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MASTER

ANNOTATED BIBLIOGRAPHY OF CURIUM

H. W. Miller

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INTRODUCTION

AN annotated bibliography of curium 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. This bibliography is complete to the year 1967.

For the most part, the information contained herein was obtained from the *Nuclear Science Abstracts*. The information given does not necessarily represent an entire summary of the papers presented 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 designated more properly as chemistry or as physics. In instances where a paper is designated as chemistry, it was difficult to decide also if the paper was analytical chemistry or separation and purification chemistry. In such cases the decision was left to the discretion of the author. Problems have been encountered in the spelling of some of the Russian names. This is because of inconsistent transliterations of the Cyrillic alphabet.

Each paper has been abstracted once and placed only in one section. To resolve problems of overlapping areas, a reader must refer to the subject index.

In addition to the two main divisions of chemistry and physics, this report provides also an author index, a subject index, and an index of organization symbols.

SECTION I CHEMISTRY

I. HISTORY

- 1
PLUTONIUM AND OTHER TRANSURANIUM ELEMENTS. G. T. Seaborg. *Chem. Eng. News.*, 24, 358-360, 397 (February 10, 1947).
Brief description of early work done with Np, Pu, Am, and Cm. Curium was found to exist only in the trivalent state. Curium-242 is prepared by an (n, β^-) reaction with americium-241. Curium-240 is produced by bombardment of plutonium-239 with 44-MeV He nuclei, with emission of three neutrons. The half lives of curium-242 and curium-240 were found to be five months and one month, respectively.
- 2
THE TRANSURANIUM ELEMENTS. G. T. Seaborg and E. Segré. *BC-33 Nature*, 159, 863-865 (June 28, 1947).
A discussion is given of the formation, discovery, and identification of Pu, Np, Am, and Cm.
- 3
CHEMISTRY AND METALLURGY OF THE TRANSURANIC ELEMENTS. *NNES, 14A*, G. T. Seaborg; AECD-2375 (ANL-JJK-14A-160) (December 1947). Chapt I, Introduction.
A brief history of element 96 and its isotopes is given along with a survey of the present knowledge of the chemical and physical properties.
- 4
THE TRANSURANIUM ELEMENTS. R. A. James. *Science Counselor*, 11, 92-93 (September 1948).
An account is given of the discovery and naming of Np, Pu, Cm, and Am, and of the necessary changes brought about in the periodic table due to their discovery.
- 5
FIRST ISOLATION OF CURIUM. L. B. Werner and I. Perlman. AECD-3155; UCRL-156 (1951).
The first isolation of Cm in μg quantities from neutron irradiated Am is described. Am and Cm were separated by the use of an ion-exchange resin and the Cm was further purified and isolated as the fluoride and the hydroxide. The absorption spectrum of Cm^{3+} was measured.
- 6
THE CHEMISTRY OF THE ACTINIDE ELEMENTS. J. J. Katz and G. T. Seaborg. London, Methuen and Co., Ltd. (1957), 520p.
The actinides are treated thoroughly, including important literature citations up to the year 1956. Sections of 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.
- 7
THE FIRST ISOLATION OF THE TRANSURANIUM ELEMENTS—A HISTORICAL SURVEY. J. C. Wallmann. *J. Chem. Ed.*, 36, 340-3 (1959).
The history of the isolation which included purification of the element from contaminants and measurement of the property of the elements is given for Pu, Np, Am, Cm, Bk, and Cf.
- 8
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 and presented.
- 9
THE ARTIFICIAL ELEMENTS. R. Dominguez. *Rev. Univ. Madrid*, 12, 479-515 (1963).
Historical aspects and recent developments in the production and separation of artificial elements are reviewed. Techniques for preparation of the following are described: Tc, Pm, Np, Pu, Am, Cm, Bk, Cf, Es, Fm, Md, No, and Lw. Steps and products of fission of uranium-235 are outlined. Principal isotopes of the artificial elements are considered, and various steps in their isolation and purification are discussed.
- 10
CHEMISTRY OF THE ACTINIDE ELEMENTS. B. B. Cunningham. *Ann. Rev. Nucl. Sci.*, 14,

323-46 (1964).

Actinide isotopes discovered since the year 1958 are reported. A brief account is given of the discoveries of elements 99 to 103. Results on the determination on electronic ground state configurations and the spectroscopic and magnetic properties of the actinides is mentioned. Work is reviewed on the preparation and study of Ac, Th, Pa, U, Np, Pu, Am, Cm, Bk, and Cf in the metallic state, and on the extension of basic crystallographic and thermodynamic data on these elements and their compounds.

II. METAL AND ALLOYS

11

THE PREPARATION AND SOME PROPERTIES OF CURIUM METAL. J. C. Wallmann, W. W. T. Crane, and B. B. Cunningham. AECD-2912 (1950).

Cm metal has been prepared on the microgram scale by the reduction of CmF_3 with Ba metal vapors at 1275°C , using a vacuum furnace. The metal is silvery and about as malleable as plutonium. The experimental conditions necessary to produce optimum results are discussed.

12

CHEMISTRY DIVISION QUARTERLY REPORT FOR MARCH, APRIL, AND MAY; UCRL-769 (1950).

Progress is reported on the preparation of curium metal.

13

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.

14

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

15

SOME OF THE PHYSICAL PROPERTIES OF CURIUM AND PROTACTINIUM METALS AND PROTACTINIUM TETRAFLUORIDE. B. M. Bansal (thesis); UCRL-16782 (1966).

The construction and operation of a semi-adiabatic microcalorimeter are discussed. The heat of solution of Cm metal in $1.0M$ HCl at $298.4 \pm 0.2^\circ\text{K}$ was measured and found to be -139.9 ± 1.0 Kcal/mole. This value was combined with available thermodynamic data to calculate the following standard heats of formation at 298°K : Cm^{3+} (aq), -140.6 ± 1.3 ; $\text{CmCl}_3(\text{c})$, -226 ± 1.2 , both in Kcal/mole. The construction and operation of a low temperature magnetic susceptibility apparatus are discussed. The magnetic susceptibility of Cm metal was investigated from room temperature to about liquid He temperature (6 to 8°K). The effective magnetic moment for the metal was found to be 8.03 ± 0.1 Bohr magnetons, indicating the presence of a $5f^7$ configuration in the metal.

III. CRYSTAL STRUCTURE

16

THE FIRST CRYSTALLOGRAPHIC DATA FOR CURIUM COMPOUNDS. L. B. Asprey and F. H. Ellinger; AECD-3627 (1953).

X-ray powder patterns for two Cm compounds, the trifluoride and the oxide, have been obtained. Treatment of CmF_3 with F_2 did not convert it to CmF_4 or higher fluorides. Air ignition of curium oxalate gave a compound having a cubic lattice with a constant expected for Cm_2O_3 rather than CmO_2 .

17

CRYSTAL STRUCTURE AND MELTING POINT ON CURIUM METAL. B. B. Cunningham and J. C. Wallmann; CONF-72-4 (1963).

Curium metal was found to crystallize in a double hexagonal close-packed structure, similar to that of alpha lanthanum. The lattice parameters are $a = 3.496 \pm 0.003 \text{ \AA}$ and $c = 11.331 \pm 0.005 \text{ \AA}$. The melting point of the metal was observed to be $1340 \pm 40^\circ\text{C}$.

18

CRYSTAL STRUCTURES OF THE TRIFLUORIDES, TRICHLORIDES, TRIBROMIDES, AND TRIIODIDES OF AMERICIUM AND CURIUM.

L. B. Asprey, T. K. Keenan, and F. H. Kruse. *Inorg. Chem.*, 4, 985-6 (1965); LA-DC-6975

The previously unreported lattice constants and crystal symmetries of the trifluoride, trichloride, tribromide, and triiodide of Cm are given. Correlations are made between these actinide trihalides and the corresponding lanthanide trihalides. CmF_3 is hexagonal, LaF_3 -type, space group $\text{P6}_3/\text{mmc-D}_{6h}$. CmCl_3 is hexagonal, UCl_3 -type, space group $\text{P6}_3/\text{m-C}_{6h}$. CmBr_3 is orthorhombic, PuBr_3 -type, space group Cmcm-D_{2h}^{17} . CmI_3 is hexagonal, BiI_3 -type, space group R3-C_{3i}^2 . When treated with hydrogen at elevated temperatures no reduction of the Cm trihalides was observed.

IV. MAGNETIC SUSCEPTIBILITY

19

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 molar magnetic susceptibility of CmF_3 has been found to be $-(22,500 \pm 4000) \times 10^{-6}$ cgs units at 295°K and $-(58,000 \pm 6000) \times 10^{-6}$ at 77°K.

The temperatures were probably higher due to the self-heating caused by radioactivity of the isotope curium-242. The susceptibility of CmF_3 is in agreement with that expected theoretically for a $5f^7$ configuration.

20

PARAMAGNETIC RESONANCE SPECTRUM OF CURIUM. P. Fields, A. Friedman, and B. Smaller. *Phys. Rev.*, 105, 757. (1957).

The paramagnetic resonance spectrum of curium in anhydrous lanthanum trichloride was observed at 3-cm wavelength and room temperature.

21

PARAMAGNETIC RESONANCE OF THE TRIPRODUCTIVE CURIUM ION IN ETHYL SULFATE AND TRICHLORIDE CRYSTALS. M. Abraham, B. R. Judd, and H. H. Wickman. *Phys. Rev.*, 130, 611-12 (1963); UCRL-10567.

The paramagnetic resonance of the Cm^{3+} ion was studied by incorporating various amounts of Cm in crystals of lanthanum-ethyl sulfate

and anhydrous LaCl_3 . For the ethylsulfate crystals, a single line was observed at He temperatures, characterized by $g_{11} = 1.925$ and $g_{\perp} = 7.73 \pm 0.02$. A similar line, for which $g_{11} = 1.925 \pm 0.002$ and $g_{\perp} = 7.67 \pm 0.02$, occurs for the trichloride crystals. The Lande g value of the ground level is found to be 1.925.

22

NUCLEAR MAGNETIC RESONANCE STUDIES IN S-STATE IONS. H. H. Wickman (thesis); UCRL-11538 (1964).

The S-state ions Fe^{3+} ($^6\text{S}_{5/2}$), Eu^{2+} ($^8\text{S}_{7/2}$), and Cm^{3+} ($^8\text{S}_{7/2}$) were investigated by means of Mössbauer or electron spin resonance experiments, or both. The paramagnetic resonance of Cm^{3+} was observed in trichloride and ethyl sulfate crystals. The large deviation of Cm^{3+} from s-state behavior was evidence by the anisotropic g values found for this ion in the above crystals. Experiments with Cm^{3+} in the double nitrate lattice are also described.

23

MAGNETIC PROPERTIES OF CURIUM METAL AND ITS COMPOUNDS. M. Sayed A. (thesis); UCRL-11984 (1965).

The magnetic susceptibility of Cm metal was measured from -235 to 250°C. The metal followed the Curie-Weiss law above liquid nitrogen temperature up to the temperature studied. The effective magnetic moment for the metal was found to be 7.99 ± 0.15 indicating the presence of $5f^7$ configuration in the metal. No magnetic transition was observed in the temperature range studied. The magnetic susceptibility of Cm^{3+} in CmF_3 , CmOF , and 5.6M CmF_3 diluted with LaF_3 was measured. The effective moment for Cm^{3+} was found to be 7.65 ± 0.1 Bohr magneton, giving a Landé g factor of 1.93 ± 0.03 pointing toward an appreciable departure from Russel Saunders coupling. The molecular field constant Δ was found to be small and decreasing with increasing magnetic dilution. The following Δ values were found for Cm compounds CmOCl , 23 ± 3 ; $\text{CmF}_3 \cdot \frac{1}{2}\text{H}_2\text{O}$, 5 ± 3 ; and 5.6 M% CmF_3 , 5 ± 3 .

V. ELECTRONIC CONFIGURATION

24

ELECTRONIC STRUCTURE OF THE HEAVIEST ELEMENTS. G. T. Seaborg. AECD-2517; UCRL-100; ANL-JJK-14B-144 (1948).

All available evidence leads to the view that the 5f electron shell is being filled in the heaviest elements giving rise to a transition series which begins with actinium. The evidence for the actinide series is based on the following:

1. Chemical properties
2. Absorption spectra in aqueous solution and in crystals
3. Crystallographic structure data
4. Magnetic susceptibility data
5. Spectroscopic data

The electronic configurations of the ground state of the gaseous atom for each of the elements from Ac to Cm is given

25

SPIN-ORBIT COUPLING CONSTANT AND $\langle r^{-3} \rangle$ IN TRANSURANIC IONS. M. E. Foglio and M. H. L. Pryce. *Mol. Phys.*, 4, 287-90 (1961).

The spin-orbit coupling parameter ζ , the quantum average $\langle r^{-3} \rangle$, and binding energy $-E$ for atomic number $Z = 92, 94, 96$, and net ionic charge approximately 1 and 5, were calculated for the 5f electrons.

26

ELECTROSTATIC ENERGY MATRICES OF THE f^7 CONFIGURATION. W. A. Runciman. *J. Chem. Phys.*, 36, 1481-9 (1962).

The f^7 electrostatic matrices were derived by the methods of Racah and are tabulated. A previous table of spin-orbit matrix elements was corrected and extended, and then used in a further analysis of the spectra of gadolinium salts. Finally, a tentative calculation was made of the energy levels for the corresponding curium salts.

27

LOW LYING LEVELS IN CERTAIN ACTINIDE ATOMS. B. R. Judd. *Phys. Rev.*, 125, 613-25 (1962); UCRL-9779.

Calculations of the ordering and properties of four lowest levels of Cm are given for configurations of the type $5f^n 6d$.

28

ELECTRONIC ENERGY LEVELS OF THE LIGHTER ACTINIDES: U^{3+} , Np^{3+} , Pu^{3+} , Am^{3+} , and Cm^{3+} . W. T. Carnall and B. G. Wybourne. *J. Chem. Phys.*, 40, 3428-33 (1964).

The results of a systematic study of the energy

levels of the light actinides U^{3+} through Cm^{3+} , in various solution media are presented. The actinides were found to show very large departures from Russell-Saunders coupling with spin-orbit constant approximately twice those of the corresponding lanthanides. A pronounced tendency towards jj coupling is noted, and its consequences are discussed.

29

ORBITAL ENERGY DIFFERENCES AND CHEMICAL BONDING IN RARE EARTHS. C. K. Joergensen; CONF-650804-24. Gmelin, AED-CONF-65-208-24 (1966).

The behavior of metallic alloys is discussed and remarks made about the 5f elements. The reluctance of lanthanides to change their oxidation state is related to the repulsion between 4f electrons.

VI. SPECTROSCOPY

A. Absorption

30

THE ISOLATION AND PROPERTIES OF CURIUM. L. B. Werner and I. Perlman; (ANL-JJK-14B-83) (ANL-JJK-129) (1948).

Microgram quantities of curium-242 were isolated from americium-241 which had been exposed to a high neutron flux. Both the emission and absorption spectrum of curium-242 were measured.

31

NEW STUDIES IN THE ISOLATION AND PROPERTIES OF CURIUM. W. W. T. Crane and I. Perlman; AECD-2911 (1950).

Method of preparation and handling pure Cm compounds are described in detail. The absorption spectra of Cm was studied and related to that of gadolinium.

32

CHEMISTRY DIVISION QUARTERLY REPORT, JUNE, JULY, AND AUGUST, 1953; UCRL-2355 (1953).

Progress is reported on the investigation of the absorption spectrum of CmF_3 .

33

TETRAVALENT AMERICIUM AND CURIUM; THE ABSORPTION SPECTRA OF THE TRI- AND TETRAFLUORIDES OF THESE ELEMENTS. L. B. Asprey and T. K. Keenan.

J. Inorg. and Nuclear Chem., 7, 27-31 (1958).
The absorption spectra of Cm^{4+} fluoride and Am^{4+} fluoride have been measured. The spectra was recorded over a region 3500 to 20,000 Å.

34

THE ABSORPTION SPECTRUM OF AQUEOUS CURIUM III. W. T. Carnall, P. R. Fields, D. C. Stewart, and T. K. Keenan. *J. Inorg. and Nuclear Chem.*, 6, 213-16 (1958).

The absorption spectra of Cm^{3+} has been studied in 0.04N HClO_4 , using the isotope curium-244. Three prominent absorption peaks have been discovered at 3754 Å, 3812 Å, and 3965 Å, in addition to absorption in the far ultra-violet. These same peaks are found in HCl , HNO_3 , and H_2SO_4 solutions. The general characteristics of the spectra in these three acids and some general observations on the radiation decomposition of aqueous Cm solutions are reported.

35

A STUDY OF THE COMPLEXES OF CURIUM (III) BY ABSORPTION SPECTROMETRY. W. T. Carnall and P. R. Fields. *J. Am. Chem. Soc.*, 81, 4445-9 (1959).

The absorption spectrum of Cm (III) in HClO_4 , HCl , HNO_3 , and H_2SO_4 in the region 220 to 1400 mμ was studied. The relative complexing of Cm^{3+} in HCl , HNO_3 , and H_2SO_4 is indicated and these results are compared with those for Pu^{3+} and Am^{3+} . Radiation decomposition of the solvent limited the study in concentrated acid solutions.

36

OPTICAL SPECTRA OF TRIPOSITIVE CURIUM-244 IN LANTHANUM TRICHLORIDE. J. B. Gruber, W. R. Cochran, J. G. Conway, and A. T. Nicol. *J. Chem. Phys.*, 45, 1423-7 (1966).

Absorption and emission optical spectra are reported for Cm^{3+} in LaCl_3 between 3000 and 8000 Å. These data are explained in terms of the Racah, spin orbit, and configuration-interaction parameters: $E^0 = 4939.29$, $E^1 = 4621.47$, $E^2 = 17.70$, $E^3 = 399.42$, $\zeta = 2841.66$, $\alpha = 57.08$, $\beta = -4761.60 \text{ cm}^{-1}$, respectively. Crystal field splitting of the ground state $^6S_{7/2}$ was observed.

B. Emission

37

SPECTRAL LINES OF CURIUM FROM 3100 Å TO 4200 Å. J. G. Conway and M. F. Moore; UCRL-78 (1948).

Fifty-four spectral lines of Cm are listed together with estimated intensities. A brief description of the manner of taking the spectra and of measuring the lines is given.

38

THE EMISSION SPECTRUM OF CURIUM. J. G. Conway, M. F. Moore, and W. W. T. Crane; AECD-2917 (1950).

The wavelengths of the most prominent lines in the arc and spark spectra, between 2516 to 5000 Å, of curium have been measured and reported.

39

SUMMARY OF THE RESEARCH PROGRESS MEETING OF JANUARY 25, 1951. B. E. Cushman; UCRL-1131 (1951).

The spectrographic investigation of the emission of Cm is mentioned. The lines identified are listed in tabular form.

40

ISOTOPE SHIFT AND WAVELENGTHS OF THE CURIUM SPECTRUM. J. G. Conway and R. D. McLaughlin; UCRL-3037 (1955).

One hundred eighty-two lines of Cm were recorded, 148 of which had isotope shift. Both positive and negative shifts were found. The magnitude of the shift ranged up to 0.131 cm^{-1} .

41

CHEMISTRY DIVISION QUARTERLY REPORT FOR MARCH, APRIL, MAY, 1965. UCRL-3068 (1955). Nuclear Chemistry

Additional spectral data are presented for curium-242 and curium-244.

42

THE USE OF ELECTRODELESS DISCHARGE LAMPS IN THE ANALYSIS OF ATOMIC SPECTRA. E. F. Worden, R. G. Gutmacher, and J. G. Conway. *Appl. Opt.*, 2, 707-13 (1963); UCRL-7199-T.

The application of electrodeless discharge lamps in obtaining the information necessary for the analysis of the first and second spectra of the actinide and lanthanide elements is discussed.

C. Fluorescence

43

FLUORESCENCE SPECTRA OF URANIUM, NEPTUNIUM, AND CURIUM. J. G. Conway, J. C. Wallmann, B. B. Cunningham and G. V. Shalimoff. *J. Chem. Phys.* 27, 1416-17 (1957).

The absorption fluorescence lines of CmCl_3 in dilute solid solution in a matrix of crystalline LaCl_3 has been studied. Absorption lines in the region 3000 to 8000 Å are listed.

D. Infrared

44

THE VISIBLE AND NEAR-INFRARED ABSORPTION SPECTRA OF SOME TRIVALENT ACTINIDE AND LANTHANIDE ELEMENTS IN DCIO_4 AND IN MOLTEN NITRATE SALTS. W. T. Carnall and P. R. Fields, p.233-47 of "Developments in Applied Spectroscopy. Vol. 1," N. Y. Plenum Press (1962).

Observations of absorption spectra of trivalent actinide and lanthanide ions in LiNO_3 - KNO_3 eutectic at 150°C in the region between 0.36 and 2.5 μ are reported. Transitions to the low-lying excited states were observed in crystals of both actinide and lanthanide elements in the near infrared region (1.3-2.5 μ) and thus should be observable in solution. The bands observed in the infra-red region should prove to be of analytical importance.

VII. SEPARATION AND PURIFICATION

A. Precipitation

45

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 aq. Na_2CO_3 or NaHCO_3 by O_3 or $\text{S}_2\text{O}_8^{2-}$ oxidation of Am. The infra-red 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.

46

SEPARATION OF AMERICIUM FROM CURIUM WITH CALCIUM FLUORIDE. H. Perry Holcomb. *Anal. Chem.*, 36, 2329-32 (1964).

Am(VI) was separated from Cm(III) and other trivalent actinides and lanthanides with a column of CaF_2 . Am(VI) is soluble in fluoride solutions and passes through the column; Cm(III) and other trivalent actinides and lanthanides are not soluble and are retained.

47

ORGANIC COPRECIPITANTS, PART 19, COPRECIPITATION OF CURIUM IN THE FORM OF CHELATES. V. I. Kuznetsov, T. G.

Akimova, and O. P. Eliseeva. pp. 44-9 *Radiokhimicheski Metody Opredeleniya Mikroelementov*, Moscow-Leningrad, Izdatel'stvo Nauka (1965).

The concentration of curium-242 in the form of chelates with organic coprecipitants is described. Curium-242 was determined radiometrically. At pH ~ 4-4.75 Cm precipitated almost quantitatively with arsenazo and crystal violet at dilutions of $1:1 \times 10^{18}$ (2×10^{-8} g/cm in 20,000 ml). Quantitative coprecipitation of Cm with other chelating agents and crystal violet took place at pH ~ 2.5-8.5 (arsenazo II), ~ 1-6 (arsenazo III and 4, 4'-biphenyl-3, 3'-dicarboxylbis [(2-azo)-1, 8-dihydroxy-3, 6-naphthalene disulfonic acid. Reagents having molecules of larger size coprecipitated Cm over a wider pH range than did structurally similar reagents with smaller molecules. Coprecipitations with the precipitate formed by arsenazo and crystal violet at pH 4.5 permits the separation of Cm from Mg present in amounts 10^{11} times as high.

B. Chromatography

48

INVESTIGATION OF THE EXTRACTION CHROMATOGRAPHY OF Am(VI) AND Bk(IV). E. K. Hulet; KR-56 (1963).

