239} (d, 2n) {}_{95}\text{Am}^{239}$ K, α $T_{1/2} = 12$ hours
 ${}_{93}\text{Np}^{237} (\alpha, 2n) {}_{95}\text{Am}^{239}$
4. ${}_{94}\text{Pu}^{239} (d, 3n) {}_{95}\text{Am}^{238}$ K $T_{1/2} = 50$ hours
 ${}_{93}\text{Np}^{237} (\alpha, 3n) {}_{95}\text{Am}^{238}$

467

NUCLEAR PROPERTIES OF TRANSPLUTONIUM ISOTOPE. G. T. Seaborg. AECD-2376 (December 1947).

The radioactive properties of the transplutonium isotopes are discussed and their method of production are presented. At present only two; At. No. 95 and 96 are known. The isotopes found are:

Am - 238, 239, 240, 241, 242, and 243.
Cm - 238, 239, 240, 241, 242, 244, 245, 246, and 247.

468

PREPARATION OF TRANSPLUTONIUM ISOTOPES BY NEUTRON IRRADIATION. A. Ghiorso, R. A. James, L. O. Morgan, and G. T. Seaborg. AECD-2822 (1950).

The preparation of Am-241 and Am-242 by pile neutrons is discussed.

469

THE COMPOSITION OF PLUTONIUM, AMERICIUM, AND CURIUM RESULTING FROM IRRADIATION OF Am-241 IN A HIGH NEUTRON FLUX. P. R. Fields and M. A. Weiss. ANL-WMM-1140 (February 1953). The isotopic composition and the conversion of Am-241 to Cm-242 as a function of time of irradiation in a high neutron flux has been calculated using known cross sections.

470

LIGHT ISOTOPES OF BERKELIUM AND CALIFORNIUM. A. Chetham-Strode, Jr. (thesis). UCRL-3322 (June 1956). Information is presented on the production of Am and Cm target materials and the yields of Bk and Cf isotopes from the He ion bombardment of Am and Cm.

471

TRANS PLUTONIUM ISOTOPE BUILDUP BY NEUTRON IRRADIATION OF PLUTONIUM. F. P. Brauer and H. H. Burley. HW-58596 (1958). Graphs suitable for estimating the Pu and trans-Pu isotopic content of irradiated Pu reactor fuel of various initial isotopic composition are presented. The curves were computed for a neutron flux of 5×10^{13} n/cm²/sec and for irradiation times up to 10 years.

472

STUDIO SULLA PRODUZIONE DE Am-243 E Cm-244 MEDIANTE IRRAGGIAMENTO DI Pu-239 IN REATTORI TERMICI. G. Restelli and E. Segre. *Comitato Nazionale per le Ricerche Nucleari Centro di Studi Nucleari, Ispra*. (December 1960). Calculations are carried out for the amounts of Pu-239, Pu-240, Pu-241, Pu-242, Am-243, and Cm-244 produced by long term irradiation of Pu-239 in thermal reactors with $\phi_{th}^{au} = 5 \times 10^{13}$, 3×10^{14} , and 5×10^{14} n/s/cm². The fission product activities produced in the samples and the shielding requirements are calculated.

473

METHODS OF PREPARATION OF ELEMENT 95. G. T. Seaborg and R. A. James. U.S. Patent 3,044,944 (July 17, 1962). A process of making Am by bombarding Pu or U with neutrons or deuterons and aging then the mass for decay of the Pu formed to Am is described. The Am may then be separated by dissolving the mass in acid and carrier precipitation of the Am, especially on LaF₃, or CeF₃.

XXVI. MISCELLANEOUS

474

LOW-ENERGY GAMMA-RAY SOURCES. R. West. *Nucleonics*, 11, No. 2, 20-3 (1953). The low-energy gamma source from Am-241 was studied with regard to its application to industry medicine and research.