Simultaneous elution of Am(VI) and Cm(III) tracers from 0.20 M bis(2-ethylhexyl) orthophosphoric acid (HDEHP) absorbed in a stationary bed of silica resulted in 90 to 92 percent Am extraction. A decontamination factor (DF) from Cm of 1000 was obtained. Non-extractable Cm(III) was quantitatively eluted giving a DF of 10 to 14 from Am.

49

PARTITION CHROMATOGRAPHY OF RARE EARTH AND TRANSURANIUM ELEMENTS IN THE SYSTEM TBHP-TBPP/NITRIC ACID. J. Mikulski, K. A. Gawrilow, and V. Knobloch. *Nukleonika*, 9, 785-94 (1964).

The extractive properties of the lanthanide (Pm, Eu, Tb, Tm) and transuranium (Am, Cm, Cf, Fm, Md) elements were studied in the system TBHP-TBPP/HNO₃ using the method of partition chromatography. The separation coefficients of neighboring rare earth elements are practically constant, amounting to 1.34. For Am and Cm the separation coefficient is 1.25 whereas for the heavier transuranium elements the coefficient is only 1.05.

50

SEPARATION OF AMERICIUM (URIUM) BERKELIUM, AND CALIFORNIUM BY EXTRACTION CHROMATOGRAPHY. J. Kooi, R. Boden, and J. Wijkstra. *J. Inorg. Nucl. Chem.*, 26, 2300-2 (1964).

An extraction chromatography procedure for the separation of Am, Cm, Bk, and Cf is described. The elements are extracted from di-(2-ethylhexyl)orthophosphoric acid (HDEHP). The method avoids the use of oxidizing and/or reducing agents and requires only dilute HCl for elution. Columns with kieselguhr/HDEHP ratios of 8.5 gave sharper elution curves.

51

THE CHROMATOGRAPHIC SEPARATION OF Am-Cm ON PAPER. W. Knoch and H. Lahr. *Radiochim. Acta*, 4, 114 (1965).

A complete separation of Pu(III), Am(III), and Cm(III) on paper impregnated with tri-n-octylamine using ascending chromatography is possible. The eluting agent may be a nitrate salt solution containing a low HNO₃ concentration (3 M LiNO₃ + 0.02 M HNO₃). A decrease of acid concentration below 10⁻³ M would promote hydrolysis.

52

PARTITION CHROMATOGRAPHY OF TRANSURANIUM ELEMENTS IN THE SYSTEM TBHP-TBPP/PERCHLORIC ACID. (PART II). Ya. Mikulski, K. A. Gavrilov, and V. Knobloch. *Nukleonika*, 10, 81-7 (1965).

The extraction properties of the transuranium elements (Am, Cm, Fm, and Md) were studied using the method of partition chromatography

with reversed phases in the system TBHP-TBPP (1:)-HClO₄. The partition and separation coefficients for the pairs of elements Eu-Am, Eu-(Fm,Md), (Fm-Md)-Am, were calculated based on the data obtained from the extraction method and on the maximums of the chromatograms.

53

DEVELOPMENT OF SOME HIGH-SPEED CHROMATOGRAPHIC METHODS. S. Ajuria-Garza. UCRL-16015 (1965).

A thin layer chromatography method was developed using as stationary phase a fine mesh ion exchange resin without any admixtures, thus eliminating the effects due to binding materials. The plates can be developed by the ascending, descending, horizontal, or centrifugal technique. This method has been applied to the separation of americium-241-curium-244.

54

PURIFICATION OF CURIUM-244 AND CALIFORNIUM-250-CALIFORNIUM-252 FOR RADIATION PROPERTY MEASUREMENTS. H. P. Holcomb; DP-962 (1965).

Curium-244 was purified by cation exchange chromatography with ammonium- α -hydroxyisobutyrate as the elutrient. The 8 mg of purified Curium-244 contained only 0.2 wt. percent americium-243 and 1×10^{-7} wt. percent californium-250-californium-252. An additional cycle of cation exchange chromatography with 0.2 mg of the purified curium-244 decreased the americium-243 concentration to 9×10^{-4} wt. percent and the californium-250-californium-252 to $<1 \times 10^{-9}$ wt. percent. α and γ spectra analyses showed the curium-244 to be radiochemically pure.

55

SEPARATION OF AMERICIUM AND CURIUM BY EXTRACTION CHROMATOGRAPHY USING A HIGH-MOLECULAR-WEIGHT QUATERNARY AMMONIUM NITRATE. E. P. Horwitz, K. A. Orlandini, and C. A. A. Bloomquist. *Inorg. Nucl. Chem. Lett.*, 2, 87-91 (1966).

A rapid method for separating Am(III) from Cm(III) by extraction chromatography using a quaternary ammonium nitrate (aliquat-336 nitrate) is described. The activities of eluate fractions were determined by standard scintillation counting techniques. Approximately two hours were required for a complete separation and recovery. Greater than 99 percent

of the Cm and Am were recovered in a radio-chemically pure state.

C. Combined

56

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

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

57

REMOVAL OF FISSION PRODUCTS FROM HIGH-LEVEL RADIOACTIVE WASTE SOLUTIONS. R. E. Blanco and J. T. Roberts; CF-59-1-32 (1959).

Ion exchange, electrolysis, solvent extraction, scavenging, and precipitation have been studied as methods for removing radioactive isotopes from high level wastes. Process development has been limited to laboratory research and small scale engineering tests so that the efficiency of these methods in large scale operations is unknown.

58

TRANSURANIUM STUDIES; ORNL-2993 (1960).

A solvent extraction flow sheet 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 lanthanides were sorbed on Dowex 1-10X resin from a solution of 8 M LiNO₃; the lanthanides were selectively eluted with 10 M LiCl and the Am-Cm with 1 M LiCl.

59

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

60

THE TRANSPLUTONIUM ELEMENTS. (Part) II. W. Kraak. *Atoomenergie Haar Toepassingen*,

5, 1-10 (January 1963)

The chemical separation methods and the properties of the heaviest elements of the periodic system, Am, Cm, Bk, Cf, Es, Fm, and Md are described.

61

TRANSURANIUM ELEMENT PROCESSING; ORNL-3452 (pp. 96-133) (1963).

The Transuranium Processing Plant (TRU) and High Flux Isotope Reactor (HFIR) are being built to produce gram quantities of the heavier actinides. Target material is prepared from Pu-Al alloy irradiated to greater than 99.9 percent burnup of plutonium-239. The irradiations and recovery of plutonium-242 by conventional solvent extraction and anion exchange procedures are being done at Savannah River. Recovery of americium-243 and curium-244 in the raffinate either by anion exchange or tertiary amine extraction from neutral nitrate salts and the final purification of americium-243 and curium-244 is by the Tramex Process (Transuranium Amine Extraction). Fission products are separated from the actinides by the Tramex Process. Subsequently, the actinides are split into an americium-curium fraction and a trans curium fraction by extraction with di-sec-butylphenyl phosphonate.

62

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

Methods of separating Am and Cm from HNO₃ solutions of Mg-ceramic fuel blocks were investigated. The actinides are first separated from the macrocomponent by extraction. The Pu(IV) is extracted using TTA. The subsequent separation of fission rare earths from the Am and Cm was studied by extracting from LiCl solutions using D2EHPA and TDA chloride in different diluents. A chromatographic method of purification is described to separate remaining impurities, mainly lanthanides.

63

RECOVERY OF AMERICIUM AND CURIUM FROM AN IRRADIATED PLUTONIUM "NAPKINRING." I THE PROPOSED PROCESS. M. Givon and M. Zangen. IA-986 (1964).

A process is proposed for recovering Am and Cm from an irradiated Pu "napkin-ring."

64

THE PURIFICATION OF 10 CURIES OF CURIUM-242. E. P. Horowitz, C. A. A. Bloomquist, H. W. Harvey, D. Cohen, and L. J. Basile; ANL-6998 (1965).

Ten curies of curium-242, produced by neutron irradiation of $^{241}\text{AmO}_2$, were processed for high decontamination from capsule material, fission products, and chemical reagents, and for moderate decontamination from Am. The equipment and chemical methods used to process the capsule are described.

65

RESEARCH AND DEVELOPMENT ON AQUEOUS PROCESSING. C. E. Stevenson. *Reactor Fuel Process.*, 9, 16-23 (1965-1966).

The separation of Am and Cm from irradiated Pu is described. Plutonium is recovered and purified in two cycles of TBP solvent extraction. Americium and curium are reclaimed from Pu-process wastes by batch extraction into 50 percent TBP in n-dodecane. The stripped product is concentrated and then purified by three cycles of solvent extraction with tertiary amine (n-octyl and n-decyl) chlorides in diethylbenzene. The separation of Am from Cm in the solvent-extraction product is effected by precipitation of the americium double carbonate $[\text{K}_2\text{AmO}_2(\text{CO}_3)_2]$. The HCl solution of Am and Cm after concentration is added to saturated K_2CO_3 solution to produce concentrations of about 10g each of Am and Cm per liter. Then KOC or $\text{K}_2\text{S}_2\text{O}_8$ is added to oxidize the Am to the pentavalent state, and the americium double carbonate is filtered off after two-hour digestion at 85°C . The separated Cm contained less than 0.5 percent of the Am.

66

QUARTERLY REPORT NO. 6 (ON PHYSICAL CHEMISTRY) APRIL 1-JUNE 30, 1965; ORNL-tr-1240. R. G. Mansfield (1966).

Results and discussions concerning studies of distribution coefficients of Pm, Am, and Cm between aqueous HNO_3 and mixtures of tri-octylphosphine oxide, tridodecylamine, and diethylbenzene are presented along with similar information on U. Data on separation of Am from Cm by ion exchange are included.

67

SIMULTANEOUS SEPARATIONS OF THE ELEMENTS Ra, Pu, U, Am, AND Cm FROM IRRADIATED THORIUM. A. Fleury and G. Simonoff.

Bull. Soc. Chim. No. 1, 251-2 (1966).

A method for the simultaneous separation of the elements Ra, Pu, U, Am, and Cm from irradiated Th in the presence of a large number of isotopes is presented. Anion resin separates the elements into two groups. Group A with Ra, Th, Am, and Cm is not fixed on the resin. Th is eliminated under different conditions on a second anion exchange resin. The extraction of Am-Cm by TBP leaves Ra in the aqueous phase. Group B with Pu and U is fixed on the resin. After elution Pu is extracted by TTA and U by 8-quinolinol. The extraction yield varies from 62 to 84 percent, according to the element extracted.

D. Volatility

68

FRACTIONATION OF FISSION PRODUCTS AND HEAVY ELEMENTS BY VOLATILIZATION METHODS. N. D. Erway and O. C. Simpson; CC-3625 (1956).

A fractionating crucible having a number of collector plates was used to separate long-lived fission product oxides by volatilization methods. The degree of separation of curium-242 from americium-241 was determined by pulse analysis of the α -activities. It was possible to separate Am by this method using a spiral baffle system crucible and collecting the volatilizing activities on a single plate above the crucible orifice.

69

VAPORIZATION OF THE ACTINIDES AND THEIR COMPOUNDS. PART I. BASIC PROBLEMS OF VAPORIZATION STUDIES; (no auth) UJV-1598 (1966).

Individual stages of vaporization studies are discussed including: identification of the gaseous species, formulation of the net reactions, vapor pressure measurements, and study of kinetics and mechanism of vaporization processes. Earlier studies in the field of vaporization of actinide elements (Th, U, Np, Pu, Am, and Cm) are reviewed. The best approximations for temperature dependence of the pressure of mono-atomic vapor, the standard free energy, enthalpy, and entropy of vaporization are presented separately for each actinide metal.

E. Electrolytic

70

THE SEPARATION OF THE LANTHANIDE ELEMENTS AND THE ACTINIDES Am AND Cm WITH

AN AMALGAM CATHODE. R. Thiele (thesis); AED-Diss. 66-7 (1966).

The characteristics of amalgams are reviewed. A separation method of curium-242 from Am using an ion exchanger is described. For electrolytic separations a well defined and constant cathode potential is essential. Optimal separation conditions are discussed. Separation factors up to 10^8 are possible.

F. Electrophoresis

71

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.

72

TRANSPLUTONIDE RESEARCH. A van Dalen, W. Kraak, J. van Ooyen, P. Polak, and J. C. Post; EUR-2640.e, (1965)

Paper electrophoresis in a complexing electrolyte medium was investigated as a method for the separation of Am, Cm, and lanthanides. Results are reported with α -hydroxyisobutyric acid and EDTA as complexing agents. Anion exchange separations of Am and Cm were accomplished in column elution experiments with $\text{Al}(\text{NO}_3)_3$ and $\text{Mg}(\text{NO}_3)_2$ solutions as eluants. Separation factors of 1.8 were obtained. Various techniques for preparing thin and thick layers of U, Np, Pu, Am, and Cm were investigated. These layers are to be used as targets for irradiations.

73

STUDY OF THE BEHAVIOR OF EUROPIUM-152, PROMETHIUM-147, AMERICIUM-241, AND CURIUM-246 IN SODIUM HEXAMETAPHOSPHATE MEDIUM IN PAPER ELECTROPHORESIS AND SEPARATION OF ZIRCONIUM-95 AND CESIUM-134. G. Marcu. *Ser. Chem.* 11, No. 1, 141-5 (1966).

The behavior of europium-152, promethium-147, americium-241, and curium-246 in the form of trivalent ions during paper electrophoresis and in Na hexametaphosphate solution was studied. The complexes formed have remarkable stability between the pH limits of 0.65 to 11.0. The electrophoretic mobility of these compounds in the pH range cited was also determined for the potential difference $\sim 900\text{v}$. On this basis a fast method was formulated for the separation of europium-152, promethium-147, americium-241, and curium-246 from zirconium-95 and cesium-134.

G. Molten Salt

74

DISTRIBUTION OF THE ACTINIDE ELEMENTS IN THE MOLTEN SYSTEM: $\text{KCl-AlCl}_3\text{-Al}$. R. H. Moore and W. L. Lyon; HW-59147 (1959). Data are reported for the distributions of elements 90 through 96 between molten salt solutions of their chlorides and molten Al (or alloy) at 725°C . 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. The pyrochemical processing implications are briefly outlined.

75

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

76

SOLVENT EXTRACTION OF ACTINIDES AND LANTHANIDES FROM MOLTEN SALTS. N. M. Isaac, P. R. Fields, and D. M. Gruen. *J. Inorg. and Nuclear Chem.*, 21, 152-68 (1962). Quantitative measurements were made of distribution coefficients of metal ions between a fused salt phase and an organic phase for the first time. The measurements were made at 150°C using a $\text{LiNO}_3\text{-KNO}_3$ eutectic and tributyl phosphate as the active extractant with a mixture of polyphenols as the inert diluent. Distribution coefficients were determined for Am(III), Cm(III) and others, and found to be higher by a factor of $\sim 10^2\text{-}10^3$ as compared with concentrated aqueous nitrate solutions.

The separation factor of 3.2 for Am(III)/Cm(III) suggests a possible application to separation of these two elements.

77

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

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

78

AMERICIUM-CURIUM SEPARATION. S. Lawroski, J. B. Knighton, and R. K. Steünenberg. 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 were 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.

79

DISTRIBUTION OF TRANSURANIUM ELEMENTS BETWEEN MAGNESIUM CHLORIDE AND ZINC MAGNESIUM ALLOY. J. B. Knighton and R. K. Steünenberg. *J. Inorg. Nucl. Chem.*, 27, 1457-62 (1965).

Distribution coefficients of Np, Pu, Am, Cm, Cf, and Es between molten $MgCl_2$ and liquid Zn-Mg were determined as a function of Mg concentration in the metal phase. Measurements were made at 800°. In general Np, Pu, and Cm tended to favor the metal phase whereas Cf, Es, and to lesser extent Am which tended to favor the salt phase. The distribution coefficients indicated that certain transuranium elements could be separated from one another and from fission products by a sequence of liquid metal molten salt equilibrations. This procedure has the potential advantages of relatively large separation factors and the use of solvents that restrict radiation damage.

H. Carrier Precipitation

80

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

A procedure for the separation of Cm from Am by oxidizing Am with peroxydisulfate is given. The equilibrium constants for the solution of CmF_3 as a neutral trifluoride complex in dilute HF at constant ionic strength of 0.102 N are as follows: $(6.0 \pm 0.2) \times 10^{-6}$ at 0°C, $(1.223 \pm 0.02) \times 10^{-5}$ at 23°C, and $(1.77 \pm 0.4) \times 10^{-5}$ at 47°C. The first dissociation constants at the same temperature are $(1.36 \pm 0.2) \times 10^{-4}$, $(1.250 \pm 0.02) \times 10^{-4}$, and $(4.31 \pm 0.8) \times 10^{-5}$, respectively. The ΔS° solution and ΔS° dissociation were calculated from the equilibrium constants at different temperatures. There was no evidence of the oxidation of Cm under conditions suitable for the preparation of AmO_2 and AmF_4 .

81

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 trivalent americium to the hexavalent state. Fluoride stabilizes the americyl ion during a series of LaF_3 scavenges. Excellent separation of Am tracer is effected from Cm and others.

I. Solvent Extraction

82

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

Progress is reported on the extraction of Am and Cm into butyl phosphate solvents from various aqueous phases. A discussion of a method of separation by means of a butyl phosphate-aqueous citrate system are included.

83

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

Progress is reported on a method for the separation of Am and Cm from the rare earths 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.

84

SEPARATION OF AMERICIUM AND CURIUM FROM AQUEOUS SOLUTIONS. D. F. Peppard and P. R. Gray. U. S. Pat. 2,683,655 (July 13, 1954).

The process comprises contacting an aqueous concentrated nitric acid medium and a substantially water-immiscible alkyl phosphate medium, one of the media containing Am and Cm in solution, whereby Cm values are preferentially held by the alkyl phosphate medium while Am values are preferentially held by the aqueous medium, and separating an alkyl phosphate phase from an aqueous phase.

85

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).

Some variations in the extraction equilibria of the thenoyltrifluoroacetates of the 3+ actinides in toluene aqueous systems were observed. Distribution ratios of Eu, Yb, Ac, Am, Cm, Bk, Cf, 99 and 100 are tabulated. The dependence of the extraction on acid concentration was measured and found to be inversely proportional to the third power of the acid concentration.

86

APPLICATIONS OF PHOSPHORIC ACID ESTERS TO THE ISOLATION OF CETRAIN TRANSPLUTONIDES BY LIQUID-LIQUID EXTRACTION. D. F. Peppard, G. W. Mason, W. J. Driscoll, and S. McCarty. *J. Inorg. and Nuclear Chem.*, 12, 141-8 (1959).

The use of $(\text{GO})_2\text{PO}(\text{OH})$ and $(\text{GO})\text{PO}(\text{OH})_2$ as extractants in a carrier solvent against an opposing aqueous mineral acid phase in effecting certain separations in the trivalent actinide lanthanide series was investigated. The separation of Cf, Es, and Fm from Am and Cm by the use of a di-2-ethylhexyl phosphoric acid-HCl system was achieved. No system readily applicable to the separation of Am and Cm was developed.

87

SEPARATION PROCESS FOR ACTINIDE ELEMENTS AND COMPOUNDS THEREOF. L. B. Werner, I. Perlman, and M. Calvin. U. S. Patent 2,894,805 (July 14, 1959).

This patent deals with the separation of Am and/or Cm salts from La salt contained in an aqueous solution by contacting the latter, after adjustment of the pH to between 2 and 4.8 with a solution of fluorinated *beta*-diketone.

where R is an alkyl, aryl, aralkyl, alkaryl, or heterocyclic radical and R^1 and R^2 are H, or F. The Am and/or Cm salt is selectively extracted as a chelate with the β -diketone. Thorium may also be extracted from Am and Cm by this method.

88

TRANSURANIUM STUDIES; ORNL-2993 (1959). 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% recovery of Am, which contained no detectable amounts of rare earths. Am and Cm were concentrated by extraction into 100% 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%.

89

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. and Nuclear 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.

90

SEPARATION OF THE TRANSPLUTONIUM AND RARE EARTH ELEMENTS BY LIQUID-LIQUID EXTRACTION. R. D. Baybarz and R. E. Leuze. CF-60-3-22 (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 counter-current extraction.

91

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. and Nuclear Chem.*, 19, 314-27 (1961).

Synergic effects noted previously only in the solvent extraction of uranyl 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 for Am being $\text{Am}(\text{TTA})_3\text{S}_2$ where S is a neutral organophosphorus ester varying from trioctyl phosphine oxide with its highly polar phosphorus oxygen bond to the very weakly basic triphenylphosphate.

92

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

The effect of synergistic agents upon the extraction of M(III) lanthanides, Y(III), Am(III), Cm(III), Th(III), and U(VI) by H_2MEHP , mono-2-ethylhexylphosphoric 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.

93

ACIDIC ESTERS OF PHOSPHORIC ACID AS SELECTIVE EXTRACTANTS FOR METALLIC CATIONS. SELECTED M(III) TRACER STUDIES. D. F. Peppard, G. W. Mason, and I.

Hucher. *J. Inorg. and Nuclear Chem.*, 18, 245-58 (1961).

The extraction of Pm(III), Cm(III), and Cf(III) from aqueous mineral acid phases of constant ionic strength into solution of (G'O)(G)PO(OH) in toluene as a carrier diluent was investigated as a function of hydrogen ion concentration in the aqueous phase, extractant concentration in the organic phase and the nature of G, using the radioactive tracer technique.

94

SEPARATION OF TRANSURANIUM ELEMENTS BY PHOSPHONATE EXTRACTION. R. D. Baybarz. *Trans. Am. Nuclear Soc.*, 5, No. 1, 18-19 (1962).

A solvent extraction process for separating Bk, Cf, and Es from Am and Cm was developed and tested on a laboratory scale. The solvent, 2-ethylhexylphenylphosphonic acid in diethyl benzene extracts the heavier transuranium elements from 1.25 N HCl. The separation factor between Cf and Cm is 100.

95

ANALYTICAL EXTRACTION OF NEPTUNIUM USING TRI-ISOOCTYLAMINE AND THENOYL-TRIFLUOROACETONE. R. A. Schneider. *Anal. Chem.* 34, 522-5 (1962); HW-SA-2216

An analytical solvent extraction method for separating Np from Pu, Am, Cm, U, Th, and fission products using triisooctylamine and thenoyl-trifluoroacetone is described.

96

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-ethyl hexylphosphonic 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 Pm were determined. Extraction varied with the inverse third power of the acid composition in the range 1-4 N and directly with the third power of the extractant concentration.

97

SEPARATION OF CALIFORNIUM FROM CURIUM BY SOLVENT EXTRACTION. D. F. Peppard and

G. W. Mason. U. S. Patent 3,034,854 (May 15, 1962).
A process is given for selectively extracting Cf away from Cm present in an aqueous 0.01 to 1 M HCl solution. The extractant is a 0.001 to 1.5 F toluene solution of either 2-ethyl hexyl hydrogen monochloromethyl phosphonate or 2-ethylhexylhydrogenphenyl phosphonate. The Cf can be back-extracted from the phosphonate with a 1 to 6 M mineral acid.

98

EKSTRAKTSIYA FERMIYA I MENDELEVIYA U SYSTEMAKH TBF-HNO₃. E. Gvuzd, K. A. Gavrilov, Ya. Maly, I. Brandshtetr, and Tung-seng Wang; JINR-P-1001 (1962).
The partition ratio of Md, Fm, and Cf, Am, Cm, and Eu by TBF extraction from nitric acid solutions was measured. The obtained results are:

$$D_{Cf} < D_{Eu} < D_{Fm} \leq D_{Md}$$

when

$$4 < D_{Md} < 5.5, 3.5 < D_{Fm}$$

$$< 4.5, \text{ for } 13.1 \text{ M HNO}_3.$$

99

MUTUAL SEPARATION OF CALIFORNIUM AND CURIUM BY EXTRACTION WITH ACIDIC PHOSPHONATES. D. F. Peppard, G. W. Mason, and I. Hucher. pp. 541-54 of "Radioisotopes in the Physical Sciences and Industry." Vol. II. Vienna, International Atomic Energy Agency (1962).

The extraction of Cm(III), Cf(III), and Pm(III) from aqueous mineral acid phases of constant ionic strength into solutions of (G'O) (G)PO(OH) in toluene as carrier diluent was investigated as a function of [H⁺] in the aqueous phase, extractant concentration in the organic phase, and the nature of G, using radioactive tracer techniques.

100

ON THE SYNERGISTIC EFFECT IN SOLVENT EXTRACTION. L. Newman; BNL-6188 (1962).
It is shown that the synergistic effect is a result of addition reactions as well as replacement reactions and is not a function of the metal being extracted. A compilation of equilibrium constants describing the synergistic effect of TBP and TOPO on TTA extractions is given for: Th⁴⁺, UO²⁺, Am³⁺, Cm³⁺, Pm³⁺, Tm³⁺, and Ca²⁺.

101

CHEMISTRY OF LANTHANIDE AND TRANS-PLUTONIUM ELEMENTS; ORNL-3452 (pp. 166-7) (1962).

The extraction of Am(III) was found to be greater than that of Am(VI) by factors greater than 10⁴ with D2EHPA from dilute HNO₃; up to 100 with tri-octylphosphine oxide from LiNO₃; and up to 30 with TBP from NaNO₃. 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).

102

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

The extraction behavior of Am and Eu is studied in a TOPO-HNO₃ system. Only free TOPO extracts Am and/or Eu. From this conclusion the maximal K_d value and corresponding acidity are estimated.

103

ORGANOPHOSPHORUS COMPOUNDS, OTHER THAN TBP, FOR PROCESSING OF IRRADIATED FUELS AND BY-PRODUCTS. T. H. Siddall, III; TID-18299 (1962).

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

104

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)

The Tramex Process for separating transplutonium elements from ionic impurities and fission products including the rare earths, was developed. The process is based on tertiary amine extraction of transplutonium elements from concentrated LiCl solutions. Single stage separation factors between the transplutonium and the lanthanide elements were found to be ≥ 100 . Extraction positions were found to be Cf > Fm > Es > Bk > Am > Cm >> lanthanides. Extraction coefficients were directly proportional to the square of the amine concentration and directly proportional to the 17 power of the LiCl concentration in the aqueous phase, and inversely proportional to the 1.3 to 2.0 power of the acid concentration in the aqueous phase.

- 105
TRANSURANIUM QUARTERLY PROGRESS REPORT FOR PERIOD ENDING AUGUST 31, 1962. D. E. Ferguson, comp; ORNL-3375 (1963). Progress is reported on a solvent extraction process for recovering Am and Cm in nitrate wastes from Pu processing.
- 106
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 thorium from HCl solutions was studied, using a combination of monoacidic phosphate or phosphonate ester (the chelating agent) with a neutral organophosphorus compound (the synergist) at varying concentrations in cyclohexane.
- 107
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 organophosphorus extractants to transuranic separations are described. The H_2MEHP (in toluene) vs. HCl system was used in effecting mutual M(III), M(IV), and M(VI) separations. Systems involving a mono-acidic phosphate, HDGP, or phosphonate, HG[GP], in a diluent vs. an aqueous mineral acid solution proved valuable in effecting the Cf-Cm separation; Cf extracting the better.
- 108
DEVELOPMENT OF CHEMICAL FLOWSHEETS FOR THE OVERALL PROCESS. K. B. Brown and R. E. Leuze; ORNL-3558 (1963). Lithium chloride anion exchange was successfully used to recover and purify Am-Cm containing 22 mg of curium-242 and to separate gram quantities of americium-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 preferential extraction of Cm(III) from Am(VI).
- 109
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 $Al(NO_3)_3$. 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.
- 110
METHODS OF RECOVERY AND SOME CHEMICAL PROPERTIES OF TRANSPLUTONIUM ELEMENTS. E. S. Gureev, V. B. Dedov, S. M. Karpacheva, I. A. Lebedev, I. K. Shvetsov, G. N. Yakovlev, M. N. Ryzhov, and P. S. Trukhloev. (A/CONF.28/P/348) (1964). To produce transplutonium elements for a relatively short time the SM-2 reactor with the 2×10^{15} n/cm²/sec. flux in the central channel was built. Complex formation constants of some transplutonium and rare earth elements with phosphorous-organic compounds, mineral acids, and a number of other compounds were determined. The extraction properties of these elements with neutral and phosphorous-organic acid compounds from water-salt solutions were studied.
- 111
NEW APPROACH TO SEPARATION OF TRI-VALENT 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 or other solvents affords an improved method for their separation from lanthanide elements. The order of decreasing extractability is $Cf > Bk > Am, Cm \gg Yb > Tm > Eu > Pm > Y > Ce > La$.
- 112
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. Weaver and F. A. Kappelmann. ORNL-3559 (1964).

Talspeak is an effective new method for the separation of Am and Cm from the lanthanide elements which does not involve high concentrations of any salt or acid and is resistant to the effects of irradiation. This method is being developed as a possible alternative to the Tramex process currently in use to separate trivalent actinides from lanthanides by extracting with tertiary amine chlorides from concentrated LiCl solutions. The Talspeak process consists in highly preferential complexing of the trivalent actinides by an aminopolyacetic acid, so that the lanthanides and yttrium are much more strongly extracted by a monoacidic organophosphonate or phosphonate. Single stage separation factors between Nd and Am are about 50 in extractions with aromatic hydrocarbon solutions of di(2-ethylhexyl) phosphoric acid (HDEHP) from 1 M solutions of any of several carboxylic acids containing only 0.05 M pentasodium diethylenetriaminepentaacetic acid (Na₅DTPA), at pH 2.5 to 3.5. After adjustment of the lanthanide free aqueous solution to about pH 1.5, the actinides are readily extractible with a dilute solution of HDEHP in a suitable hydrocarbon diluent. The extracted elements may be stripped from the extractant by a dilute mineral acid.

- 113 THE EXTRACTION OF CURIUM AND AMERICIUM BY TRI-N-OCTYL PHOSPHINE OXIDE. K. Watanabe and R. Ono. *J. Nucl. Sci. Technol.*, 1, 75-76 (1964).

The extraction of Cm by tri-*n*-octylphosphine oxide (TOPO) from nitric acid solutions was studied, together with the extraction of Cm, Am, and Eu from NH₄NO₃ solutions. The extraction of Am by 5 percent TOPO from HCl solution was also investigated.

- 114 THE SEPARATION OF CALIFORNIUM FROM CURIUM BY SOLVENT EXTRACTION. D. F. Peppard and G. W. Mason. German Patent 1,166,166 (March 26, 1964).

The separation of trivalent Cf from trivalent Cm when both are present in aqueous HCl is described. The acidity is adjusted between 0.01 and 1 M, and contacted with a solution of 2-ethylhexylhydrogenmonochloromethylphosphonate

or 2-ethylhexylhydrogenphenylphosphonate in an aromatic hydrocarbon or in CCl₄. The trivalent Cf passes over into the organic phase while the trivalent Cm remains in the aqueous phase.

- 115 METHOD FOR SEPARATING TRANSPLUTONIUM ELEMENTS FROM RARE EARTH FISSION PRODUCTS. F. L. Moore. U. S. Patent 3,178,256 (April 13, 1965).

A method of separating Am and Cm values from lanthanide was developed. By this method Am and Cm are extracted with an organic solution of tertiary amine from an aqueous solution containing a high concentration of LiCl. The lanthanides remain in the aqueous phase.

- 116 BEHAVIOR OF THE TRANSPLUTONIUM ELEMENTS IN SOLVENT EXTRACTION SYSTEMS. R. E. Leuze, R. D. Baybarz, F. A. Kappelmann, B. Weaver; ORNL-P-1577 (1965).

Very high activity levels were encountered during the separation of multigram amounts of curium-244-ameridium-243, and curium-242-ameridium-241 from fission products by the Tramex process, in which actinides are extracted into a tertiary amine from concentrated LiCl. Rapid loss of acid and formation of a strong oxidant in the LiCl feed solution were the principal effects of the high activity level. Methanol was added to control acid loss and thus prevent precipitation of Am and Cm hydroxides. Formation of complexes to preferentially suppress actinide extraction is the basis for a proposed method for actinide-lanthanide group separation, Talspeak (Trivalent Actinide-Lanthanide Separation by Phosphorous Reagent Extraction from Aqueous Complexes). Optimum results were obtained by extraction with di(2-ethylhexyl)phosphoric acid from lactic acid solutions containing diethylenetriamine pentaacetic acid. Separations obtained for Am-Cm from the lanthanides approach those given by the Tramex process.

- 117 SEPARATIONS CHEMISTRY RESEARCH; ORNL-3627 (p.177-708) (1965).

New separation methods and reagents are being developed particularly for use in radiochemical processing. The current emphasis is principally

on solvent extraction. Progress is reported in programs of descriptive chemical studies pertinent to existing and potential separations, for development of selected separations into specific complete processes, and of fundamental chemical studies to increase knowledge of the reaction mechanisms and better define their potential applications.

118

DISSOCIATION CONSTANTS OF THE TRANS-PLUTONIUM ELEMENT CHELATES OF DI-ETHYLENETRIAMINEPENTAACETIC ACID (DTPA) AND THE APPLICATION OF THE DTPA CHELATES TO SOLVENT EXTRACTION SEPARATIONS OF TRANSPLUTONIUM ELEMENTS FROM THE LANTHANIDE ELEMENTS. R. D. Baybarz. *J. Inorg. Nucl. Chem.*, 27, 1831-9 (1965); ORNL-P-1016.

The dissociation constants of the DTPA complexes with Am, Cm, Bk, Cf, Es, and Fm were determined by an ion exchange technique and the values obtained are: Am $10^{-22.92}$, Cm $10^{-22.99}$, Bk $10^{-22.79}$, Cf $10^{-22.57}$, Es $10^{-22.62}$, and Fm $10^{-22.70}$. A solvent extraction system was developed to completely separate the transplutonium elements from the lanthanide fission products by extracting the lanthanides into an organophosphonate solution from a carboxylic acid buffered solution of DTPA.

119

PHYSICO-CHEMICAL RESEARCH ON THE TRANSPLUTONIUM ELEMENTS. F. Caligara, Ph. Dreze, G. Duyckaerts, J. Fuger, J. Goffart, and W. Mueller; EUR-2297e (1965).

Results are summarized for the following studies: (1) triaurylamine in HCl medium, (2) extraction of lanthanides and actinides with alkyl phosphine oxides, (3) extraction of lanthanides and actinides with di-n-butylphosphoric acid, and (4) electrochemical studies in molten salts.

120

DI-N-OCTYL PHOSPHINIC ACID AS A SELECTIVE EXTRACTANT FOR METALLIC CATIONS. SELECTED M(III) AND M(VI) TRACER STUDIES. D. F. Peppard, G. W. Mason, and S. Lewis. *J. Inorg. Nucl. Chem.*, 27, 2065-73 (1965). Hydrogen ion dependencies and extractant dependencies of M(III) elements represented by Ce^{+3} , Eu^{+3} , Tm^{+3} , Yb^{+3} , Y^{+3} , Am^{+3} , and Cm^{+3} and of an M(VI) element, UO^{2+} into a benzene solution of di-n-octylphosphinic acid, from an aqueous acidic chloride medium were determined radiometrically.

A plot of $\log K$ vs. Z , in a study involving all of the lanthanides (III) except Gd, showed a slight odd-even effect, the even Z elements lying above a straight line, which acceptably represents the odd- Z elements.

121

LIQUID-LIQUID EXTRACTION OF METAL IONS FROM AQUEOUS SOLUTIONS OF ORGANIC ACIDS WITH HIGH-MOLECULAR-WEIGHT AMINES. THE TRIVALENT ACTINIDE-LANTHANIDE ELEMENTS. F. L. Moore. *Anal. Chem.*, 37, 1235-9 (1965); ORNL-P-1298.

Liquid-liquid extraction systems for trivalent actinide and lanthanide elements are described. High molecular weight amines are excellent extractants for anionic complexes of these elements from aqueous solutions of most organic acids. Liquid-liquid extraction behavior is described for the acid systems, citric, tartaric, oxalic, (ethylenedinitrilo) tetraacetic (EDTA) α -hydroxyisobutyric, and acetic, with various primary, secondary, tertiary, and quaternary amines. In the actinide-lanthanide series the order of decreasing extractability is Am, Cm, Cf, > Eu > Sm > Pm > Ce > Y > Tm. Several potential applications in separations are discussed.

122

QUARTERLY REPORT NO. 7 (ON PHYSICAL CHEMISTRY) JULY 1 - SEPTEMBER 30, 1965; ORNL-tr-1241, R. G. Mansfield (1966).

Research is described on distribution coefficients of Pm, Am, and Cm between aqueous HNO_3 and solutions of trioctylphosphine oxide and dodecylamine in cyclohexane. Discussions of similar investigations are included in which diethyl benzene diluent is used.

123

EXTRACTION OF AMERICIUM-CURIUM-EUROPIUM FROM LITHIUM CHLORIDE-HYDROCHLORIC ACID BY TERTIARY AMINES. J. A. Roth and H. E. Henry. *J. Chem. Eng. Data*, 10, 298-301 (1965). TID-21066.

Phase equilibrium data at 25°C for the system Adogen 364- or Alamine 336-HCl with Am, Cm, or Eu were determined in the presence of LiCl, $SnCl_2$, and $SnCl_4$. The data were combined with data in the literature correlated, and expressed by a mathematical representation for use in analytical investigations of the process.

124

SEPARATION OF BERKELIUM FROM OTHER ELEMENTS. APPLICATION TO PURIFICATION AND RADIOCHEMICAL DETERMINATION OF BERKELIUM. F. L. Moore and W. T. Mullins. *Anal. Chem.*, 37, 687-9 (1965).

A radiochemical method for the purification and determination of Bk tracer is based on a two-cycle-liquid-liquid extraction system. Bk(IV) is extracted into 0.15 M di(2-ethylhexyl)-orthophosphoric acid-heptane from 10 M HNO₃, followed by reduction and stripping into 11.8 M LiCl-0.4 M HCl solution. Thirty percent tricaprylamine-xylene is used in the second cycle to separate Bk(III) from Cm(III).

125

EXTRACTION OF CURIUM AND FERMIUM WITH THENOYLTRIFLUOROACETONE. B. A. Gvozdev, Yu. T. Chuburkov. *Radiokhimiya* 7, 419-23 (1965).

The quantitative extraction of Cm and Fm by solutions of TTA in toluene from acetate solution and solutions of α -hydroxybutyric acid at different concentrations and pH values was studied and the stability constants of the complexes formed were determined. Cm and Fm were simultaneously extracted from a 0.1 M solution of acetate buffer at different pH values. The phases were separated and dried on gold planchets for measurement of the α activity. Cm was also extracted with 0.2 M solution of TTA from 0.1 and 0.4 M solution of α -hydroxyisobutyric acid. The extraction constituents were calculated along with the two phase stability constants ($\beta_2 Q_2$) of Cm and Fm complexes with TTA: $K_{Cm} = (2.2 \pm 0.3) \times 10^{-9}$; $K_{Fm} = (2.6 \pm 1.1) \times 10^{-8}$; $(\beta_2 Q_2)_{Cm} = (2.1 \pm 0.3) \times 10^{15}$; and $(\beta_2 Q_2)_{Fm} = (2.3 \pm 1.0) \times 10^{16}$. Assuming that, in the investigated concentration and pH range, the Cm complex with α -hydroxyisobutyric is of the CmB form a complete stability constant was calculated for this complex, equal to $(2.3 \pm 0.6) \times 10^{-6}$.

126

ISOLATING AMERICIUM AND CURIUM FROM Al(NO₃)-NaNO₃-HNO₃ SOLUTIONS BY BATCH EXTRACTION WITH TRIBUTYL PHOSPHATE. H. E. Henry; DP-972, (1965).

Batch solvent extraction was used to isolate americium-243 and curium-244 from the aqueous solution remaining after dissolution of an irradiated Pu-Al alloy in HNO₃ and the recovery of

the Pu by anion exchange. The solution was adjusted to 6.5-6.8 M in extractable nitrate and 0.10-0.35 M HNO₃ before extracting the Am-Cm with an equal volume of 50 volume percent tri-*n*-butylphosphate in a hydrocarbon diluent and then back extracting into 0.2 M HNO₃. Recovery was greater than 95 percent with up to one liter batches in laboratory tests and with 1500 gal. batches on a plant scale. Factors affecting the degree of extraction were measured in the laboratory.

127

METHOD FOR SEPARATING AMERICIUM AND CURIUM FROM THE LANTHANIDE RARE EARTHS AND YTTRIUM. F. A. Kappelmann, B. S. Weaver. U. S. Patent 3,230,036 (January 18, 1966).

A method of separating Am and Cm from the rare earth fission products by extracting these fission products from an aqueous mixture of an aminopolycarboxylic acid and a water-soluble organic acid with an organic solution of a monoacidic alkyl phosphoric acid, leaving Am and Cm in the aqueous phase is presented.

128

MEASUREMENT OF THE DISTRIBUTION COEFFICIENT OF ACTINIDES AND LANTHANIDES BETWEEN AQUEOUS NITRIC ACID AND SOLUTIONS OF TRI-N-OCTYLPHOSPHINE OXIDE (TOPO) AND TRIAURYLAMINE (TLA) IN DIETHYLBENZENE; SYNERGISTIC EFFECTS. H. Ihle, H. Michael, A. Murrenhoff, CONF-650966-1 (1966).

Coefficients for the distribution of Pu⁴⁺, Am³⁺, Cm³⁺, and Pm³⁺, between aqueous HNO₃ and organic solutions of TOPO and TLA in diethylbenzene were measured as a function of the HNO₃ and LiNO₃ concentration in aqueous phase, the TOPO and TLA concentration in aqueous phase, and the TOPO/TLA concentration in organic phase. The Am/Cm separation factor measured for TLA solutions without an admixture of TOPO was only slightly reduced by a small addition of TOPO, whereas the distribution coefficients could be substantially increased thereby.

129

INVESTIGATION OF THE SOLVENT EXTRACTION OF CALIFORNIUM, FERMIUM, AND MENDELIVIIUM. K. A. Gavrilov, E. Gvuzdz, J. Sary, and W. T. Seng. *Talanta*, 13, 471-6 (1966).

Extraction constants for the systems di-(2-ethylhexyl) orthophosphate|toluene|HCl and Am, Cm, Cf, and Fm were determined.

130

IMPROVED EXTRACTION METHOD FOR ISOLATION OF TRIVALENT ACTINIDE-LANTHANIDE ELEMENTS FROM NITRATE SOLUTIONS. F. L. Moore, *Anal. Chem.*, 38, 510-11 (1966).

The method for liquid-liquid extraction of trivalent actinide-lanthanide elements from relatively dilute solutions of $\text{Al}(\text{NO}_3)_3$ - HNO_3 with a quaternary ammonium salt, tricaprylmethylammonium nitrate (Aliquat 336-S- NO_3) is presented. The effects of the HNO_3 concentration of the extraction efficiency are considered. Extractability of all elements decreases with increasing HNO_3 . The order of decreasing extractability is $\text{Ce} > \text{Am} > \text{Pm} > \text{Cf} > \text{Bk} > \text{Cm} > \text{Eu} > \text{Tm} > \text{Y}$. The trivalent actinide-lanthanide elements are easily stripped from the 30 percent Aliquat 336-S- NO_3 -xylene solution into mineral acid or water.

131

LIQUID-LIQUID EXTRACTION OF CERTAIN TRIPOSITIVE TRANSPLUTONIUM IONS FROM SALTED NITRATE SOLUTIONS WITH A TERTIARY AND QUATERNARY AMINE. E. P. Horowitz, C. A. A. Bloomquist, L. J. Sauro, D. J. Henderson. *J. Inorg. Nucl. Chem.*, 28, 2313-24 (1966).

The distribution coefficients of $\text{Am}(\text{III})$, $\text{Cm}(\text{III})$, and $\text{Cf}(\text{III})$ were measured from Li, Mg, Ca, Al, and $\text{Fe}(\text{III})$ nitrate solutions using a high molecular weight tertiary and quaternary amine. The separation factor for $\text{Cm}(\text{III})/\text{Am}(\text{III})$ was determined for the two amine systems. The quaternary amine was shown to be a superior extractant for the transplutonium(III) ions compared to the tertiary amine.

J. Ion Exchange

132

ISOLATION OF CURIUM. L. B. Werner and I. Perlman; AECD-2148 (BC-74) (August 9, 1947). Curium-242 was prepared by the irradiation of americium-241 in a high flux pile.

Curium was isolated by ultramicrochemical techniques, involving ion-exchange resins. Absorption spectra was obtained and in accord with the actinide hypothesis the Cm like Gd absorbed no light in the visible spectrum due to the stability achieved by the half-filled f orbital. Strong absorption was found in the uv-region but none from 450-1100 mμ.

133

ISOLATION AND PROPERTIES OF CURIUM. L. B. Werner; AECD-2729 (July 28, 1948). The isolation of Cm in relatively pure form is reported. The discovery of a higher oxidation state of Am led to a method of separating Am from Cm. Separation was also accomplished by use of ion exchange resins. Details of the isolation of Cm, the results of spectrographic analysis, specific activity measurements and calorimetric determination of half-life are given. Some physical effects of the radiation from Cm are noted.

134

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, 2 M NH_4NO_3 and various concentrations of HCl, HBr, and HClO_4 in a resin ion exchange column was performed. The pH strongly influenced the time of elution of the Am and Cm with respect to the rare earths. It is suspected that Am and Cm form weak covalent coordination complexes involving large numbers of chloride ions with the covalent complex ion of Am slightly more stable than that of Cm.

135

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

Ion exchange column elution methods for the separation of Am and Cm using tartrate and lactate solutions have been developed. Tartrate solutions are suitable for slow elutions and lactate solutions are satisfactory for rapid separations. The decay schemes of curium-240 and curium-241 were studied.

136

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

137

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

A process is described for separating the actinides from each other and from the lanthanides. The cations to be separated are first adsorbed on a cation-exchange resin such as sulfonated polyvinyl aryl resin and then selectively eluted by strong, 6 to 13.3 M HCl.

138

PRODUCTION OF CURIUM-243. S. G. Thompson, B. B. Cunningham, and A. Ghiorso. U. S. Patent 2,741,627 (April 10, 1956).

Curium isotopes curium-243 may be produced by bombarding $\text{Am}_2^{241}\text{O}_3$ with a 40 MeV beam of α -particles in a cyclotron. The target is dissolved in HNO_3 and then treated with NH_3 to precipitate Am and Cm hydroxides. This is dissolved in K_2CO_3 and treated with NaOCl to remove the Am. The filtrate is treated with KOH to form $\text{Cm}(\text{OH})_3$ and $\text{Am}(\text{OH})_3$ and retreated as above to reduce the Am content. Final purification from Am is made by adsorbing the Cm and the remaining Am on a cation exchange resin and selectively eluting with ammonium citrate.