475

EFFECTS OF NUCLEAR STRUCTURE ON THE DEGREE OF ANGULAR ANISOTROPY IN FISSION PROCESSES. A. N. Protopopov and V. P. Eismont. *Zhur. Eksptl. i Teoret. Fiz.*, 36, 1573-4 (1959). A thermodynamic interpretation was attempted for the relation between the degree of angular distribution anisotropy $\sigma(0^\circ)/\sigma(90^\circ)$ and the fissioning nucleus parameter Z^2/A . The temperature of the nuclei in critical deformation state was determined for the 14.3 to 14.8 Mev neutron fission of Th-232, U-238, U-235, U-233, Np-237, Pu-239, and Am-241 and the dependence of $\ln\sigma(0^\circ)/\sigma(90^\circ)$ on $1/T$ was plotted.

476

ON THE ANGULAR ANISOTROPY OF FRAGMENT SEPARATION IN Am-241 FISSION BY 17.4 MEV NEUTRONS. A. N. Protopopov, S. A. Baranov, and V. P. Eismont. *Zhur. Eksptl. i Teoret. Fiz.*, 36, 920-1 (1959). The relative number of fragments distributed in the parallel and perpendicular direction to the dropping neutrons was found and the degree of Am-241 angular anisotropy, considering the center mass motion, angular resolution end effect, and the background of scattered neutrons was determined to be 1.08 ± 0.06 .

477

THE ANGULAR DISTRIBUTION OF PHOTOFISSION FRAGMENTS. A. P. Baerg, R. M. Bartholomew, F. Brown, L. Katz, and S. B. Kowalski. *Can. J. Phys.*, 37, 1418-37 (1959). Angular distribution of photofission fragments relative to the photon beam were measured as a function of maximum bremsstrahlung energy in the range 6 to 20 Mev. The nuclide Am-241 gave an isotropic distribution at all energies studied.

478

PRESSURE-TEMPERATURE-RESISTANCE PROPERTIES OF LANTHANUM, BISMUTH, NEPTUNIUM, PLUTONIUM AND AMERICIUM TO 450°C AND 30kb. D. B. McWhan, P. W. Montgomery, H. D. Stromberg, and G. Jura. UCRL-9808 (1961).

The possibility of pressure induced electronic transitions, such as those in Ce and Cs, is suggested by the electronic configurations of the actinides. The program involved the following: Development of apparatus capable of developing high pressures and temperatures which could allow electrical resistance measurements to be made on milligram quantities of metal.

479

POINT SOURCE TECHNIQUE FOR GAMMA RAY ABSORPTION STUDIES. J. Bubernak, M. S. Lew, and G. M. Matlack. *Anal. Chem.*, 34, 585-6 (1962). A new technique for gamma absorptiometric analysis of solutions with a radioactive source such as Am-241 is reported. The Am is contained as a point source placed in the center of the sample solution. Very little Am is required, about 10^{-8} g; hence, the cost is negligible and radiation hazards are eliminated. Gamma absorption curves for Am, Ca, Hg, Ag, and U are given.

480

SELECTION RULES IN THE ODD-EVEN SHIFT OF CERTAIN NUCLEAR ROTATIONAL BANDS. N. D. Newby, Jr. *Phys. Rev.*, 125, 2063-70 (March 15, 1962). A displacement of energy levels was observed in the $K = 0$ band of odd-odd deformed nuclei. It is shown

that this shift is due to scattering in which the final state is obtained from the initial state by a rotation of 180° . This circumstance provides selection rules on the parts of the n-p residual interaction responsible for the shift. The Wigner component of force cannot contribute to the shift. In certain cases the contribution of all central forces will be strongly damped allowing observation of the tensor-force scattering contribution. Numerical results are presented.

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RADIOISOTOPIC SPACE POWER PROSPECTS AND LIMITATIONS. C. A. Rohrmann and E. D. Sayer. Am. Inst. of Aeronautics and Astronautics, 1964, Paper No. 64-453; CONF-600-28. The properties of Am-241 are reviewed for use in radioisotope heat sources for direct conversion devices.