139

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

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

140

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 tripositive lanthanides and americium and curium from 0.110 M HClO_4 solutions on Dowex-50 cation-exchange resin has been studied at 25°. 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.

141

ION EXCHANGE BEHAVIOR AND DISSOCIATION CONSTANTS OF AMERICIUM, CURIUM, AND CALIFORNIUM COMPLEXES WITH ETHYLENEDIAMINETETRAACETIC ACID. J. Fuger *J. Inorg. and Nuclear Chem.*, 5, 332-8 (1958).

Separation factors between Cf, Cm, and Am on ion 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 Cm and Cf. In the experimental conditions only 1:1 complexes are formed, and by ion exchange techniques, the dissociation constants are found to be equal to: Cf $10^{-19.09 \pm 0.2}$; Cm $10^{-18.45 \pm 0.1}$; Am $10^{-18.16 \pm 0.1}$. Preliminary column experiments show that this complexing agent will be quite useful for separating actinide elements.

142

ANION EXCHANGE SEPARATION OF TRIVALENT ACTINIDES AND LANTHANIDES. M. H. Lloyd and R. E. Leuze; CF-60-3-23 (1960).

A process for separating Am and Cm from lanthanides by anion exchange based on selective chloride complexing was developed. The separation is accomplished by sorption of Am, Cm, and lanthanides on Dowex 1-10X resin from a solution of 8 M LiNO_3 followed by selective elution of lanthanides with 10 M LiCl and Am-Cm elution with 1 M LiCl .

143

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

Sorption of $\text{Am}(\text{III})$ and $\text{Cm}(\text{III})$ on cation resin KU-2 as a function of lactate ion concentration was studied. The results show the presence of

Am Lact²⁺, Am Lact₂⁺, Cm Lact²⁺ and Cm Lact₂⁺.
Instability constants were calculated.

144

TRANSURANIUM DEVELOPMENT FACILITY. B. B. Klima. pp. 27-34 of "Proceedings of the Ninth Conference on Hot Laboratories and Equipment, Chicago, Illinois. November 7-9, 1961." Chicago, American Nuclear Society. (1961).
An alpha-tight transuranium development facility was designed and is being installed in a cell with the objective of studying the chemistry of the recovery of Am and Cm from rare earths and fission products by ion exchange techniques.

145

RAPID AND EFFICIENT PURIFICATION OF AMERICIUM. T. K. Keenan. *J. Inorg. and Nuclear Chem.*, 20, 185-8 (1961).
The thiocyanate-resin system was not effective in purifying curium-244. Even at comparable levels of total α -activity, much more thiocyanate decomposition was observed with Cm than with Am. The specific activity or density of α -radiation is postulated as the controlling factor.

146

DETERMINATION OF COMPOSITION AND STABILITY CONSTANTS OF Am³⁺, Cm³⁺, AND Ce³⁺ RHODANIDE COMPLEXES BY ION EXCHANGE. I. A. Lebedev and G. N. Yakovlev. *Radiokhimiya*, 4, 304-8 (1962).
Sorption of Am³⁺, Cm³⁺, and Ce³⁺ on cation resin at ionic strengths from 0.5 to 5.0 was studied. AmSCN²⁺, Am(SCN)₃, CmSCN²⁺, Cm(SCN)₃, CeSCN²⁺, and Ce(SCN)₃ were prepared and their stability constants calculated. The feasibility of a group separation of trivalent lanthanides and actinides on anionite is discussed.

147

AMERICIUM-CURIUM RECOVERY FROM PLUTONIUM PROCESS WASTES. M. H. Lloyd. *Trans. Am. Nuclear Soc.*, 5, No. 1. 17 (1962).
An anion exchange process for the recovery of Am and Cm from Pu processing raffinates has been developed and tested on a laboratory scale. In the process, Am, Cm, and lanthanide fission products are sorbed from neutral concentrated Al(NO₃)₃ solutions. While the process has general application, it was developed specifically to recover Am and Cm present in highly irradiated Pu-Al alloy which is being processed at Oak Ridge National Laboratory for Pu recovery.

148

ION EXCHANGE BEHAVIOR OF THE TRANSURANIUM ELEMENTS IN LiNO₃ SOLUTIONS. S. Adar, R. K. Sjoblom, R. F. Barnes, P. R. Fields, E. K. Hulet, and H. Wilson; TID-16595 (1962); UAC-6498.

The distribution coefficients of trivalent Pu, Am, Cm, and Cf between LiNO₃ solutions (cont. 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 and 87°C. The separation factor was found to be higher than that obtained with an ammonium alpha-hydroxyisobutyrate-cation column system.

149

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 lanthanides, but in reverse atomic number order. A second power dependence of distribution coefficients on amine concentration was found.

150

ION EXCHANGE STUDIES OF ALPHA-HYDROXYCARBOXYLIC ACID-LANTHANIDE AND ACTINIDE SYSTEMS. G. R. Choppin, D. Moy, and L. W. Holm. p.283-99 of "Radioisotopes in the Physical Sciences and Industry, Vol. III," Vienna International Atomic Energy Agency (1962).

Alpha-hydroxy carboxylic acids have been used extensively for the separation of lanthanides and actinide elements with cation exchange resins. Sorption of these elements in the same solutions occurs on strong base anion-exchange resins. A study was made by elution and equilibrium distribution techniques of the behavior at tracer-level concentrations of these anion-exchange systems. One objective was to measure the separation factors to assess anion exchange as a possible complement to cation exchange separation. A second objective was to attempt to characterize the complexed species by means

of cation and anion exchange data. Glycolic, lactic, and α -hydroxyisobutyric acids were used together with radioactive tracers of lanthanides and Cm.

151

PROCESS FOR SEPARATING AMERICIUM AND CURIUM FROM RARE EARTH ELEMENTS.

R. D. Baybarz and M. H. Lloyd. U. S. Patent 3,079,225 (February 26, 1963).

The invention relates to methods of separating Am and Cm values from rare earth values. Am, Cm, and rare earths values are sorbed on an anion exchange resin. A major portion of the rare earth values are selectively stripped from the resin with a concentrated aqueous solution of LiCl, and Am, Cm, and a minor portion of rare earth values are then stripped from the resin with a dilute aqueous solution of LiCl. The Am and Cm are further purified by increasing the concentration of LiCl in the solution to at least 8 M and selectively extracting the rare earth values from the resulting solution with a mono-alkylphosphoric acid.

152

THE SEPARATION OF CURIUM-242 FROM JRR-1 NEUTRON IRRADIATED AMERICIUM-241 CATION EXCHANGE WITH α -HYDROXY-ISOBUTYRATE. T. Fujino. *Nippon Genshiryoku Gakkaishi*, 5, 640-3 (1963).

The separation was carried out at room temperature by elution with 0.5 M ammonium α -hydroxyisobutyrate of pH 3.68 from a column of 8 percent cross linked Diaion SK No. 1. The flow rate of 1 drop/5 min. was found to give a good separation of curium-242 from americium-241. The separation factor was calculated to be 1.49. Radiochemical purity of Cm fraction was checked by means of the decay curve and α -pulse height analysis.

153

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

An anion exchange process for the recovery of Am, Cm, and Rare Earths contained in the waste effluent from Pu processing was developed and tested on a laboratory scale. In the process waste, which is a solution of Am, Cm, Al, and F. P.'s, in concentrated HNO₃, the feed concentration is adjusted to 2.34 M Al(NO₃)₃. The Am, Cm, and

Rare Earths are sorbed on Dowex-1-10 X resin; Al is washed from the column with 8 M LiNO₃; and the Am, Cm, and Rare Earths are eluted with 0.65 M HNO₃.

154

ION EXCHANGE PROCEDURES: I CATION EXCHANGE IN CONCENTRATED HCl AND HClO₄ SOLUTIONS. F. Nelson, T. Murase, and K. A. Kraus. *J. Chromatog.*, 13, 503-35 (1964).

A broad survey of the cation exchange behavior of the elements in HCl and HClO₄ solutions is presented and adsorption functions are given. Many elements are strongly adsorbed from concentrated HClO₄ solutions. There are large differences in adsorbability between HCl and HClO₄ solutions, particularly at high ionic strength.

155

NITRIC ACID-ORGANIC SOLVENT MIXTURES FOR SEPARATION OF PLUS-THREE ACTINIDES ON ANION RESINS. I. SURVEY OF SOLVENTS.

D. C. Stewart, C. A. A. Bloomquist, and J. P. Faris; ANL-6999 (1965).

More than 60 water-miscible organic solvents were surveyed for use as possible components in mixed solvent-nitric acid elutriants to accomplish transplutonium separations in anion-exchange resin systems. Several solvents for accomplishing such separations were found, nine of which met preliminary criteria established to determine their suitability for hot cell use with high levels of radiation. Americium-curium separation factors superior to those of previously reported systems were found in a number of the solvent mixtures.

156

THE SEPARATION OF AMERICIUM AND CURIUM BY ANION EXCHANGE WITH THE USE OF A SOLUTION CONTAINING A MIXTURE OF METHYL ALCOHOL AND NITRIC ACID AS THE ELUANT.

V. A. Bochkarev and E. N. Voevodin. *Radiokhimiya*, 7, 461-5 (1965); ORNL-tr-893.

The adsorption of Am and Cm on AV-17 and Dowex 1 x 8 anion resins from solution mixtures of CH₃OH and HNO₃ was investigated. The distribution coefficients increased considerably on increasing the HNO₃ concentration from 0.1 to 1.6 M and CH₃OH and HNO₃ are large as compared to those obtained from other more frequently used eluants such as citrate, lactate, and ammonium α -hydroxyisobutyrate.

157

SORPTION OF CURIUM, LANTHANUM, ERBIUM, AND YTTERBIUM FROM LITHIUM CHLORIDE SOLUTIONS BY AV-17 ANION EXCHANGE RESIN. V. A. Bochkarev, A. A. Lbov. *Izdatel'stvo "Nauka"* pp. 190-4 (1965).

The distribution coefficients of La, Yb, and Cm between LiCl solutions and the anion exchange resin AV-17 were determined as a function of the LiCl and HCl concentrations and the temperature. The distribution coefficients of La, Er, Yb, and Cm from LiCl solutions containing ethyl alcohol, were determined. An increase in the percentage of alcohol in the eluent to 15 percent significantly increased the distribution coefficient of Cm and only slightly affected the distribution coefficient of La. The optimum conditions for the separation of trace amounts of Cm and Am were selected: concentration of LiCl 10 M, HCl 0.1 M, ethyl alcohol $\approx$ 15 ml/100 ml sol, and temperature 60°C. For these conditions the distribution coefficient $D_V(\text{Cm})/D_V(\text{La})$ is 35. It was established that the resin AV-17 can be used for the successful separation of trace quantities of the transplutonium and rare earth elements.

158

SORPTION OF CERTAIN TRANSPLUTONIUM IONS ON AMORPHOUS ZIRCONIUM PHOSPHATE. E. P. Horowitz. *J. Inorg Nucl. Chem.*, 28, 1469-78 (1966).

The sorption of tracer concentrations of Am(III), Cm(III), Bk(IV), and Cf(III) on amorphous zirconium phosphate with a PO_4/Zr mole ratio of 1:34 was investigated. The distribution coefficients were investigated at 75°C as a function of time and HNO_3 concentration. Small separation factors were found for ions with the same charge; large separation factors were found for Bk(IV)/Cm(III).

159

ANION EXCHANGE SEPARATION BETWEEN AMERICIUM AND CURIUM AND BETWEEN SEVERAL LANTHANIDE ELEMENTS. W. Kraak and W. A. Van Der Heijden. *J. Inorg. Nucl. Chem.*, 28, 221-4 (1966).

A complete separation between Am and Cm was obtained from an anion-exchange column in concentrated $\text{Al}(\text{NO}_3)_3$ medium. Distribution coefficient for a number of lanthanide elements were determined in batch experiments. The results suggested good separation possibilities for several of the rare earth elements.

160

ANION-EXCHANGE SEPARATION TECHNIQUES WITH METHANOL-WATER SOLUTIONS OF HYDROCHLORIC AND NITRIC ACIDS. R. J. Morrow. *Talanta*, 13, 1265-74 (1966); UCRL-14312. Mixed methanol-water systems were shown to be of use in analysis of samples containing 500 mg amounts of metallic impurities for rare earths and actinides. Detailed study of the $\text{HCl}-\text{CH}_3\text{OH}$ system led to improved separation of Es and Cf from Am and Cm as well as to lanthanide-actinide separations. Comparisons of elution orders are also drawn between these systems and the corresponding lithium salt systems, with emphasis on ion-hydration theories.

161

EFFECT OF TEMPERATURE ON RARE EARTH SEPARATIONS ON CATION RESIN COLUMNS WITH LACTATE. E. Schonfeld, D. C. Stewart. *Radiochim. Acta.*, 5, 176-7 (1966).

A study was made to determine if higher column operating temperatures of the lactate-cation resin system would improve the separation of the individual ions of the rare earths. Data for Cm, Eu, and Tb at temperatures from 24° to 89°C show that when the temperature was increased there was an improvement in the separation of the ions studied.

162

ANION EXCHANGE BEHAVIOR OF THE TRANSPLUTONIUM ELEMENTS WITH ETHYLENE-DIAMINETETRAACETIC ACID. R. D. Baybarz. *J. Inorg. Nucl. Chem.*, 28, 1723-31 (1966); ORNL-P-1466

Transplutonium elements form a single negatively charged complex ion with EDTA. The separation factors of the various complex ion pairs (Fm/Es, 1.90, Es/Cf, 1.42, Cf/Cm, 1.63) in anion exchange resins systems were independent of the complex ion dissociation constant, and appeared to be strongly dependent on its size.

VIII. ANALYTICAL

163

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

An analytical method is described which employs the oxidation of Pu and Np to the (+6) state with $\text{Ce}(\text{SO}_4)_2$ and the subsequent precipitation of

- Am³⁺ and Cm³⁺ with HF. Modifications of this method include using Ce(ClO₄)₄ as the oxidant and dissolution of the precipitate with zirconyl ion and reprecipitation with fluoride. Am may be determined alone by using H₂S₂O₈ as an oxidant.
- 164
COLLECTED RADIOCHEMICAL PROCEDURES. J. W. Barnes, N. A. Bonner, C. I. Browne, D. C. Hoffman, H. A. Potratz, H. L. Smith, B. Warren, and J. Kleinberg; AECD-3674 (1954).
Analytical procedures are presented for the determination of ²³⁰Th, ²³⁷U, ²³⁵U, ²³³Pa, Np, Pu, Am, and Cm in fission product material.
- 165
COLLECTED RADIOCHEMICAL PROCEDURES. J. Kleinberg; LA-1721 (1958).
The properties of the chemical elements are discussed on the basis of electronic configuration. Procedures for the separation from fission product materials and radiochemical determinations of numerous elements including Cm are presented.
- 166
COLLECTED RADIOCHEMICAL PROCEDURES (RADIOCHEMISTRY GROUP J-11). J. Kleinberg, comp; LA-1721 (2nd Ed.) (Rev.) (1958).
Revised and/or added radiochemical procedures are presented which supersede or complement those compiled previously. The procedures concern the determination of Cs, Sb, Sn, Mo, ⁹⁵Zr, ⁹⁷Zr, rare earth elements, U, ²⁴²Cm, and ¹⁴⁴Ce.
- 167
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. Satisfactory measurements of the main isotopic abundances were made.
- 168
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 samples and counting techniques, and a collection of radiochemical procedures are given.
- 169
ANALYTICAL METHOD FOR THE DETERMINATION OF AMERICIUM-241 AND CURIUM-242 IN THE FEED SOLUTION TO THE PRIMARY SEPARATION PLANT; PG-Report-280 (1961).
A portion of the feed solution is mixed with a solution of trioctylphosphine oxide in cyclohexane. Uranium and Pu(IV) are extracted into the solvent phase. Am and Cm are not extracted and are determined by counting the α -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 α -disintegration rate of the feed solution.
- 170
DETERMINATION OF LANTHANUM IN ACTINIDE-LANTHANIDE MIXTURES BY ISOTOPIC DILUTION AND MASS SPECTROMETRY. W. B. Hess and H. P. Holcomb. *Anal. Chem.*, 37, 169-70 (1965).
Isotopic dilution and mass spectrometry were used to determine La in highly radioactive solutions of Am, Cm, and rare earths. A relative standard deviation of ± 1.9 percent was obtained for the analysis of a process sample containing 27.1 g/l of La.
- 171
ISOTOPE DEVELOPMENT; ORNL-3650 (pp. 221-38) (1965).
Research and development are reported on nuclear analysis, application of radioisotopes in analytical chemistry, determination of gamma-emitting nuclides by electronic spectra, the Cm-program, and other topics.
- 172
ARSENazo III. METHODS OF PHOTOMETRIC DETERMINATION OF RARE EARTH AND ACTINIDE ELEMENTS. S. B. Savvin. (Moscow) *Atomizdat* (1966).
A brief review is given of the theoretical and practical aspects of Arsenazo III and its analogs used in determining the lanthanides and actinides. Topics covered include: complexing and color reactions; composition and structure of compounds; and selectivity. Most of the described methods were developed for a certain material, however, with some alterations, they can be used for other types of materials.
- IX. HIGHER VALENCE STATES
- 173
OBSERVATIONS ON CURIUM VALENCE STATES: A RAPID SEPARATION OF AMERICIUM AND

CURIUM. S. E. Stephanou and R. A. Penneman. AECD-3339; LADC-1114 (1952).

No evidence of Cm^{6+} , Cm^{5+} , or Cm^{4+} was found in the oxidation of Cm^{3+} - Am^{3+} mixtures in either acid or alkaline media. The Cm^{3+} - Cm^{6+} couple is probably more negative than -2 volts (the peroxydisulfate-argentic couple). A rapid separation method based on the precipitation of CmF_3 from Am^{6+} was developed. The solubility of CmF_3 was found to be $\sim 12 \mu\text{g/ml}$.

174

EVIDENCE FOR QUADRIVALENT CURIUM. X-RAY DATA ON CURIUM OXIDES. L. B. Asprey, F. H. Ellinger, S. Fried, and W. H. Zachariasen. *J. Am. Chem. Soc.*, 77, 1707-8 (1955).

The preparation of several curium oxides has been carried out and their x-ray lattice constants measured. These unequivocally show the existence of an oxide with a O/Cm ratio more nearly 2/1 than 1.5/1 on the basis of lattice constants.

175

EVIDENCE FOR QUADRIVALENT CURIUM: II CURIUM TETRAFLUORIDE. L. B. Asprey, F. H. Ellinger, S. Fried, and W. H. Zachariasen. *J. Am. Chem. Soc.*, 79, 5825 (1957).

Curium tetrafluoride was made by the treatment of CmF_3 with F_2 at 400°C . The lattice constants and ionic radii of the monoclinic CmF_4 are:

	a_0	b_0	c_0
CmF_4	1245 ± 0.06	10.45 ± 0.05	8.16 ± 0.05
	β	I.R.	
	$126^\circ \pm 30'$	0.88	

The light greenish-tan crystals had a mean refractive index of 1.62.

176

FIRST OBSERVATION OF AQUEOUS TETRA-VALENT CURIUM. T. K. Keenan. *J. Am. Chem. Soc.*, 83, 3719-20 (1961).

Curium tetrafluoride was prepared by treating CmF_3 with F_2 . Addition of the resulting CmF_4 to 15 M NH_4F produced a white CmF_3 from the yellow CmF_4 . Upon addition of CmF_4 to 15 M CsF at 0° , a solution of tetravalent Cm as a fluoride complex is obtained. The spectrum of the compound is discussed.

177

POSSIBLE CURIUM (VI) IN AQUEOUS SOLUTION. J. Akatsu, *Radiochim. Acta*, 4, 58-60 (1965). Am and Cm were oxidized to a higher oxidation state in acetate buffer solution treated with ozone. Both of their k_d values varied inversely as the first-power dependence on the concentration of acetate. It was assumed that both Am and Cm were oxidized to the VI state. In addition to an ion exchange study, a solvent extraction of the ions using a 3-percent solution of amberlite LA-1 in kerosene as an upper layer and an acetate buffer solution as a lower layer was carried out. It was suggested that the increase of k_d values was not brought about by the ion exchange for the extractant used, but by treatment with ozone. It was clear that Cm treated with ozone was absorbed by anion resin or extracted with long chain alkyl amine. It was assumed that this behavior was brought about by the oxidation of Cm to the hexavalent state.

178

THE EXISTENCE OF CURIUM (VI). K. W. Bagnall and J. F. Easey. *Radiochim. Acta*, 5, 180 (1966).

A study was made to determine if solvent extraction and ion exchange results obtained with ozonized solutions of Cm (III) was evidence of oxidation of Cm(III) to Cm(VI). In solvent extraction with di-isooctylamine the absorption spectra of the aqueous phase remained that of Cm(III) throughout the ozonization. Samples of the extractant were examined by the layer chromatography and it was found that di-isooctylamine was completely destroyed by the ozone in aqueous phase. It was concluded that Cm(III) is not oxidized by ozone in aqueous medium.

X. COMPLEXES

179

THE CHLORIDE COMPLEXES OF TRIVALENT PLUTONIUM, AMERICIUM, AND CURIUM.

M. Ward and G. A. Welch. *J. Inorg. and Nuclear Chem.*, 2, 395-402 (1956).

The relative complexing power of the monochloride complexes of the trivalent actinides in concentrated HCl has been shown to be:

This result has been discussed with reference to a theory of *f*-orbital hybridization in the actinides.

180

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

The stability constants of Cm and Am α -hydroxyisobutyrate complexes were determined by means of ion exchange equilibrium measurements on Dowex-50, (four percent resin in the ammonium form). The values obtained for Cm α -hydroxyisobutyrate are $K_1 = 290$, $pK_1 = 2.46$, $K_2 = 93$, $pK_2 = 1.97$, and $K_3 = 9$, $pK_3 = 0.95$. The value for K_1 is probably good to within 10 percent, for K_2 to within 40 percent, and for K_3 to within a factor of 2. The total

$$pK = pK_1 + pK_2 + pK_3 = 5.38.$$

181

STUDY OF AMERICIUM AND CURIUM COMPLEXES WITH α -HYDROXYISOBUTYRIC ACID. V. B. Dedov, M. N. Ryzhov, P. S. Trukhlyaev, and G. N. Yakovlev. *Akademiya Nauk. SSSR. Institut Atomnoi Energii* (1960).

Separation and behavior of Am and Cm Complexes with α -hydroxyisobutyrate were studied. Ion exchange was used in the investigation.

182

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 $AmLact^{2+}$, $Am(Lact)_2^+$, $CmLact^{2+}$, and $Cm(Lact)_2^+$. Instability constants were calculated.

183

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*.

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.

184

COMPLEX FORMATION OF AMERICIUM AND CURIUM WITH α -HYDROXYISOBUTYRIC ACID. V. B. Dedov, I. A. Lebedev, M. N. Ryzhov, P. S. Trukhlyaev, and G. N. Yakovlev. *Radiokhimiya*, 3, 701-5 (1961).

Ion exchange chromatography was used in studies of trivalent actinide separation. The formation of complex $Am(o-But)^{2+}$, $Cm(o-But)_2^+$, and $Am(o-But)_3$ was observed during Cm(III) sorption on KU-2 cations of ammonium α -hydroxyisobutyrate. The stability constants of the complex ions were determined at 0.5 and zero ion strength.

185

NEGATIVE CHELATE COMPLEXES OF LANTHANIDE AND ACTINIDE ELEMENTS. L. W. Holm, G. R. Choppin, and D. Moy. *J. Inorg. and Nuclear Chem.*, 19, 251-61 (1961).

Ion exchange and electrophoretic studies of the glycolic, lactic, and α -hydroxyisobutyric acid-lanthanide and actinide systems show the presence of negative mononuclear complexes in solutions at ligand ion concentrations above 0.1 M. These negative complexes are monovalent with four ligands attached to the central atom.

186

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. $AmSCN^{2+}$, $Am(SCN)_3$, $CmSCN^{2+}$, $Cm(SCN)_3$, and $Ce(SCN)_3$ were prepared and their stability constants calculated. The feasibility of a group separation of trivalent lanthanides and actinides on anionite is discussed.

187

ON THE STABILITY OF THE ACETATE AND GLYCOLATE COMPLEXES OF TRIVALENT CURIUM. I. Grenthe, *Acta Chem. Scand.*, 17, 1814-15 (1963).

The stability constants β_1 for the curium acetate and glycolate complexes were found to be somewhat larger than the β_1 values for the corresponding Am complexes and much larger than those for the gadolinium acetate and glycolate systems. The difference in stability between the lanthanide complex and its corresponding actinide complex is most pronounced for the glycolate systems.

188

THE INVESTIGATION OF COMPLEXES OF AMERICIUM, CURIUM, CALIFORNIUM, AND FERMIUM WITH LACTIC ACID. V. A. Ermakov, I. Stary; JINR-P-2224 (1965).

The extraction constants for americium, curium, californium, and fermium with TTA in benzene were determined. For curium it was determined to be ($\log K_{ex} = -7.84$). The composition and stability constants of the complex of curium ($\log \beta_3 = 5.76$) with lactic acid was determined using the extraction method. With the aid of an ion exchange method the following stability constant for curium was determined: $\beta_3 = 5.78$.

189

THIOCYANATE COMPLEXES OF SOME TRIVALENT LANTHANIDE AND ACTINIDE ELEMENTS. G. R. Choppin and J. Ketels. *J. Inorg. Nucl. Chem.*, 27, 1335-9 (1965).

The stability constants for the formation of $MSCN^{+2}$ and $M(SCN)_2^+$ where $M = Nd(III), Eu(III), Pu(III), Am(III), Cm(III),$ and $Cf(III)$ were determined using the solvent extraction method and an ionic strength of 1.00 M. The enthalpy and entropy values for the formation of $NdSCN^{+2}$ and $AmSCN^{+2}$ indicated that these complexes are outer sphere ion pairs.

190

INVESTIGATION OF COMPLEXES OF CURIUM AND EUROPIUM USING SOLVENT EXTRACTION. I. Stary; JINR-P-2001 (1965).

On the basis of an investigation of the extraction of Cm and Eu with TTA in benzene the extraction constants have been determined ($\log K = -7.30$ for Cm and $\log K = -7.18$ for Eu). Further composition and stability constants were determined for complexes of Cm and Eu with tartaric acid ($\log \beta_2 = 6.84$ for Cm and $\log \beta_2 = 6.79$ for Eu), with oxalic acid ($\log \beta_2 = 8.8$ and $\log \beta_3 = 12.1$ for Cm and Eu); with nitrilotriacetic acid ($\log \beta_2 = 20.13$ for Cm and $\log \beta_2 = 20.42$ for Eu), with EDTA ($\log \beta_1 = 17.10$ for Cm and $\log \beta_1 = 17.34$ for Eu) and with 1,2-diaminocyclohexanetetraacetic acid ($\log \beta_1 = 18.35$ for Cm and $\log \beta_1 = 18.51$ for Eu). From the results obtained, it follows that the stability of complexes of Cm is higher than those of Am, but it is lower than the stability of corresponding complexes of Eu.

191

PAPER ELECTROPHORETIC STUDY OF THE FORMATION OF COMPLEX COMPOUNDS OF EUROPIUM, PROMETHIUM, AMERICIUM AND

CURIUM IN A TARTARIC ACID MEDIUM. G. Marcu, and K. Samochocka. *Stud. Univ. Babes-Bolyai, Ser. Chem.*, 10, No. 2, 71-7 (1965).

The isotope ^{246}Cm and other nuclides, were studied in a tartaric acid medium of about 0.041 M, by paper electrophoresis. The mobilities of the compounds were established for different pH values at a potential difference of 925v. The stability constant of $(CmTart_2)^-$ was found to be $\lg \beta_2 = 7.40$. The instability constant of Cm was found to be $K_{Cm} = 2.51 \times 10^{-9}$.

192

DISSOCIATION CONSTANTS OF THE TRANS-PLUTONIUM ELEMENT CHELATES OF 1,2-DIAMINOCYCLOHEXANETETRAACETIC ACID. R. D. Baybarz. *J. Inorg. Nucl. Chem.*, 28, 1055-61 (1966); ORNL-P-1509.

The dissociation constants of the DCTA complexes with Am, Cm, Bk, Cf, Es, and Fm were determined by an ion exchange technique. The values obtained are: Am, $10^{-18.79}$; Cm, $10^{-18.81}$; Bk, $10^{-19.16}$; Cf, $10^{-19.42}$; Es, $10^{-19.44}$; and Fm, $10^{-19.56}$.

XI. COMPOUNDS

193

SNAP PROGRAMS; TASK 6 - FUEL TECHNOLOGY DEVELOPMENT PROGRAM; (MND-P-3015-III) (1961).

Experimental work on the purification of Cm and procedures for preparing curium carbide is reported.

194

A STRUCTURAL TRANSFORMATION OF CURIUM SESQUIOXIDE. J. C. Wallmann. *J. Inorg. Nucl. Chem.*, 26, 2053-7 (1964).

An additional structure for Cm_2O_3 is reported. Cubic Cm_2O_3 was produced by hydrogen reduction of a higher curium oxide and found to transfer spontaneously after several weeks to hexagonal Cm_2O_3 , of La_2O_3 type structure. The hexagonal structure has lattice parameters of $a = 3.80 \pm 0.02$ and $c = 6.00 \pm 0.03 \text{ \AA}$ and presumably results from radiation damage effects in the crystal lattice.

195

CONCERNING THE SOLID STATE CHEMISTRY OF THE ACTINIDE OXIDES. C. Keller; KFK-225 (1964).

A bibliographic review is made of the solid-state chemistry of the ternary and polynary oxides and

oxide phases of the actinide elements Th, Pa, U, Np, Pu, Am, and Cm. The general and special methods and the analytical procedures used for the study of these compounds were described.

196

MELTING POINTS OF CURIUM AND AMERICIUM OXIDES. R. E. McHenry. *Trans. Am. Nucl. Soc.*, 8, 75-6 (1965).

Data for the melting point of CmO_2 , AmO_2 , and mixtures of CmO_2 - AmO_2 are given. Both CmO_2 and AmO_2 are known to decompose to Cm_2O_3 and Am_2O_3 . CmO_2 is more readily reduced than AmO_2 . Curium oxide was observed to melt at 1950°C . This is believed to be the melting point of CmO_2 formed as a result of the decomposition of Cm_2O_3 .

197

CURIUM OXIDE FABRICATION AND STABILITY. G. R. Cole, P. K. Smith, E. F. Sturcken, and M. C. Thompson. *Trans. Am. Nucl. Soc.*, 8, 49 (1965).

A sintered curium oxide pellet was made, identified as Cm_2O_3 , and was found to be resistant to gross physical deterioration. CmO_2 was pressed and sintered to form a hard, coherent, dark gray cylindrical pellet weighing 15.3 mg with a bulk density of 8.5 g/cm^3 . The oxide was made by calcining curium oxalate at 425°C in air for 3 hours. The CmO_2 was prepressed without any binder at approximately $20,000 \text{ lb/in}^2$ (1406 kg/cm^2), forced through a 20-mesh sieve and re-pressed at $60,000 \text{ lb/in}^2$ (4218 kg/cm^2). The density of the as-pressed pellet was 4.2 g/cm^3 . The crystal system was indexed as cubic with a lattice parameter of $11.160 \text{ \AA}$. No evidence for the presence of hexagonal Cm_2O_3 was found in contrast to the cubic-to-hexagonal transition observed by Wallmann in powdered cubic Cm_2O_3 .

198

THE PRODUCTION OF PLUTONIUM-242 AND CURIUM-242 BY IRRADIATING AMERICIUM-241 WITH NEUTRONS. V. B. Dedov, V. V. Volkov, B. A. Gvozdev, V. A. Ermakov, I. A. Lebedev, V. M. Razbitnoi, P. S. Trukhlyaev, Yu. T. Churburkov, G. N. Yakovlev. *Radiokhimiya*, 7, 453-61 (1965); ORNL-tr-892.

Plutonium-242 and curium-242 are isolated from neutron-irradiated americium-241 by means of solvent extraction and ion exchange techniques. The properties of a number of solid Cm compounds (oxide, hydroxide, carbonate, oxalate, and double sulfates with potassium) are described.

Some of the solubilities recorded are: Cm_2O_3 , soluble in 1 M HCl ; $\text{Cm}(\text{OH})_3$, solubility 10 mg/l ; $\text{Cm}_2(\text{CO}_3)_3$, 13.2 mg/l and completely soluble in 40 percent K_2CO_3 ; $\text{Cm}_2(\text{C}_2\text{O}_4)_3$, solubility 22 mg/l ; $\text{K}_2\text{SO}_4 \cdot \text{Cm}_2(\text{SO}_4)_3$ solubility $10\text{-}20 \text{ mg/l}$. All solubilities recorded under conditions of preparation.

199

MELTING POINTS OF CURIUM AND AMERICIUM TRIFLUORIDES. J. L. Burnett. *Trans. Amer. Nucl. Soc.*, 8, 335 (1965).

CmF_3 was prepared by two methods; in the first, the oxide was reacted with $\text{NH}_4\text{F} \cdot \text{HF}$ and in the second, $\text{CmF}_3 \cdot x\text{H}_2\text{O}$ was precipitated from solution and subsequently reacted with $\text{NH}_4\text{F} \cdot \text{HF}$. The dry powder was pressed into pellets that were heated on a molybdenum support in a carbon-element resistance furnace under a low He pressure. Temperature measurements with an optical pyrometer gave a melting point of $1406^\circ \pm 20^\circ\text{C}$ for CmF_3 .

200

ON THE KNOWLEDGE OF CURIUM (III) PHOSPHATES. F. Weigel and H. Haug. *Radio Chim. Acta.*, 4, 227-8 (1965).

The elementary cell of CmPO_4 was determined. The lattice constants $a = 6.72$, $b = 6.93$, and $c = 6.37 \text{ \AA}$ with $\beta = 104^\circ 6' 30''$ were determined. The volume of the elementary cell was calculated as $v = 287.7 \text{ \AA}^3$, with a density of $\rho = 7.83 \text{ g/cm}^3$. The experimental techniques are described.

201

PREPARATION, LATTICE CONSTANTS, AND CHEMICAL PROPERTIES OF SOME TERNARY OXIDES OF PLUTONIUM, AMERICIUM, AND CURIUM OF THE TYPE $\text{Me}^{\text{III}}\text{X}^{\text{V}}\text{O}_4$. C. Keller and K. H. Walter. *J. Inorg. Nucl. Chem.*, 27, 1253-60 (1965).

The following compounds of Cm could be obtained by precipitation or solid state reactions: CmPO_4 , CePO_4 structure, and $(\text{Cm}_{0.5}\text{Pa}_{0.5})\text{O}_2$ (CaF_2 structure). These compounds are isotypic with the compounds of rare earth elements having the same ionic radius. Reaction conditions, chemical properties, and lattice constants of these compounds are discussed.

202

MELTING POINTS OF CmF_3 AND AmF_3 . J. L. Burnett. *J. Inorg. Nucl. Chem.*, 28, 2454-6 (1966). The melting points of $^{244}\text{CmF}_3$ and $^{241}\text{AmF}_3$ were determined. The average value for CmF_3 was $1406 \pm 20^\circ\text{C}$ and for AmF_3 was $1393 \pm 20^\circ\text{C}$.

203

COMPOUNDS OF TRIVALENT PLUTONIUM, AMERICIUM, AND CURIUM WITH 8-HYDROXY-QUINOLINE AND SOME OF ITS DERIVATIVES.

C. Keller, S. H. Eberle, K. Mosdzelewski.

Radiochim. Acta., 5, 185-8 (1966).

Solutions of 8-hydroxyquinoline in CHCl_3 extract the compounds $\text{Am}(\text{oxine})_3$, $\text{Cm}(\text{oxine})_3$, and $\text{Am}(5,7\text{-dichloro-oxine})_3$ into the organic phase, Y probably being OH^- . The overall stability constant of $\text{Am}(5,7\text{-dichloro-oxine})_3$ is $\log \beta = 21.93$ at $T = 25.0^\circ \pm 0.5^\circ\text{C}$ and $\mu = 0.1$.

204

CHEMISTRY. I. Perlman, J. M. Hollander, F. Reynolds, B. B. Cunningham; UCRL-16580 (1966).

Research progress is reported on CmCl_3 crystal structure, heat of formation, and curium heat of solution.

XII. GENERAL CHEMISTRY

205

ACTINIDE SERIES OF CHEMICAL ELEMENTS.

T. J. Hardwick. Proceedings of the Nuclear Conference on Nuclear Chemistry. Chemical Institute of Canada 44-50 (1947).

It is proposed that the actinide elements presently found in Group III A through Group VIII should be reclassified either as another period or as a second rare earth group with electrons filling the 5f orbital. The chemical and physical properties of the transuranic elements Np, Pu, Am, and Cm are discussed.

206

THE TRACER CHEMISTRY OF AMERICIUM AND CURIUM. S. G. Thompson, R. A. James, and L. O. Morgan. (ANL-JJK-14B-84) December 1947; (ANL-JJK-122) January 1948.

The investigation of the chemical properties of element 96 (Cm) by means of tracer techniques has led to the conclusions that Cm is predominantly trivalent, exhibits a high degree of similarity to the lanthanide, and that it is a member of an "actinide series" of elements.

207

FISSION OF ATOMIC NUCLEI. PART I. TRANSURANIUM ELEMENTS. B. C.

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

The isotopes of Cm are discussed and a table

of nuclear reactions and isotope properties for elements of atomic number 92-97 is given. The techniques of ultramicro-chemistry are summarized. The author concludes with a discussion of the electronic structure of the actinide series.

208

CHEMISTRY DIVISION QUARTERLY REPORT FOR JUNE, JULY, AND AUGUST, 1950; UCRL-923 (1950).

Progress is reported in the chemistry of the lanthanide and actinide elements and nuclear properties and transformations.

209

SOME PHYSICAL AND CHEMICAL PROPERTIES OF CURIUM. W. W. T. Crane (thesis). AECD-3161; UCRL-1220 (1951).

Improved methods of isolating Cm are outlined. The absorption spectra of Cm^{3+} is given as well as most of the prominent lines in the arc and spark spectra. The method of production of Cm metal is outlined and the density is reported as 7. The molar magnetic susceptibility of CmF_3 is reported at 296°K .

210

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

The actinide elements are treated thoroughly, including important literature citations up to 1956. Information is given on history, isotopes, occurrence and isolation, and properties of compounds.

211

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 (1958). Advances in the chemistry of Am and Cm include the discovery and isolation of new valence states, the characterization of metals and compounds and a discussion of solid-phase studies of Am and Cm.

212

RECENT RESEARCH ON TRANSPLUTONIUM ELEMENTS. S. G. Thompson; UCRL-8683 (1959).

Work which is being done on very heavy elements is described. The subject matter includes, production of isotopes, their chemical properties, and studies of nuclear properties. The elements discussed include Am, Cm, Bk, and Cf.

213

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

The chemistry of Am and Cm is discussed, and methods for producing these elements are reviewed. It has not been possible to obtain any oxidation state other than (III) for Cm in solution, although a (IV) state can exist in the solid. The use of curium-244 has made possible discoveries in the chemistry of Cm which would not have been possible if the curium-242 isotope had been used.

214

THE FLUORIDES OF THE ACTINIDE ELEMENTS.

N. Hodge., p. 138-82 of *Advances in Fluorine Chemistry*, Vol 2, London, Butterworths (1961).

Both horizontal and vertical relationships between the actinide fluorides are described. Preparative procedures, physical properties, chemical properties, and complex compounds are discussed.

215

NEW TREATISE ON INORGANIC CHEMISTRY. VOL XV, URANIUM AND TRANSURANIC ELEMENTS. PART 3., TRANSURANIC ELEMENTS.

P. Pascal. ed. Paris, Masson et Cie, 1962.

A brief introduction to the chemistry of the radioactive elements is given and the naturally radioactive and transuranium elements are discussed. The separation, purification, preparation of compounds, systems, and properties of Np, Pu, Am, and Cm are then surveyed.

216

THE HEAVIEST ELEMENTS CURIUM AND TRANSCURIUM ELEMENTS. M. Taube,

Wiadmosci Chemi, 17, 69-90 (1963).

A survey of the chemical and nuclear properties of curium and transcurium elements was made and the possibility of synthesizing transnobelium elements is discussed.

217

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

A brief summary is given of the recent developments in the inorganic 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(VI) and Cm(IV) in solutions.

218

NEPTUNIUM, PLUTONIUM, AND TRANSURANIUM ELEMENTS. *Nature*, No. 3340, 336-7 (1963).

(No author)

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

219

RESEARCH LABORATORIES SEMI-ANNUAL REPORT, JULY-DECEMBER, 1964; (no author) IA-1021 (1964).

Research is reported on molten salt chemistry, chemistry of actinides and rare earths, and solution chemistry.

220

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

The transuranium elements place in the periodic classification is described as are their various valency states. Oxides and other compounds are listed. Radioactive hazards in working with the transuranium elements are discussed and methods of handling indicated.

221

ELEMENT 96 AND COMPOSITIONS THEREOF.

G. T. Seaborg. U. S. Patent 3,161,462 (December 15, 1964)

The element having atomic number 96, known as Cm, to certain compounds of Cm, and methods for producing curium and for separating Cm from solutions thereof are discussed.

222

PREPARATION AND ROENTGENOGRAPHIC STUDY OF HIGHLY RADIOACTIVE MATERIALS.

F. Weigel (thesis); NP-15826 (1965).

Information is given on: methods and techniques used in the separation of plutonium-238 and americium-241; properties of Am compounds, isolation of Cm in microquantities; Cm precipitation as the phosphate and determination by its x-ray pattern; and CmPO₄ crystallization in the monoclinic form.

223

CHEMICAL PROPERTIES OF ELEMENT 104.

I. Zvara, Yu. T. Chuburkov, R. Caletka, T. S. Zvarova, M. R. Shalayevsky, B. V. Shilov; JINR-D-2710 (1966).

Using the method of rapid continuous separation

of the elements of subgroups III B and IV B, the properties of Cm, Cf, Hf, and $^{260}\text{104}$ chlorides were compared. It was found that the chemical properties of element 104 are close to Hf.

XIII. ELECTROCHEMISTRY

224

ELECTROLYTIC PRECIPITATION OF AMERICIUM AND CURIUM FROM THEIR AQUEOUS SOLUTIONS ONTO A PLATINUM CATHODE. A. G. Samartseva. *Radiokhimiya*, 4, 696-700 (1962).

The problem of electrolytic separation of Am and Cm from their aqueous solution was investigated; the study developed into a quantitative electrolytic separation method for the two elements. The HNO_3 solution contained 1.4×10^{-10} M ^{241}Am and 10^{-13} M ^{242}Cm . A small Pt cup served as anode, while the Pt strip cathode with a surface of 1 cm^2 was rotated. The element was deposited simultaneously on both surfaces of the cathode. The electrolysis of the solution resulted in the quantitative deposition of Am at pH = 1.3 to 4.3 and of Cm at pH 1.3 to 3.0; the differential behavior is due to the hydrolysis of Cm which starts at lower pH values than Am. A deposition yield of 100 percent was obtained for both elements at current density of 500 milliamp/ cm^2 . HNO_3 favors the complete separation of the two elements.

225

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.

226

ELECTROPHORETIC SEPARATION OF SOME ACTINIDE AND LANTHANIDE ELEMENTS.

W. Kraak and G. D. Wals. *J. Chromatog.*, 20, 197-201 (1965).

The potentialities of the electrophoretic method for separation of actinide and lanthanide elements were studied. All of the elements studied were radioactive and were used in tracer concentration. They were americium-241, curium-244, and others. After completion of electrophoresis, the paper strips were cut into sections of 0.5 cm and counted for relative activities.

227

ON THE FORMATION OF COMPLEX COMBINATIONS OF AMERICIUM-241 AND CURIUM-246 IN CITRIC ACID MEDIA BY ELECTROPHORESIS ON PAPER.

G. Marcee and K. Samochocka. *Ser. Chem.*, 11, No. 1, 15-20 (1966).

The formation of Am and Cm complexes in citric acid medium ~ 0.04 M, by electrophoresis on Whatman paper No. 4 was studied. The constants of stability in the case of $[\text{AmCit}_2]^{-3}$ and $[\text{CmCit}_2]^{-3}$ compounds $\lg\beta_2(\text{Am}) = 9.66$ and $\lg\beta_2(\text{Cm}) = 10.26$, were determined after establishing the electrophoretic mobilities of these compounds at various pH values for the potential difference of $\sim 925\text{v}$. The existence in the solution of the ions of $[\text{CmCit}_2]^{-3}$ form was deduced from the behavior of Cm which resembles Am. The instability constants, $K_{\text{Am}} = 4.5 \times 10^{-11}$ and $K_{\text{Cm}} = 1.82 \times 10^{-12}$ were calculated.

XIV. SOURCE PREPARATION

228

ELECTRODEPOSITION OF THE ACTINIDE ELEMENTS. R. Ko; HW-41025 (1956).

Thorium, U, Np, Pu, Am, and Cm have been deposited at metal cathodes by the electrolytic formation of bases. The electrolyses have been made in various acid solutions containing ammonium formate. The presence of formate reduces hydrogen ion formation at the anode and makes the quantitative precipitation of the metal hydroxides at the cathode possible.

229

THE PREPARATION OF THIN FILMS OF PLUTONIUM, AMERICIUM, AND CURIUM BY AN ELECTROLYTIC METHOD. G. N. Yakovlev, P. M. Chulkov, V. B. Dedov, V. N. Kosyakov, and Y. P. Sobolev. *J. Nuclear Energy*, 5, No. 1, 159-61 (1957).

Methods for quantitative electrodeposition 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.

230

ELECTRODEPOSITION OF ACTINIDE ELEMENTS AT TRACER CONCENTRATIONS. R. F. Mitchell. *Anal. Chem.*, 32, 326-8 (1960).

The electrodeposition of the actinides from an electrolyte of $\text{NH}_4\text{Cl-HCl}$ is a rapid method for recovering trace concentrations of these elements in high yields. The deposits are adherent and uniform over the plate area. The effect of current density, pH of electrolyte, salt concentration, volume of electrolyte, and the time of plating by electrodeposition are discussed.