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CORIOLIS INTERACTIONS IN ODD-ODD NUCLEI: Am-242m ALPHA DECAY. F. Asaro, M. C. Michel, S. G. Thompson, and I. Perlman. UCRL-11379 (1964). Nuclear spectroscopic studies of the alpha decay of Am-242m have led to the identification of new excited states and gamma transitions in Np-238. A number of the gamma intensities were interpreted in terms of Coriolis interactions between states having common neutron and proton quasiparticles and differing in K by 1.

ORGANIZATION SYMBOLS

SYMBOL	FULL TITLE OF ORGANIZATION		
A	Calif. Univ., Berkeley, Radiation Lab.	CRP	National Research Council of Canada, Atomic Energy Project, Chalk River, Ontario.
AE	Aktiebolaget Atomenergi, Stockholm.	CRRP	National Research Council of Canada.
AECD	U.S. Atomic Energy Commission Declassified Document.	CT	University of Chicago, Metallurgical Laboratory.
AECL	Atomic Energy of Canada Ltd., Chalk River, Ontario.	DASA	Defense Atomic Support Agency, Washington, D.C.
AEC-tr	Division of Technical Information Extension, AEC.	DEG-Report	United Kingdom Atomic Energy Authority, Development and Engineering Group, Risley, Lanes, England.
AECU	Division of Technical Information Extension, AEC.	DP	DuPont de Nemours (E. I.) and Co., Wilmington, Del.
AEDC	Arnold Engineering Development Center, Arnold AF Station, Tenn.	ERDL	Engineer Research and Development Labs., Fort Belvoir, Va.
AEEW	United Kingdom Atomic Energy Authority, Research Group, Atomic Energy Establishment, Winfrith, Dorset, England.	EUR	European Atomic Energy Community, Nuclear Research Center, Ispra, Italy.
AERE	United Kingdom Atomic Energy Authority, Atomic Energy Research Establishment, Harwell, Berkshire, England.	EURAEC	United States - Euratom Joint Research and Development Program.
AFSWC	Air Force Special Weapons Center, Kirtland AFB, New Mexico.	GEAP	General Electric Co.
ANL	Argonne National Laboratory, Argonne, Ill.	HW	General Electric Co. Hanford Atomic Products Operation, Richland, Wash.
BC	Calif. Univ., Berkeley, Radiation Lab.	HW-SA	General Electric Co. Hanford Atomic Products Operation, Richland, Wash.
BMI	Battelle Memorial Inst., Columbus, Ohio.	IA	Israel Atomic Energy Commission, Rehovath, Israel.
BNL	Brookhaven National Laboratories, Upton, N. Y.	IDO	Idaho Operations Office, AEC.
CAPE	Division of Technical Information Extension, AEC (to identify engineering materials).	IGO	Gt. Britain, Windscale Works, Sellafield, Cumb., England, Industrial Group Report.
CC	University of Chicago, Metallurgical Laboratory.	IGR	Gt. Britain, Windscale Works, Sellafield, Cumb., England, Industrial Group Report.
CEA	France. Commissariat a-l'Energie Atomique, Paris.	IS	Ames Laboratory, Ames, Iowa.
CEI	National Research Council of Canada, Atomic Energy Project, Chalk River, Ontario.	ISC	Iowa State College, Ames, Iowa.
CF	University of Chicago, Metallurgical Laboratory.	JENER	Joint Establishment for Nuclear Energy Research, Kjeller, Norway.
CF-(yr-mo)	Oak Ridge National Laboratory, Tennessee.	JINR-P	Joint Institute for Nuclear Research, Laboratory of Nuclear Problems, Dubna, USSR
CH	University of Chicago, Metallurgical Laboratory.	JPRS	Joint Publications Research Service, New York.
CI	National Research Council of Canada.	JUL	Kernforschungsanlage, Julich, Germany.
CK	University of Chicago, Metallurgical Laboratory.	K	Carbide and Carbon Chemicals Corp., K-25 Plant, Oak Ridge, Tenn.
CL	University of Chicago, Metallurgical Laboratory.	KAPL	Knolls Atomic Power Lab., Schenectady, N.Y.
CN	University of Chicago, Metallurgical Laboratory.	KFK	Kernreaktor Bau-und Betrieb-Gesellschaft, M.H., Karlsruhe, Germany.
CONF	Serial number assigned to conference cataloged by the AEC Division of Technical Information Extension.	KR	Norway Institutt for Atomenergi, Kjeller.
COO	Chicago Operations Office, AEC.	LA	Los Alamos Scientific Lab., New Mexico.
CRC	National Research Council of Canada, Atomic Energy Project, Chalk River, Ontario.	LADC	Los Alamos Scientific Lab., New Mexico.
CRDC	National Research Council of Canada, Atomic Energy Project, Chalk River, Ontario.	LAMS	Los Alamos Scientific Lab., New Mexico.
		LRL	California Research and Development Co., Livermore Research Lab., Livermore, California.
		LWS	California Research and Development Co., Berkeley, Calif.
		MDDC	Manhattan District, Oak Ridge, Tennessee.