231

THE RADIOACTIVE, INDEPENDENT TRANSDUCER-RECEIVER (RIT-R) SYSTEM; AGN-3027-15 (1960).

Fabrication techniques and experimental results for electrodeposition of the curium-242 sources used in the radioactive transducer are presented.

232

PREPARATION OF THIN ELECTRODEPOSITS OF ACTINIDES FROM AQUEOUS SOLUTIONS OF ETHYLENEDIAMINETETRAACETIC ACID.

J. Fuger. *Bull. Soc. Chim. Belges*, 71, 134-41 (1962).

A cathodic electrodeposition of several actinide elements from aqueous solutions of EDTA partially neutralized with ammonia is studied. On platinum cathodes, the deposited films are thin, adherent, and reasonably uniform. A yield of 90 to 95 percent can be achieved under suitable conditions.

233

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. Addition of uranium as the carrier for actinides of high specific activity was necessary for quantitative electrodeposition. A recovery of 99.8 percent was obtained in a detailed study with Pu solutions. This technique was also found to improve the electrodeposition

yields of Np, Am, and Cm. The quality of the deposits permitted α -counting with a relative standard deviation of ± 0.2 percent.

234

EVAPORATION OF THIN METALLIC SAMPLES INDUCED BY FISSION FRAGMENTS. V. K. Gorshkov, L. N. L'vov. *At. Energ. (USSR)*, 20, 327-30 (1966).

It was shown that thin sources prepared from salts containing curium-242 and curium-244 evaporated under the action of fission fragments. The fragments passing along the surface of the source produced the most pronounced effects. The number of atoms evaporating increased with the source thickness (h) and reached a maximum at $h = 1.5 \times 10^{-6}$ cm.

235

PREPARATION OF α -ACTINIDE FOILS BY ELECTROLYSIS. M. Valentin and J.

Champion. Commissariat a l'Energie Atomique Fontenay-Aux-Pioes., Centre d'Etudes Nucleaires (1966).

Electrolytic procedures are given for preparing foils of U, Np, Pu, Am, Cm, Cf, and their mixtures. Details of the procedures vary for different elements. Only slight deposits of Cm and Cf are obtainable.

XV. PROCESSING AND PRODUCTION

236

PROCESS OF PRODUCING CURIUM-244 AND CURIUM-245. W. M. Manning, M. H. Studier, H. Diamond, and P. R. Fields. U. S. Patent 2,859,095 (November 4, 1958).

A process is presented for the preparation of curium-244 and curium-245. Plutonium-239 is subjected to a high neutron flux and dissolved in HCl. The Pu is oxidized to the tetravalent state and contacted with an anion exchange resin. This results in retaining the Pu while the fission products and transplutonium elements remain in the effluent solution. The effluent is contacted with a cation exchange resin causing the transplutonium elements to be absorbed while the fission products remain in solution. The cation exchange resin is then contacted with an aqueous citrate solution and the transplutonium elements are differentially eluted in order of decreasing atomic weight.

237

THE PRODUCTION AND CHEMICAL ISOLATION OF CURIUM-242 IN THOUSAND CURIE QUANTITIES. G. H. Higgins and W. W. T. Crane. UCRL-5021; A/CONF 15/P/1883 (1958).

An integrated system of process equipment and chemical separations was designed which would isolate gram quantities of Cm. The chemical process consisted of combinations of ion exchange separations. Three thousand to 4000 curies of curium-242 were separated from 400 g of Fe and Al, and from about 500 curies of fission product activity with a chemical yield of >80 percent. Without extensive modification, this equipment could be used to process other highly radioactive substances.

238

AMERICIUM-241 AND CURIUM-242 FUEL PROCESSING HAZARDS. MND-P-1972 (1959).

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

239

LARGE SCALE METHOD FOR THE PRODUCTION AND PURIFICATION OF CURIUM. G. H. Higgins and W. W. T. Crane. U. S. Patent 2,887,358 (May 19, 1959).

A large scale process for production and purification of curium-242 is described. Al slugs containing americium-241 are irradiated and de-clad in NaOH-NaNO₃ solution at 100°C. The resulting slurry is filtered and washed with NaOH, NH₄OH, and H₂O. The Cm is precipitated from the wash and filtrate with Fe(OH)₃. The precipitates are dissolved in HCl and the refractory oxides are centrifuged out, fused with Na₂CO₃ and dissolved in HCl. The solution is evaporated and LiCl solution added. The Cm, rare earths, and anionic impurities are adsorbed on a strong-base anion exchange resin. Impurities are eluted with LiCl-HCl solution; lanthanides, and Cm are eluted by HCl. The Cm is finally precipitated as a fluoride.

240

REACTOR FUEL PROCESSING. *Technical Progress Review*, Vol. 4, No. 3. S. Lawroski, ed. Argonne National Lab., Ill. (July 1961).

Information is given regarding commercial aspects of fuel processing, including data on the production and properties of a curium-242 radionuclide heat source.

241

ISOTOPIC POWER SOURCES—A COMPENDIUM, PROPERTY AND PROCESSES REVIEW PART II. MND-P-2581-III (Pt. II) (1961).

A selective bibliography was compiled on the nuclear, physical, and chemical properties and separation processes of Pu, americium-241, and Cm.

242

SNAP PROGRAMS. Quarterly Progress Report No. 6 Jan. 1 through March 31, 1961. MND-P-3014-III (1961).

Curium purification by ion exchange techniques is under study to determine the operating conditions and design parameters for the Hot Cell Facility.

243

SNAP PROGRAMS: TASK 6 FUEL TECHNOLOGY DEVELOPMENT PROGRAM. Quarterly Progress Report No. 7, April 1 - June 30, 1961. MND-P-3015-111. Martin Co. Nuclear Div., Baltimore.

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.

244

TRANSURANIUM DEVELOPMENT FACILITY.

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

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 for testing design concepts, and equipment, for use in a larger transuranium facility now in the preliminary stages of design.

245

CHEMICAL PROCESSING REQUIREMENTS FOR TRANSURANIUM ELEMENT PRODUCTION.

R. E. Leuze. *Nucl. Sci. Eng.*, 17, 448-51 (1963). Transuranium elements will be produced by long-term neutron irradiation of Pu-Al alloy to

produce plutonium-242, americium-243, and curium-244, which will be irradiated in the HFIR to produce Bk, Cf, Es, and Fm. Methods based primarily on ion exchange and solvent extraction are outlined for processing both irradiated Pu-Al alloy and irradiated HFIR targets. The calculated content of irradiated plutonium-242 and californium-252 HFIR targets is given.

246

APPLICATION OF AMINE AND PHOSPHONATE EXTRACTANTS TO TRANSPUTONIUM ELEMENT PRODUCTION. R. E. Leuze, R. D. Baybarz, and B. 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 from irradiated High Flux Isotope Reactor targets. A process was developed for splitting transplutonium elements into two fractions. Transcurium elements are extracted into mono-2-ethylhexyl phenyl phosphonic acid from dilute HCl while the Am-Cm and Ni contaminants from the Tramex Process remain in the aqueous phase.

247

ANALYTICAL STUDIES AND ADVANCED CONCEPTS. Quarterly Progress Report, July, August, September, 1963. M. M. Hendrickson and J. K. Green, eds. HW-79280 (1963). "Impact of High Curium-244 and Plutonium-238 Prices." High market prices for curium-244 and plutonium-238 would influence reactor and fuel element design and operation to emphasize production of these isotopes in preference to heat and neutrons.

248

CURIUM PROCESSING; ORNL-3452 (pp. 134-43) (1963).

The recovery of 30 g of Pu and 4 g of actinides from highly irradiated Pu-Al alloy fuel rods was completed in a pilot plant. A study of flow sheets featuring anion-exchange separation methods was made. The first gram quantities of americium-243 and curium-244 from the Pu irradiation will be recovered in this facility using fission product Am-Cm concentrates isolated at Savannah River. Curium-242 has a specific heat generation rate of 120 w/g and decays with a 162.5 day half-life.

249

CURIUM PROCESSING; ORNL-3452 (1963).

The high-level solvent extraction development facility for the Transuranium Program is being modified to supply multigram quantities of

curium-242 free of fission products for the fabrication of heat sources such as SNAP-13, SNAP-11, and others, and Surveyor lunar probes.

250

TRANSURANIUM QUARTERLY PROGRESS REPORT FOR PERIOD ENDING FEBRUARY 29, 1964. W. D. Burch, comp; ORNL-3651 (1964). Progress is reported on the development of separation processes for the transuranium elements, process equipment development, HFIR target fabrication development, construction of the TRU processing plant, corrosion studies, and analytical research and development.

251

TRANSURANIUM QUARTERLY PROGRESS REPORT FOR PERIOD ENDING NOVEMBER 30, 1963. W. D. Burch, comp; ORNL-3597 (1964). Progress is reported on the development of separation processes for the transuranium elements, process equipment, design, development and fabrication, HFIR target fabrication development, construction of the TRU processing plant, corrosion studies, and analytical research and development.

252

DEVELOPMENT OF CHEMICAL FLOWSHEETS FOR THE OVERALL PROCESS. K. B. Brown and R. E. Leuze; ORNL-3558, pp. 7-55 (1964).

A series of five counter current solvent extraction tests was made of the Tramex flowsheet with curium-242 power densities varying from 5 to 10 w/liter. No adverse effect on the extraction process was noted due to alpha radiation, and the results indicated that the Tramex process can achieve both high recovery of transplutonium elements and high decontamination from fission products. Extraction by di(2-ethylhexyl) phosphoric acid from dilute HNO₃ showed a preference of 10⁴ for Am(III) and indicated a possible method for preferential extraction of Cm(III) from Am(VI).

253

Reactor Fuel Processing, 8, No. 4, S. Lawroski, ed. (1965).

Commercial aspects of fuel reprocessing, mechanical preparation for fuel processing, recovery and separation of Am and Cm, and other topics are discussed.

254

TRANSURANIUM ELEMENT PROCESSING; ORNL-3627 (pp. 115-35) (1965).

The Transuranium Processing Plant (TRU) and the High Flux Isotope Reactor (HFIR) are being built to provide gram quantities of many of the transuranium elements and milligram quantities of some of the transcalifornium isotopes for research purposes. Long-term irradiation of a 10-kg batch of plutonium-239 in a Savannah River production reactor produced about 400 g of plutonium-242 and a 200 g mixture of americium-243 and curium-244. These materials were recovered for fabrication into target rods after which they will be further irradiated for 12 to 18 months in the HFIR, and the transcurium elements will be recovered as products. The Cm isotope will then be returned to the reactor for additional irradiation. The Curium Recovery Facility (CRF) is under construction and will be used to test transuranium process chemistry at full scale radioactivity levels, to recover multi-gram quantities of americium-243 and curium-244 for incorporation into HFIR targets, and to purify gram-quantities of curium-242 and curium-244 for use in thermoelectric converters.

255

TRANSURANIUM QUARTERLY PROGRESS REPORT FOR PERIOD ENDING AUGUST 31, 1964. W. D. Burch, comp; ORNL-3739 (1965).

The transuranium program is directed toward the production of sizeable quantities of the heavy actinide elements for research work. The anion-exchange behavior of the transcurium elements with EDTA was investigated in an effort to develop a new separation system for the heavy actinide elements. All equipment was installed in the Cm Recovery Facility and cold runs were begun.

256

CURIUM-244 PRODUCTION AND SEPARATION—STATUS OF THE PILOT PRODUCTION PROGRAM AT SAVANNAH RIVER. H. J. Groh, R. T. Huntoon, C. S. Schlea, J. A. Smith, and F. H. Springer. *Nucl. Appl.*, 1, 327-36 (1965); TID-21458. At Savannah River curium-244 is being produced from plutonium-239 in reactor irradiations designed for successive neutron captures. A separation process, which was successfully piloted, isolates Cm from intermediates (Pu-isotopes and americium-243) and fission products. The 2.65-w of heat generated per gram of Cm in the product can be used in isotopic power sources.

257

THE OAK RIDGE NATIONAL LABORATORY CURIUM PROGRAM. E. Lamb; ORNL-TM-1047 (pp. 62-8) (1965).

The recovery and purification of curium-242 and curium-244, fabrication of isotopic power sources containing Cm and their characterization with respect to normal operational and extreme conditions are discussed. The operations involved in the preparation of curium-242 heat sources are americium-241 target fabrication, reactor irradiation, recovery, and purification of curium-242 — americium-241 from irradiated targets, and preparation of the source form. A flowsheet for the preparation of curium-242 heat sources, target capsule assembly, irradiation assembly, TrameX process flowsheet, source fabrication facility, curium-242 power source program and source fabrication operations are illustrated.

258

RADIOISOTOPE PRODUCTION IN POWER REACTORS. A. F. Rupp, J. A. Cox, and F. T. Binford; ORNL-3792 (1965).

The possibility of producing large amounts of radioisotopes in 18 power reactors, together with some of the problems of establishing such a program, was investigated. Because of limitation of flux, irradiation time, and possible uses, seven radioisotopes, among which were curium-242 and curium-244, were chosen for study. The amounts and specific activities which might be produced in all 18 reactors were calculated and the approximate costs were estimated for one particular reactor.

259

TRANSURANIUM QUARTERLY PROGRESS REPORT FOR PERIOD ENDING NOVEMBER 30, 1964. W. D. Burch, comp; ORNL-3847 (1965). Large scale production of transuranium elements is centered in the HFIR, and TRU facilities. Target rods irradiated in the HFIR are processed in TRU for recovery of transuranium elements and refabrication for further irradiation. The process development includes work on the Talspeak process for separation of actinides from lanthanides. Cold runs and initial hot operations were carried out in the Curium Recovery Facility.

260

TECHNICAL FEASIBILITY OF RADIOISOTOPE PRODUCTION IN POWER REACTORS. A. F. Rupp, J. A. Cox, and F. T. Binford. "Proceedings of the Atomic Industrial Forum 1964 Annual Conference," November 30, — December 3, Vol. 3, (1965).

The technical and economic aspects of radioisotope production in power reactors are discussed. Characteristics of power reactors are reviewed.

Criteria for radioisotopes suited for power reactor production are outlined. Production of plutonium-238, polonium-210, curium-242, curium-244, and others is considered economically feasible.

261

RADIOISOTOPE PRODUCTION CAPABILITIES OF U. S. POWER REACTORS. E. J. Hennelly and R. Hood; DP-1015 (1965).

The future production capability of the U. S. nuclear power complex is estimated for four radioisotopes that are of interest as heat sources; namely, promethium-147, polonium-210, plutonium-238, and curium-244. Production estimates for the next 15 years were derived from forecasts of the growth rate of nuclear power and published data on isotope yields.

262

PRODUCTION OF TRANSPLUTONIUM ELEMENTS AT SAVANNAH RIVER. W. P. Overbeck, C. H. Ice, G. Dessauer; DP-1000 (1965).

A production effort is being made to produce 3 kg of curium-244. Extended irradiation of the HFIR target material was accomplished in a high flux test at 5.4×10^{15} n/cm²/sec and a high flux mode will be used to accelerate the production of curium-244.

263

MANAGEMENT OF AMERICIUM IN POWER REACTOR FUELS TO OPTIMIZE PRODUCTION OF ALPHA-EMITTING ISOTOPES. L. W. Lang; BNWL-SA-472 (1965).

The choice of a reactor and the length of irradiation time are unique production determinants in isotope yield from the mixed Am isotopes. Calculations were performed for two neutron spectra (PWR) and (HWR), at neutron fluxes of 5×10^{13} , 2×10^{14} , and 1×10^{15} nvt and periods of radiation of one to 24 months to determine isotope yields. The harder flux spectra, typical of PWR, with short irradiation periods result in a greater production of α -emitting isotopes than the softer neutron spectrum for equivalent or long irradiation times. The data are summarized.

264

CURIUM PROCESSING EXPERIENCE, V.C.A. Vaughen, R. D. Baybarz; ORNL-P-1968 (1965). About 35 g each of curium-244 and americium-243 were prepared in pure form, and about 12 g of curium-242 were also prepared. Processes were demonstrated to yield recoveries of about 95 percent across the two cycle (Clanex-Tramex) process, with decontamination factors of up to 500 for gross γ . Final purification and separation

of curium-244 from americium-243 yielded an Am product of better than 99.9 percent purity and a Cm product containing about 0.5 percent Am. Beta-gamma emitting contaminants were below detectable limits.

265

TRANSURANIUM ISOTOPES NATIONAL TRANS-URANIUM PROGRAM. A. Chetham-Strode, Jr.; ORNL-TM-1047 (pp. 60-1) (1965).

The National Transuranium Program includes the interim irradiations of plutonium-239, plutonium-242, and americium-241, the irradiation of kilogram quantities of plutonium-239 to produce HFIR targets of plutonium-242, americium-243, and curium-244, and the HFIR irradiation of such targets to produce gram quantities of Bk and Cf and smaller amounts of heavier transuranium isotopes and other transuranium isotopes of special interest. The present status and tentative schedule for these irradiations (revised to June 1954) are tabulated. The isotopes listed are being produced for research activities. Their distribution, foreign and domestic, is limited to small quantities for this purpose.

266

PREPARATION OF PLUTONIUM-242 AND CURIUM-242 FROM NEUTRON-IRRADIATED AMERICIUM-241. V. B. Dedov, V. V. Volkov, B. A. Gvozdev, V. A. Ermakov, I. A. Lebedev, V. M. Razbitnoi, P. S. Trukhlyayev, Yu. T. Chuburkov, G. N. Yakovlev. *Radiokhimiya*, 7, 453-61 (1965).

Irradiation of americium-241 with thermal neutrons produces plutonium-242, curium-242, and americium-243. The yield of fission products is small since they are produced mainly during fission of americium-242. This facilitates the chemical processing of irradiated substances. The chemical separation of plutonium-242, curium-242, and americium-243 from irradiated americium-241 is described. The main separation steps involve chromatographic and chemical extraction methods. Some properties of curium oxalate, potassium curium sulfate, curium hydroxide, and curium carbonate are discussed.

267

WORKING METHODS-EQUIPMENT IN USE AT THE 1000 CURIE-1 MeV TRANSPLUTONIUM COMPLEX AT THE MEDIUM ACTIVITY LABORATORY. J. M. Gondolfo. "International Symposium on Working Methods in High Activity Hot Laboratories." Vol. II (1965).

The chemical separation of transplutonium elements obtained by irradiation of targets containing

americium-241, plutonium-242, americium-243, and curium-244 in the BR-2 reactor made necessary a group of 1000-Curie, 1-MeV α - β - γ -n cells. The equipment used for the chemical processing of a slug containing 2.5 g of americium-241, irradiated for four years in the MTR, is described.

268

CHEMICAL PROCESSING OF CURIUM-STATUS OF THE PILOT PRODUCTION PROGRAM AT SAVANNAH RIVER. R. B. Neel, I. D. Eubanks, M. C. Thompson, and G. A. Burney; CONF-660305-7 (1966).

A process for purifying curium-244 produced in Savannah River reactors was successfully demonstrated in the laboratory. Radiochemically pure Cm was produced in pilot demonstrations that are adaptable to large-scale production. Improvements were made in the processing scheme that simplify chemical processing without sacrificing product quality. Actinide-lanthanide partitioning by solvent extraction with ternary amines in a chloride system was successfully demonstrated. Thermo-gravimetric studies defined the calcination temperatures for producing CmO₂ as the final product.

269

CRITICAL EXPERIMENTS WITH HIGHLY BURNED-UP PLUTONIUM IN D₂O. R. L. Olson, W. E. Graves; DP-MS-66-38 (1966).

The research program for producing curium-244 in the Savannah River Production Reactors is discussed. The feed material for the program is primarily plutonium-239.

270

PRODUCTION AND INDIFFERENCE PRICING OF TRANSURANIUM ISOTOPES. D. E. Deonigi, E. A. Eschbach; BNWL-223 (1966).

The computed rates at which neptunium-237, plutonium-238, americium-241, curium-242, and curium-244 are incidentally produced by simulated power reactors are reported. Also shown is the extent to which some power reactor fueling methods can be altered to increase the production and purity of plutonium-238 and curium-244. An explanation of the indifference price concept is introduced in order to access the effect of various plutonium-238 and curium-244 credits on the equitable price of the precursor, or target isotopes.

271

CURIUM PROCESS DEVELOPMENT, I GENERAL PROCESS DESCRIPTION. I. D. Eubanks and G. A. Burney; DP-1009 (1966).

Chemical processing steps to purify curium-244

produced in the Savannah River reactors are described, and specifications on radioactive impurities in the product are stipulated.

272

TRANSURANIUM ELEMENT PROCESSING (n.a.); ORNL-3945 (1966).

Methods were developed for the preparations of americium-241, curium-244, and mixed americium-243-curium-244 solutions. Equipment was designed and built to separate and recover the actinides from irradiated HFIR target rods.

273

POSSIBILITIES OF MANUFACTURING THE ACTINIDE ELEMENTS USABLE AS HEAT SOURCE IN ISOTOPIC POWER GENERATORS. R. Berger; *Bull. Inform. Sci. Tech.*, No. 104, 35-63 (1966).

The factors involved in a potential manufacture of the actinide elements usable as heat sources in isotopic power generators are reviewed. They include raw materials availability and recovery means, irradiation possibilities, chemical process efficiency and conditioning method development. This study shows that industrial production of the isotopes actinium-227, thorium-228, uranium-232, plutonium-238, curium-242, and curium-244 can be performed by target irradiation in nuclear reactors.

274

TRANSURANIUM QUARTERLY PROGRESS REPORT FOR PERIOD ENDING FEBRUARY 28, 1965. W. D. Burch; ORNL-3880 (1966).

Recovery of gram amounts of heavy actinide elements for research work is accomplished in the TRU facility. Process development, work in the Cm Recovery Facility, experimental engineering studies, design and development of target fabrication processes and equipment, design of equipment and construction of the TRU Process Plans, corrosion studies, and development of analytical methods are reviewed.

275

CURIUM PROCESSING. Chemical Technology Division Annual Progress Report for Period Ending May 31, 1966; ORNL-3945.

Details of the Clanex, Dapex, and Tramex recovery processes are discussed, followed by sections devoted to curium-242 and curium-244 recoveries in the CRF and a series of tests conducted at high radiation levels to evaluate a number of alternate flowsheets. A brief description of equipment, modifications, and operating experience in the CRF is also included.

276

THE LARGE SCALE PRODUCTION AND UTILIZATION OF RADIOISOTOPES IN THE UNITED KINGDOM. H. Sheard; DP-1066, Vol. I (1966).

Large-scale production and utilization of radioisotopes in the United Kingdom has been confined to cobalt-60. The use of radioisotopic heat sources for electric power generation is receiving more attention through studies of curium-242, curium-244, and plutonium-238.

277

LARGE SCALE PROCESSING AND SOURCE PREPARATION OF NEUTRON PRODUCED ISOTOPES. E. Lamb; DP-1066 Vol. I (1966).

Large-scale processing of radioisotopes for commercial and isotopic power applications is summarized. The discussion is limited to radioisotopes produced by the (n, γ) reaction.

XVI. GEOCHEMISTRY

278

THE MISSING HEAVY ELEMENTS. N. K. Saha and J. Verma. *Indian J. Phys.*, 25, 409-16 (1951). The possible causes of the absence of elements with Z greater than 92 and of isotopes of the $4n+1$ series in nature are considered.

279

POSSIBLE EXISTENCE OF CURIUM-247 OR ITS DAUGHTERS IN NATURE. H. Diamond, A. M. Friedman, J. E. Gindler, and P. R. Fields. *Phys. Rev.*, 105, 679-80 (1957).

The absence of any detectable plutonium-243 daughter activity in a sample of Cm containing 2 μ g of curium-247 indicates that the α -half life of curium-247 exceeds 4×10^7 yr. and probably exceed 9×10^7 yr. The possibility of finding curium-247 in nature and of finding high uranium-235: Uranium-238 ratios in very old rare earth minerals are discussed.

280

NUCLEAR CHEMISTRY RESEARCH AT CARNEGIE INSTITUTE OF TECHNOLOGY; TID-6322 (1960).

Progress on the search for natural curium-247 is reported.

281

SOME POSSIBLE GEOLOGIC RELATIONSHIPS IN THE FORMATION OF URANIUM-235 FROM CURIUM-247. H. H. Adler. *Econ. Geol.*, 56,

689-94 (1961). RME-4093.

A mechanism for the derivation of uranium-235 from curium-247 is considered as a possible source of uranium-235 enrichment in radioactive rare earth minerals. The amount of enrichment of uranium-235 that might be expected from curium-247 decay is calculated for monazite for several geologic ages. The curium-247 would not provide sufficient enrichment in uranium-235 to be of economic importance, but its possible existence in early geologic time may be of interest in geochronology studies.

282

POSSIBLE EXISTENCE OF CURIUM IN NATURE (Part II). P. R. Fields, A. M. Friedman, J. Lerner, D. Metta, and R. Sjolom. *Phys. Rev.*, 131, 1249-50 (1963).

A lower limit to the alpha half-life of curium-247 was previously reported as 4×10^7 yr., but the determination reported here with a Cm sample containing 30 times more curium-247, yields a half-life of $(1.64 \pm 0.25) \times 10^7$ yr. This result implies that no detectable amount of primordial curium-247 exists on earth and that curium-247 will not account for the high ^{235}U : ^{238}U ratios reported for certain minerals.

283

THE PRIMORDIAL TRANSURANIUM ISOTOPE IN NATURE. V. V. Cherdyn'tsev and V. F. Mikhailov. *Geokhimiya*, No. 1, 3-14 (1963).

In some young natural samples a primordial radioactive α -emitter is obtained. The α -spectrum main line extends from 4.2 to 4.6 MeV and the γ -rays have energies in the region of 90 to 250 keV. This isotope, apparently, is curium-247. Decay products of americium-243 and plutonium-239 accompany it. The curium-247 content in natural minerals is about $n \times 10^{-8}$ percent and $^{247}\text{Cm}/^{238}\text{U} = n \times 10^{-2}$ (activity units). The decay period of the isotope is estimated as 2.5×10^8 yr.

284

SEARCH FOR NATURAL CURIUM-247. G. W. Wetherhill, W. F. Libby, and G. W. Barton. *J. Geophys. Res.*, 69, 1603-5 (1964).

A sample of rare earth concentrate, derived from euxenite, was analyzed for the long-lived isotope curium-247 by mass spectrometric isotope dilution. Less than 10^{-14} g of curium-247 per gram of rare earth was found. It is difficult to reconcile this negative result with the reported discovery of this isotope in nature.

XVII. PHYSIOLOGICAL CHEMISTRY

285

SUMMARY OF THE RESEARCH PROGRESS MEETING. R. K. Wakerling; RL-28.5.135 (1947). Studies concerning the metabolism of Cm and Am are reported. Comparisons are made between the uptake of these elements in the liver and skeletal structure.

286

THE METABOLISM OF CURIUM IN THE RAT. K. G. Scott, D. Axelrod, and J. G. Hamilton; UCRL-35 (January 15, 1948). The fate of Cm has been studied in the rat several days after intramuscular administration. Curium was found to be primarily deposited in the liver and skeleton.

287

THE ANALYSIS OF URINE FOR TRACES OF AMERICIUM AND OTHER ALPHA EMITTERS. E. N. Jenkins and G. W. Sneddon; AERE-C/R-1399 (1954). The alpha emitters were coprecipitated on bismuth phosphate from a nitric acid solution of oxidized urine, followed by re-solution of the precipitate in HCl and a second coprecipitation with LaF_3 . Recoveries of the order of 90 percent were obtained from urine samples at a level of 3d/min of added Am.

288

THERAPY OF RADIOELEMENT POISONING. Transcription of a Meeting on Experimental and Clinical Approaches to the Treatment of Poisoning by Radioactive Substances. Held October 20 and 21, 1955. M. W. Rosenthal, ed.; ANL-5584 (1956). A discussion is given of available material, both experimental and clinical, on the treatment of internally deposited radioelements. Data are presented on the absorption tissue distribution, excretion and treatment after absorption of curium-242 and numerous products from fallout. The effectiveness of BAL, EDTA, Zr, and miscellaneous chelating agents in the removal of radioelements, and the relationship of Ca metabolism to the deposition of metallic ions in bone are discussed.

289

PRELIMINARY HAZARDS OF CURIUM-242 AUXILIARY POWER SUPPLY. W. W. T. Crane; MND-1963 (1959).

A survey of curium-242 hazardous properties is presented along with concepts of its use in radio-isotopic space vehicle auxiliary power units.

290

URINALYSIS FOR CURIUM BY ELECTRO-DEPOSITION. I. Dupzyk and M. W. Biggs; UCRL-6168 (1960). A urinalysis method was developed for the determination of Cm by electrodeposition. The urine is wet ashed, and the Cm coprecipitated with bismuth phosphate, then LaF_3 , and finally $\text{La}(\text{OH})_3$. The Cm is separated from the La carrier using Dowex-50 colloidal ion exchange resin. Electrodeposition on stainless steel or platinum discs gives a uniform film suitable for pulse-height analysis. Cm recoveries of approximately 45 percent are obtained on quantities as low as 0.2 d/m.

291

CURRENT STATUS OF CURIUM INHALATION EXPOSURES IN HUMANS. H. G. Parker, M. D. Thaxter, and M. W. Biggs; UCRL-9361 (1960). An incident is described concerning a curium accelerator target aerosolized by explosion. Management of the spill, sampling, particle sizing, and medical findings are presented. Seven of the 27 persons present showed low levels of Cm excretion. Data from this incident were compared with those from three other inhalation exposures to Cm compounds.

292

BIOLOGY AND MEDICINE SEMI-ANNUAL REPORT, SPRING 1961. J. H. Lawrence, ed.; UCRL-9617 (1961). Results are included from preliminary studies on the effect of a complexing agent and mode of administration on the distribution of curium-242 in rats.

293

ALPHA EMITTERS IN REACTOR WASTES. H. A. C. McKay. Atomic Energy Waste. Its Nature, Use, and Disposal. pp. 99-108. E. Glueckauf, ed.; New York, Interscience Publishers, Inc. (1961). The four α -emitters to be considered in waste disposal are neptunium-237, plutonium-238, americium-241, and curium-242. It is pointed out that with one minor exception no α -emitter is ever likely to be a greater hazard than

strontium-90 in unseparated fission product wastes. Data are tabulated on the most hazardous α -emitting nuclides under various conditions.

294

TRANSFER OF SOME TRANSURANIC ELEMENTS TO MILK. R. O. McClellan, H. W. Casey, and L. K. Bustad. *Health Phys.*, 8, 689-94 (1962). The transfer of curium-244, and other elements, from plasma to milk following a single intravenous dose was studied in mature sheep. Plasma concentration of curium-244 showed an initial decline followed by a slightly increased concentration at 7 hr. and then a continuous decline for the remainder of the 10 day study.

295

URINALYSIS FOR CURIUM BY ELECTRODEPOSITION. I. Dupzyk and M. W. Biggs; TID-7616 (pp. 39-50) (1962).

A urinalysis method was developed for the determination of Cm by electrodeposition. The urine is wet ashed, and the Cm coprecipitated with bismuth phosphate, then LaF_3 , and finally $\text{La}(\text{OH})_3$. The Cm is separated from the lanthanum carrier using Dowex-50 colloidal ion exchange resin. Electrodeposition on a stainless steel or Pt disc gives a uniform film suitable for pulse-height analysis or low-background proportional counting. Final analysis of weak samples is done by radioautography. Curium recoveries of approximately 45 percent are obtained. Quantities of the order of 0.2 dpm can be detected by this method.

296

A METHOD FOR DETERMINING LOW LEVEL ALPHA ACTIVITY FROM AMERICIUM-241, CURIUM-244, AND CALIFORNIUM-252 IN BIOLOGICAL MATERIALS. A. de G. Low-Beer and T. L. Story, Jr.; DP-831 (pp. 58-63) (1963). The nuclides are coprecipitated with LaF_3 . Separation is affected on specially designed small columns, using a series of three different ion exchange resins. The final eluate is collected on Pt and counted directly by pulse-height analysis. The method is sensitive to 0.3 dpm, and is applicable to both urine and tissues. Separation can be carried out in about two hours. Identification is made by pulse-height analysis.

297

TRANSFER OF SOME RADIONUCLIDES TO MILK. R. O. McClellan, H. W. Casey, and L. K.

Bustad; HW-76000 (pp. 98-108) (1963).

The transfer of several radionuclides from plasma to milk following a single intravenous dose was studied in mature sheep. The rate of plasma clearance of the radionuclides for the 10 days following administration in decreasing order are: uranium-233, curium-244, calcium-45, radium-226, strontium-90, promethium-147, and ruthenium-106. The average milk to plasma ratios were: calcium-45, 30; strontium-90, 10; radium-226, 6; promethium-147, 2.5; curium-244, 2; ruthenium-106, 0.015; and uranium-238, 0.08.

298

PRELIMINARY REPORT ON PUBLIC HEALTH HAZARD ANALYSES OF SPACE ISOTOPIC POWER SOURCES. J. J. Fitzgerald, G. L. Brownell, and N. I. Sax, J. J. Gabay, ed.; RSG-A-1 (1964).

A preliminary analysis was made of potential public health problems associated with the large quantities of radioisotopes required for space energy. External and internal exposures from specific radioisotopes were calculated and specific credible incidents were evaluated. It was concluded that the planned space operations can be conducted at an acceptable level of safety if appropriate consideration is given to the selection of isotopes and if adequate safeguards are provided. Data are appended on the physical, chemical, radiological, and toxicological characteristics of space heat source materials including curium-242 and curium-244.

299

DETERMINATION OF URANIUM AND AMERICIUM-CURIUM IN URINE BY LIQUID ION EXCHANGE F. E. Butler. *Anal. Chem.*, 37, 340-2 (1965). Exchange of Th, Pa, U, Np, Pu, Am, Cm, and Cf from various concentrations of HNO_3 and HCl to liquid ion exchangers was determined. Both anion and cation exchangers were used; the former was triisooctylamine (TIOA) while the latter was di-2-ethylhexylphosphoric acid (HDEHP). Tests with TIOA indicated preferential and rapid removal of U from other actinides. HDEHP extracted more than 90 percent of all eight actinides from an acid solution adjusted in the pH range 4 to 5. At higher acidities, e.g., 4 N HNO_3 , all the actinides were extracted except Am, Cm, and Cf. Procedures were developed for the determination of americium-241-curium-244 in urine. Tracer recoveries were greater than 90 percent and decontamination

factors were sufficiently high for other actinides. Detection limits were 0.3 d/m for 250 ml urine samples.

300

METABOLISM OF TRANSURANIC ELEMENTS. J. M. Debois. *Belgicatom. Ass. Belge Develop. Pac. Energ. At., Bull. Inform.*, 11, No. 60., 13-17 (1966).

The toxicity and metabolism of the transuranium elements are reviewed. Special aspects of the metabolism of neptunium-237, plutonium-239, americium-241, curium-242, and californium-252 are discussed. The resorption and inhalation of Pu are considered in some detail.

301

GLOVEBOX HANDLING OF GRAM QUANTITIES OF CURIUM-244 AT ROCKY FLATS. R. A. Kirchner, K. J. Freiberg, E. A. Putzier; RFP-811 (1966).

Approximately 3 g of curium-244 were processed from oxide to metal in a standard glovebox. It was demonstrated that gram amounts of curium-244 can be handled safely in standard gloveboxes. The average whole body exposure for 11 persons was 298 mRem. The maximum whole body exposure was 475 mRem.

XVIII. APPLICATION

302

13-WATT CURIUM FUELED THERMOELECTRIC GENERATOR FOR A SIX-MONTH SPACE MISSION. J. L. Bloom; MND-P-2373 (1960).

The development of a design concept for a thermoelectric generator suitable for use in extraterrestrial space missions for periods up to six months is outlined. The generator derives its power from radioactive decay of the isotope curium-242. It weighs 16.6 pounds and produces 13 watts of d-c power (at 3 volts output) continuously over its six months operational period.

303

CURIUM FUELED GENERATORS FOR LUNAR AND SPACE MISSIONS. C. O. Riggs; MND-P-2366 (1960).

Two thermoelectric generators that use curium-242 as the heat source are described. One designed for a lunar mission, is fueled with 3.76 g of curium-242 with an activity of 12,480 c. The

second designed for a satellite or space probe mission is fueled with 6.28 g having an activity of 20,400 c.

304

SNAP PROGRAMS: QUARTERLY PROGRESS NO. 5; MND-P-3013-II (1960).

The procedure for fueling a thermionic generator with curium-242 heat source was evaluated. Fuel technology development was centered around curium-242 and plutonium-238.

305

RADIOACTIVE MATERIALS LABORATORY SAFETY REPORT, MARTIN NUCLEAR FACILITY, QUEHANNA SITE; MND-2410 (1960).

An evaluation is given in support of fabrication work on the production of safe isotopic power sources from curium-242. The chemical, nuclear, and radiobiological properties of curium-242 are outlined.

306

SNAP PROGRAMS. THERMIONIC ISOTOPIC POWER SYSTEMS. QUARTERLY PROGRESS REPORT NO. 6; MND-P-3014-II (1961).

Studies were begun to design an encapsulated curium-242 heat source suitable for fueling a vacuum diode generator.

307

ISOTOPIC POWER SOURCES. A COMPENDIUM. PROPERTY AND PROCESS REVIEW. E. H. Smith, comp.; MND-P-2581-I (1961).

A selective bibliography was compiled containing 2063 references to reports and published literature on isotopes usable as power sources. Nuclear, physical, chemical properties, and separation processes were emphasized. Among the isotopes covered were curium-242, curium-243, and curium-244.

308

RADIONUCLIDE POWER FOR SPACE. PART I. ISOTOPIC COSTS AND AVAILABILITY. H. L. Davis. *Nucleonics*, 21, No. 3, 61-5 (1963).

Projections of the production of isotopes needed for space power systems reveal a potential shortage of plutonium-238. Production of curium-244 to supplement the plutonium-238 is proposed. Merits of various isotopes as space fuels are evaluated, and plutonium-238, curium-244, polonium-210, and curium-242 are deemed best due to their low shielding requirements.

309

DIRECT CONVERSION OF KINETIC ENERGY OF FISSION PRODUCTS INTO ELECTRIC ENERGY.

K. Schetzmann. *Kerntechnik*, 5, 377-81 (1963).

The nuclear fission energy arising in the form of kinetic energy of the fission products can be partially converted directly into electric energy in devices like diodes or triodes. Up to now extremely low efficiencies have been obtained.

310

ALPHA SOURCES FOR LOW THRUST TASKS IN SPACE.

W. Diethorn, Intern. *J. Appl. Radiation Isotopes*, 15, 127-31 (1964).

A recoil thrust exerted on a flat-plate α source was calculated for α -particle escape from one side of the source. The thrust is low even for the high specific activity α -emitter polonium-210, plutonium-238, and curium-244. It is suggested that these three α -emitters may find some future applications in space exploration requiring low-thrust devices.

311

SHIELDING ISOTOPIC POWER SOURCES FOR SPACE MISSIONS.

J. P. Nichols and E. D. Arnold. *Nucleonics*, 22, No. 2, 52-6 (1964).

Separation distance, rather than shielding, is suggested for protection of payloads from the isotopic power sources for 5-year missions. Radiation-level calculations are presented for unshielded sources using cesium-137, strontium-90, plutonium-238, curium-244, promethium-147, curium-242, and polonium-210.

312

HANDBOOK OF SHIELDING REQUIREMENTS AND RADIATION CHARACTERISTICS OF ISOTOPIC POWER SOURCES FOR TERRESTRIAL, MARINE, AND SPACE APPLICATIONS.

E. D. Arnold; ORNL-3576 (1964).
The radiation intensities from shielded and unshielded sources fabricated from 17 isotopes that show promise for use in isotopic power or radiation applications were calculated. Source sizes in the range of 100 to 20,000 thermal watts were evaluated. Among others, curium-242 (oxide matrix with void space for gas collection) and curium-244 (oxide) were studied.

313

RADIOISOTOPIC SPACE POWER-PROSPECTS AND LIMITATIONS.

C. A. Rohrmann and E. D.

Sayre. Am. Inst. of Aeronautics and Astronautics (1964) Paper No. 64-453; (CONF-600-28) (1964).

The properties of various nuclides including curium-242 and curium-244 are reviewed for use in radioisotope heat sources for direct conversion devices.

314

UTILIZATION OF RADIOISOTOPES FOR PRODUCTION OF ELECTRIC ENERGY ABOARD SPACE VEHICLES.

P. Bemelmans and J. P. Contzen; BLG-330 (1964).

Comparing the characteristics of the primary energy sources available on board space vehicles, it is shown that radioisotopes exhibit definite potentialities for missions of intermediate to long duration. A survey of the suitable conversion systems was given, and the different criteria a radioisotopic source must meet before it can be applied to the production of auxiliary electric energy on board space vehicles were discussed. Eleven isotopes, including Cm, were selected for their characteristics, summarized in tabular form, and discussed individually.

315

RADIOISOTOPE HEAT SOURCE EVALUATION PROGRAM; N-66-12928 (1964).

The primary objective of the radioisotope heat source evaluation program was the compilation of an annotated bibliography on the nuclear characteristics of several isotopes, including curium-242 and curium-244. A secondary objective of the program was the generation of a Fortran computer program capable of computing the low energy bremsstrahlung (<250 Kev) emanated by candidate isotopic fuels. The following characteristics for isotopes are presented: Half life, spontaneous fission half life, energy levels, decay schemes, spins alphas/spontaneous fission, and neutrons/spontaneous fission.

316

CURIUM PROCESSING. CHEM. TECH. DIV. ANN. PROG. REPORT; ORNL-3627 (1964) (no author).

A program was established to produce Cm heat sources for use in thermoelectric converters. Irradiated targets of $^{241}\text{AmO}_2$ in an Al matrix will be processed to separate curium-242 from Al, fission products, and eventually from americium-241, although the first products will contain the residual americium-241 as well as curium-242. A HNO_3 solution of the product will be processed

and fabricated into thermoelectric heat sources. Laboratory scale development of the chemical processes search for alternative process methods which may be used in existing processing facilities, and design construction and operation of the Cm Recovery Facility (CRF) to test the processes and to isolate multigram amounts of curium-242 and curium-244 are reported.

317

RADIATION PROPERTIES OF CURIUM-244 PRODUCED FOR ISOTOPIC POWER GENERATORS. D. H. Stoddard, comp.; DP-939 (1964).

The radiation properties of Cm (~ 95 wt. percent curium-244) that would be produced in a large-scale program at the Savannah River Plant are similar to the properties of pure curium-244. The alpha, gamma, and neutron radiations associated with the curium-244 product are presented for evaluation by users of curium-244 as a heat source in isotopic power generators.

318

HANDBOOK OF SHIELDING REQUIREMENTS AND RADIATION CHARACTERISTICS OF ISOTOPIC POWER SOURCES FOR TERRESTRIAL, MARINE, AND SPACE APPLICATIONS. E. D. Arnold; TID-7698 (Pt I) (pp. 33-248) 1965.

This handbook is intended primarily for use in preparation of preliminary design estimates in the field of isotopic source development and application. Calculations have been made of the radiation intensities from shielded and unshielded sources fabricated from 17 isotopes that show promise for use in isotopic power or radiation application. Source sizes in the range of 100 to 20,000 thermal watts were evaluated. Curium-242 (oxide matrix with void space for gas collection) and curium-244 oxide were among the isotopes studied.

319

CURIUM PROCESSING. (No author listed); ORNL-3830 (pp. 157-73) (1965).

Activities in a program to produce Cm heat sources for use in thermoelectric converters are reported. Information is included concerning development of processes for use in existing Cm processing facilities and in operation of a Cm recovery facility now under construction.

320

ISOTOPIC POWER DATA SHEETS. S. J. Rimshaw, comp.; TID-7698 (pp. 17-30) (1965).
Nuclear and physical properties are listed for curium-242 and curium-244.

321

USE OF ACTINIDE ELEMENTS IN ISOTOPIC POWER GENERATORS. R. Berger; *Bull. Inform. Sci. Tech. No. 104*, 23-34 (1966).

Some alpha emitter actinides can be used as heat sources for isotopic power generators. They are choice fuels for space propulsion and auxiliary electric energy production. An economic study shows that the specific investment in an 8-hour or 24-hour orbit for thermionic generators using actinium-227 and curium-244 is in the range of the silicon solar cell generator. That of the thermo-electric-generator, using plutonium-238, is two to three times as high.

322

ISOTOPIC POWER DATA SHEETS. S. J. Rimshaw. *Isotop. Radiat. Technol.*, 3, 147-51 (1965-1966).

Nuclear and physical properties of some unclassified radioactive source materials that have potential applications to terrestrial, marine, and aerospace power requirements were compiled from various publications. The radioisotopes considered were curium-242, curium-244, and others. Where information was not available, the probable values were derived from data in the literature on inactive or related materials.

323

METALLOGRAPHY OF Cm-244 OXIDES. P. K. Smith and J. T. Livingston; DP-MS-66-8 (1966).
Metallographic facilities and methods for production and fabrication of Cm₂O₃ fuels for isotopic heat sources are described. Information on microstructures of curium oxides is presented.

324

Cm-244 FOR RADIOISOTOPIC HEAT SOURCES WORK AT SAVANNAH RIVER LABORATORY.

W. R. McDonell, P. K. Smith, E. F. Sturcken, J. T. Livingston, M. C. Thompson, and W. C. Mosley, Jr.; CONF-660305-12 (1966).

Preliminary studies of the curium-oxygen system have demonstrated the existence of five compounds of lower oxygen content than CmO₂. One or two of these oxides appear to be sufficiently refractory to fuel a high temperature heat source. Thermal and physical properties of these and other

compounds of Cm and their compatibility with refractory containment metals are being determined. A facility specifically designed for studying properties of small quantities of curium-244 and other α -emitting compounds is nearing completion, and shielded facilities for handling larger quantities are being designed.

325

THE U. S. ATOMIC ENERGY COMMISSION DEVELOPMENT PROGRAM FOR HIGH SPECIFIC-ACTIVITY ISOTOPES FOR RESEARCH AND INDUSTRIAL APPLICATIONS. P. S. Baker; ORNL-P-2190 (1966).

The development program for high specific activity isotopes for research and industrial applications is discussed and the isotopes involved are indicated. Properties and production methods of the isotopes considered are discussed.