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MLM	Mound Laboratory, Miamisburg, Ohio, operated for USAEC.		
MND	Martin Co., Nuclear Division, Baltimore.	RFP	Rocky Flats Plant - Operated by The Dow Chemical Co. for USAEC.
Mon	Clinton Labs., Oak Ridge, Tennessee.	SCR	Sandia Corp., Albuquerque, N. M.
(Letter)		SCTM	Sandia Corp., Albuquerque, N. M.
N	Argonne National Laboratory, Argonne, Ill.	TID	Division of Technical Information Extension, AEC.
NAA	North American Aviation, Inc., Downey, California.	TRQ- Report	United Kingdom Atomic Energy Authority, Reactor Group, Atomic Energy Research Establishment, Harwell, Berks., England.
NAA-SR	North American Aviation, Inc., Downey, California.	UAC	Argonne National Laboratory, Lemont, Illinois.
NAS	National Academy of Sciences.	UCLA	California Univ., Los Angeles.
NBL	New Brunswick Lab., AEC, N. J.	UCRL	Calif. Univ., Berkeley, Lawrence Radiation Lab.
NDA	Nuclear Development Associates, Inc., White Plains, N. Y.	UK	United Kingdom Atomic Energy Authority, Research Group, Atomic Energy Research Establishment, Harwell, Berks., England.
NP	Division of Technical Information, AEC. Non-AEC Report.	UR	Rochester, N. Y. University.
NRDC	Nuclear Reactor Data Committee, Harwell, Berks, England.	USNRDL	U.S. Naval Radiological Defense Laboratory, San Francisco, Calif.
NUMEC	Nuclear Materials and Equipment Corp., Apollo, Pennsylvania.	WAPD	Westinghouse Electric Corp., Atomic Power Division, Pittsburgh.
NYO	New York Operations Office, AEC.	WASH	Atomic Energy Commission, Washington, D.C.
CRNL	Oak Ridge National Laboratory, Tennessee.	WCAP	Westinghouse Electric Corp., Commercial Atomic Power Activity, Pittsburgh.
ORNL-TM	Oak Ridge National Laboratory, Tennessee.	WSL	United Kingdom Atomic Energy Authority, Windscale Works, Sellafield, Cumb., England.
PAN	Polish Academy of Sciences, Inst. of Nuclear Research, Warsaw.	WT	Assigned to reports to the Scientific Director of Joint AEC-DOD weapons tests.
PG	United Kingdom Atomic Energy Authority, Production Group.		
PGR	United Kingdom Atomic Energy Authority, Production Group.		
RDB(W)	United Kingdom Atomic Energy Authority,		

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