326

APPLICATION OF A RADIOISOTOPE HEAT SOURCE INTERIOR TO A TUBULAR THERMO-ELECTRIC GENERATOR. L. H. Boman; DP-1066 (Vol. 2) (1966).

A cylindrical isotopic heat source of curium-242 or curium-244 surrounded by a tubular thermoelectric generator with provision for cooling, forms a simple, light weight, rugged, compact power generating system.

327

RADIOISOTOPE CONVERTERS. T. Alleau, B. Devin, and M. Vandevyver; CEA-R-2788 (1966).

Due to the surface power density required for thermoelectric and thermionic converters, available radioactive sources are surveyed and listed. Curves of minimum diameter versus thermal flux density are given. Polonium-210 and curium-242 appear to be suitable for direct thermionic conversion.

XIX. MISCELLANEOUS

328

HEAVY ELEMENT IMPURITY IN A BERYLLIUM SHIM SAFETY ROD. H. G. Simens, J. I. Mueller, and R. E. Mayes; PWAC-157 (1956).

By means of a routine radiological monitoring technique, it was discovered that there was a radiation associated with the Be pieces in a

Be shim safety rod for the MTR. Alpha pulse analysis of a α contamination showed it to be 99 percent curium-244 and 1 percent curium-242 and the Cm activity was a volume phenomenon and was not caused by surface contamination. Curium was produced by neutron capture in a 540 ppm U impurity in the pre-irradiated Be rod.

329

ABSTRACTS OF ATOMIC ENERGY PROJECT UNCLASSIFIED REPORTS AND PUBLISHED LITERATURE ON THE ACTINIDE ELEMENTS. PART 5. TRANS-PLUTONIUM ELEMENTS. R. W. Clarke; AERF-C/R-2472 (Pt. 5) (1958). Abstracts of reports and published literature on trans-plutonium elements, dated January 1957 and later, are presented. Author and subject indexes are provided.

330

SNAP PROGRAMS. QUARTERLY PROGRESS REPORT NO. 3; MND-P-3011 (1960).

An evaluation of the effectiveness of the Cm shipping cask is made. Equations are presented concerning the reaction kinetics involved in the neutron irradiation of americium-241 with the subsequent production of curium-242.

331

EQUIPMENT ADVANCES IN THE TRANS-CURIUM ELEMENT RADIOCHEMISTRY FACILITY. M. S. Coops, C. L. Hanson, R. W. Hawk, and V. E. Scribner. *Trans. Am. Nucl. Soc.*, 7, 486-7 (1964).

Specialized equipment was incorporated in the Livermore neutron cell for use in isolating and purifying heavy actinide elements. Among these were: modified model E master slave manipulators, push button console for controlling dissolution of slugs, a photocell for monitoring highly radioactive species, and a spontaneous fission counter.

332

SHIPMENT OF A LARGE LIQUID SOURCE--A CASE HISTORY. F. A. Ernest and R. Maher; CONF-641201-2 (1964).

Equipment was designed for shipment of 150 gallons of HNO_3 solution containing 26,000 curies of α -activity from Am and Cm isotopes and 200,000 curies of associated rare earth fission products. Several of the design features are discussed in detail.

333

PREPARATION COATING EVALUATION, AND IRRADIATION TESTING OF SOL-GEL OXIDE MICROSPHERES. R. G. Wymer, J. H. Coobs; ORNL-P-1725 (1965).

Microspheres of ThO_2 , PuO_2 , AmO_2 , and CmO_2 and others were prepared at ORNL by sol-gel techniques. Sphere forming was accomplished by dispersing sols in 2-ethyl-1-hexanol containing appropriate surfactants or adulterants. Engineering feasibility of microsphere forming was demonstrated using a variety of sol dispersing techniques. Sol-gel microspheres, because of their sphericity and uniform size are well suited to coating in fluidized beds. Irradiation results indicate that carbon coated oxide microspheres will be satisfactory fuels for high-temperature, gas-cooled reactors.

334

RARE EARTH ACTINIDE METAL SOLS. F. T. Fitch, J. G. Smith. U. S. Patent 3,264,224 (August 2, 1966).

An invention is described relating to stable sols of particles composed of actinide and rare earth oxides as an intimate mixture or as solid solution oxide phases and the method of preparing these sols.

335

SOLS OF ZIRCONIA AND HAFNIA WITH ACTINIDE OXIDES. F. T. Fitch and J. G.

Smith. U. S. Patent 3,265,626 (August 9, 1966). An invention is described concerning the preparation of stable sols composed of actinide oxides and ZrO_2 or HfO_2 in mixtures or as solid solution oxide phases. The particles in these sols and solid solutions range from about 10 to 120 μ in diameter.

336

PREPARATION OF CURIUM HYDROXIDE SOL-GEL SPHERES AS AN INTERMEDIATE TO CmO_2 MICROSPHERE PREPARATION. R. D. Baybarz. *Inorg. Nucl. Chem. Lett.*, 2, 129-32 (1966); ORNL-P-2143.

A sol-gel procedure was developed to produce spheres of CmO_2 for incorporation into irradiation targets. The Cm sol was produced by the precipitation of the hydroxide from a HNO_3 solution with NH_4OH . Sufficient 0.1 M HNO_3 was added to the precipitate to give a NO_3^- to Cm mole ratio of 0.15 to 0.25. The slurry was stirred and heated at 50° to 70°C for 1 to 2 hr. during which it became a thin sol. The maximum sol concentration achieved was about 100 g Cm/l, at which concentrated curium-244 has a power level of 300 w/l. The sol is then cast into gel particles by introducing small droplets of sol into a counter current flowing column containing a drying agent. The resulting gel microspheres are in the form of a free-flowing powder. They are calcined quickly.

SECTION 2

PHYSICS

XX. NUCLEAR SPECTROSCOPY

A. Decay Schemes

337

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 americium-241, curium-242, thorium-230, protactinium-231, and uranium-233. Internal conversion coefficients of these elements calculated from coincidence data are tabulated.

338

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

A decay scheme is proposed for curium-242.

339

ANGULAR CORRELATION AND COINCIDENCE STUDIES OF ALPHA-GAMMA CASCADES FROM PROTACTINIUM-231, CURIUM-242, AND AMERICIUM-241. R. L. Moore; AECU-2757 (1957).

The decay scheme and the spins and parities of the daughter nuclei of curium-242 were studied. Spins of the states, properties of the radiations, and angular correlations between α particles and γ rays emitted in cascade were investigated.

340

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.

341

A STUDY OF THE PROPERTIES OF THE TRANS-URANIC ELEMENTS. T. Veresh, V. G. Solov'ev, and T. Shiklosh. *Izv. Akad. Nauk SSSR, Ser. Fiz.*, 26, 1045-60 (1962).

The section concerned with Cm gave the energies of the ground states and of the two-quasiparticle excited levels in curium-244 which were computed along with values of $\log(ft)_{\text{theor}}$ for the corresponding β -transitions. The 6+ level in curium-244 was found to have an energy of 1.042 MeV and a $\log(ft)_{\text{exp}} = 5.9$. These values are in good agreement with the calculated values which give an energy of 0.92 MeV and $\log(ft)_{\text{theor}} = 6.0$.

342

DECAY OF AN ISOMERIC STATE IN CURIUM-244. P. G. Hansen, K. Wilsby, C. V. K. Baba, and S. E. Vandenbosch. *Nucl. Phys.*, 45, 410-16 (1963).

The 1042-keV state in curium-244, which is populated in the β -decay of 10.1-hv americium-244, has previously been assigned $(K, I\pi) = (6.6^+)$. This assignment has been confirmed through an angular correlation measurement, and it was found that the 746 keV γ ray is a mixture of 46 percent quadrupole (E2) and 54 percent dipole (M1). The half-life of the 1042 keV state was determined by measurement of delayed coincidences between β particles and conversion electrons. The result is 34 ± 2 ms.

343

CORRECTIONS TO ROTATIONAL SPECTRA IN EVEN-EVEN NUCLEI IN THE ACTINIDE REGION. S. D. Sharma, R. K. Gupta, and P. C. Sood. "Nuclear Physics and Solid State Physics Symposium." Bombay, Atomic Energy Establishment. (1964).

First- and second-order corrections to the rotational spectra, due to the rotation-vibration interaction, are obtained for several actinide nuclei, using the Bohr-Mottelson hydrodynamical model. Comparisons of calculated parameters and experimental results are made.

344

LOW-LYING ENERGY LEVELS OF TRIVALENT CURIUM. B. G. Wybourne. *J. Chem. Phys.*, 40,

1456-7 (1964).

Low lying energy levels for Cm at $F_2 = 280 \text{ cm}^{-1}$ and $\zeta 5f = 2948$ were calculated. For the ground state, a magnetic splitting factor of $g = 1.932$ was calculated.

345

THE INFLUENCES OF PAIRING FORCE ON THE PROPERTIES OF ACTINIDE NUCLEI. T. Wu and C. Tseng. *Wu Li Hsueh Pao*, 21, 915-50 (1965).

By making use of the method for treating the pairing force, which conserves the number of particles, the influences of pairing force on the various properties of actinide nuclei were analyzed, including the intrinsic spectra of odd-A nuclei and even-even nuclei, β -decays and α -decays, etc.

346

ODD-PARITY ROTATIONAL BANDS IN CURIUM-

246. S. F. Stephens, F. Asaro, S. Fried, and I. Perlman. *Phys. Rev. Letter*, 15, 420-4 (1965).

An experimental study is reported of the sequence plutonium-246 ($\beta^-/11d$) americium-246 ($\beta^-/25 \text{ min}$) curium-246. The interpretation of the levels given is discussed. The $K = 2^-$ band observed in curium-246 at 842 keV seems to be somewhat lower in energy and more collective in nature than was expected. The strongest evidence for the collective nature of the 2^- band in curium-246 is the systematic occurrence of such levels at comparable energies in neighboring nuclei. These $K = 2^-$ bands presumably correspond to octupole vibrations similar to the well known $K = 0^-$ band in the Ra-Th-U region.

347

NUCLEAR DECAY PROPERTIES OF HEAVY NUCLIDES PRODUCED IN THERMONUCLEAR EXPLOSIONS. Par and Barbel Events. *Phys. Rev.*, 148, 1192-8 (1966).

The nuclear decay properties of heavy nuclides ($A \leq 257$) produced in two low yield thermonuclear explosions, the Par and Barbel events, were studied. The upper limit for the half life of curium-252 was set at 2 days. The spontaneous fission $T_{1/2}$ of curium-250 was found to be $1.74 \pm 0.24 \times 10^4$ years.

348

L-SUBSHELL RATIOS FOR E2 TRANSITIONS IN DEFORMED HEAVY ELEMENTS. J. H. Hamilton, B. van Nooyen, A. V. Ramayya, W. H. Brantley. "Internal Conversion Processes." J. H. Hamilton (ed); New York, Academic Press (1966).

A study of the L subshell ratios in deformed heavy elements was undertaken to help clarify the systematics of reported deviations. The L subshell ratios of the $2^+ \rightarrow 0^+$ first excited to ground state transition of 42.9 keV in plutonium-240 populated by the α -decay of curium-244 is reported. The spectra are shown and the experimental L subshell ratios for the E2 transitions are given.

B. Alpha-Decay

349

SUMMARY OF THE RESEARCH PROGRESS

MEETING OF AUGUST 16, 1951. S. Shewchuck; AECD-3292; UCRL-1458 (1951). Complex Alpha Structure in Heavy Elements. F. Asaro.

Studies with a magnetic α -ray spectrograph and nuclear films are presented showing the following energy levels in keV above the ground state of the daughter nuclide and the percentages, in parentheses, of α -decays to the given level

curium-242 : 0(73), 44(27).

350

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

The complex alpha particle energy spectrum of curium-242 comprises two groups: one at $6.110 \pm 0.003 \text{ MeV}$, 73 ± 1 percent abundant; and one group $45.9 \pm 1.0 \text{ keV}$ lower in energy, 27 ± 1 percent abundant.

351

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

In curium-242 two α -particle groups were found whose energies and abundances are 6.110 MeV , 73 percent and 6.064 , 27 percent. The α decay scheme is correlated with gamma rays and conversion electrons. The degrees of hindrance of the various α -transitions are discussed with reference to normal trends in even-even nuclei.

352

AN INVESTIGATION OF THE ISOTOPES OF BERKELIUM AND CALIFORNIUM. E. K. Hulet (thesis); UCRL-2283 (1953).

The energies of the α -particles and the α -half-life of curium-245 have been measured.

353

CALCULATION OF INTENSITIES OF FINE-STRUCTURE LINES OF SOME EVEN-EVEN α EMITTERS. P. Falk-Variant and J. Teillac. *Compt. Rend.*, 236, 914-16 (1953).

The intensities of the α -fine structure lines corresponding to the first excited state for which $J = 2$, have been calculated by the equations of Preston and Gamow for curium-242.

354

THE ALPHA SPECTRA OF CURIUM-242, CURIUM-243, AND CURIUM-244. F. Asaro, S. G. Thompson, and I. Perlman; UCRL-2193 (1953).

The α and γ spectra of curium-242, curium-243, and curium-244 have been studied with an α -particle spectrograph and γ -ray scintillation counters.

Curium-242 has α groups of 6.110 (73.7%), 6.066 (26.3%), and 5.964 MeV (0.035%) and γ rays of 44 (0.041%) 100 (0.006%), and 157 keV (0.0027%).

Curium-243 has γ -rays of 104, 226, and 278 keV in coincidence with the 5.777 MeV α -group. Curium-244 has α -groups of 5.798 (75%) and 5.755 MeV (25%). The spectra are discussed relative to α -decay theory and corresponding excited states reached by β -decay processes.

355

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

Some decay characteristics of curium-245, curium-244, and curium-243 are presented. Spectroscopic studies of the low-energy conversion spectra in curium-243 and curium-242 are outlined. A correlation of α -decay energies with α -half lives by means of a generalized Gamow relationship has been obtained. The inward numerical integrations have been completed for curium-242. A delay curve of the α - γ coincidences in the α -decay of curium-243 was made.

356

ALPHA DECAY OF SPHEROIDAL NUCLEI. J. O. Rasmussen and B. Segall. *Phys. Rev.*, 103, 1298-1308 (1956).

The consequences of spheroidal deformation of nuclei on the barrier transmission in α -decay are considered. The cases of the decay of thorium-228 and curium-242 were studied numerically and from them information regarding the probability distribution of α -particles on the nuclear spheroidal surface is obtained. The shift in the surface distributions of thorium-228 and curium-242 may be

explained qualitatively in terms of the order of nucleon orbital filling.

357

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 curium-244 and other actinides was made. An investigation of the gamma-rays associated with curium-242 and curium-244 was also made. Decay schemes have been suggested.

358

PHYSICS REPORT OF THE RESEARCH OPERATION FOR SEPTEMBER, OCTOBER, NOVEMBER 1956; KAPL-1660 (1957).

The α -energy spectrum of curium-244 obtained with a new magnetic alpha analyzer is given.

359

ABSOLUTE ENERGY MEASUREMENT OF ALPHA PARTICLES FROM POLONIUM-210. F. A. White, F. M. Rourke, J. C. Sheffield, R. P. Schuman, and J. R. Huizenga. *Phys. Rev.*, 109, 437-42 (1958). Measurement of the energy (α_0) of the alpha particles from curium-244 leading to the ground state of plutonium-240 was made. A value of 5.8025 ± 0.002 MeV was obtained for this curium-244 α_0 energy.

360

CURIUM-242 α -DECAY. L. N. Kondratév, V. B. Dedov, and L. L. Gol'din. *Izv. Akad. Nauk. SSSR Ser. Fiz.*, 22, 99-100 (1958).

Experimental measurements were made for the α -decay energies for non-spherical nuclei at the second excitation level 4^+ , and the results were compared with the theoretical values. The values were not in agreement for curium-242 and curium-244, and it is shown that the discrepancy is real. The α -levels are tabulated.

361

ON THE ALPHA DECAY OF STRONGLY DEFORMED ODD-A NUCLEI. O. Prior. *Arkiv. Fysik*, 16, 15-18 (1959).

The hindrance factor is correlated with changes in the so-called asymptotic quantum numbers characterizing the single particle orbitals of deformed nuclei for Np through Cf. With $F \sim 1$ to 4, α -transitions are favored in most cases.

362

RADIOACTIVE PROPERTIES OF AMERICIUM-238, AMERICIUM-239, CURIUM-240, AND CURIUM-241.

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

Some electron-capture and α -decay properties of neutron-deficient americium and curium isotopes were investigated. A new α -particle energy of 6.26 MeV was established for curium-240. For curium-241 a new α -particle energy of 5.95 MeV and abundance of 0.96 percent and a γ -ray of 478 keV (97%) were established.

363

ENERGIES OF ALPHA PARTICLES. A. H.

Wapstra. *Nucl. Phys.*, 18, 587-95 (1960).

Energies of α -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.

364

EQUATIONS FOR ALPHA-DISINTEGRATION ENERGIES. Y. P. Varshni and R. N. Bhargava. *Nuovo cimento* (10), 22, 449-56 (1961).

For nuclei with $Z \geq 84$ and $N \geq 128$, it is shown that $(Q - 0.625 Z)$ is a smooth function of the mass number A , where Q is the α -disintegration energy. This relation is utilized to develop two equations for Q . Results by these two equations are compared with those given by Roger's equation.

365

FAVORED ALPHA REDUCED WIDTHS FOR URANIUM, PLUTONIUM, CURIUM, AND CALIFORNIUM. A. Sandulescu and M. Stihl; (IFA/FT/41) (1962).

Reduced widths for favored alpha transitions of even-even isotopes of uranium, curium, plutonium, and californium are calculated for values of the angular momentum equal to 0.2 and 4.

366

SHELL MODEL CALCULATIONS OF ALPHA DECAY RATES OF EVEN-EVEN SPHEROIDAL NUCLEI. H. J. Mang and J. O. Rasmussen. *Kgl Danske Videnskab Selskab. Mat.-fys. Skrifter*, 2, No. 3, 1-39 (1962).

The formulation of the alpha decay rate theory based on the independent-particle shell model wave functions is extended to apply to spheroidally deformed nuclei. The absolute transition probability calculated for curium-242 is about a factor of 60 too low assuming a particular optical model potential for the barrier.

367

MEASUREMENT OF THE α -PARTICLE ENERGIES OF A NUMBER OF CURIUM ISOTOPES. R. B.

Ivanov, A. S. Krivokhatskii, and V. G. Nedovesov. *Izv. Akad. Nauk SSSR, Ser. Fiz.*, 26, 976-8 (1962).

The α -particle energies of curium-242, curium-243, and curium-244 were compared with the α -particle energies of bismuth-212. The α -transitions in curium-242 were found to be 6071 ± 1 and 6115 ± 1 keV, and also 5971 keV for the α transition to the $4+$ level of the daughter nucleus (0.035%). The α transitions in curium-241 were 5763 and 5806 keV, as obtained by comparison with the 5769 keV transition in bismuth-212. The α transition of curium-244 to the $4+$ level of the daughter nucleus turned out to be equal to 5666 keV. The α transitions in curium 243 were 5991, 5784, and 5739 keV.

368

α -DECAY OF CURIUM-245 AND CURIUM-246. L. M.

Belov, B. S. Dzhelepov, R. B. Ivanov, A. S. Krivokhatskii, V. G. Nedovesov, and V. P. Chechev. *Radiokhimiya*, 5, 394-5 (1963).

Tabulated data are given for curium-245 and curium-246 α spectra measured with a magnetic α -spectrometer. The obtained data on energies and intensities of curium-245 and curium-246 α groups are correlated with published data. Levels and characteristics of the curium-245 daughter nucleus are also included.

369

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

By utilization of the recoil properties associated with the alpha decay process, perturbations of α - γ angular correlations in americium-241, americium-243, and curium-243 were observed in a variety of media including vacuum, metals, Mylar, oxides, and liquids.

370

INVESTIGATION OF ALPHA-DECAY OF CURIUM ISOTOPES. B. S. Dzhelepov, R. B. Ivanov, V. G. Nedovesov, and V. P. Chechev. *Zh. Eksperim. i Teor. Fiz.*, 45, 1360-71 (1963).

The α -spectra of curium-242, curium-243, curium-244, curium-245, and curium-246 was investigated with a magnetic α -spectrometer with focusing at an angle $\pi/2$. The energies and intensities of the α -transitions of the isotopes are determined. A possible interpretation of some excited states of

plutonium-239 and plutonium-241 nuclei produced in α -decay of curium-243 and curium-245 is discussed on the basis of the Nilsson scheme. Decay schemes for the curium isotopes are presented.

371

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

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

372

NOTE ON THE Y_{40} DEFORMATION IN HEAVY NUCLEI. K. Harada. *Phys. Letters.*, 10, 80-2 (1964); UCRL-11234.

Perturbation theory is used to calculate the Y_{40} deformation in the α -decay rates of isotopes of radium, thorium, uranium, plutonium, californium, and curium.

373

EFFECT OF NONLOCAL POTENTIAL IN FAVORED ALPHA TRANSITIONS. A. Sandulescu and H. Stefan. *Rev. Roumaine Phys.*, 9, 591-8 (1964).

The effect of the Chaudhury nonlocal interaction potential between an α -particle and a nucleus on the relative intensities of preferred alpha transitions is studied. The odd-A nuclei uranium-233, plutonium-239, americium-243, and curium-243 are studied using a relation between the reduced widths of preferred α -transitions for nuclei of odd and of even A.

374

ALPHA DECAY OF CURIUM-245. A. M. Friedman and J. Milsted. *Phys. Let.*, 21, 179-80 (1966). The alpha spectrum of curium-245 was studied with Au-Si surface barrier detectors.

C. Beta-Decay

375

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

Electron spectra from conversion of low-energy nuclear gamma radiation (up to 350 keV) in several isotopes of the heavier elements, including curium-242, have been investigated.

376

RELATIVE INTENSITY AND INTERPRETATION OF SOME ELECTRON LINES IN CURIUM-243.

J. F. Schooley; UCRL-3038 (1955).

The beta-ray spectrum of curium-243 has been studied. Three K lines of transitions from 277-keV level were observed, and their relative intensities were determined. L conversion lines were not clearly distinguishable but lower limits were set on the K/L conversion ratios. Data were obtained on L conversion lines of the transition from the 321-keV level to the 277-keV level.

377

ENERGY LEVELS OF PLUTONIUM-238 AND PLUTONIUM-239 NUCLEI. S. A. Baranov and K. N. Shlyagin. *Soviet J. Atomic Energy*, No. 1, 51-56 (1956).

A double-focusing magnetic β -spectrometer, a γ -scintillation spectrometer, and a proportional counter were used to study the radiations from curium-242.

378

CONVERSION ELECTRON SPECTRA OF CURIUM-242 AND CURIUM-244. W. G. Smith and J. M. Hollander. *Phys. Rev.*, 101, 746-50 (1956).

The conversion electron spectra of curium-242 and curium-244 have been studied by means of two 180° photographic recording beta-ray spectrographs. Conversion coefficient ratios in the L and M subshells have been measured for several E2 transitions in the decay of these nuclides, and the values obtained compared with theoretical ratios.

379

ENERGY LEVELS OF PLUTONIUM-238 AND PLUTONIUM-239 NUCLEI. S. A. Baranov and K. N. Shlyagin: p. 393-407 of "Soviet Research on the Lanthanide and Actinide Elements, 1949-1957" Part III, Nuclear Chemistry and Nuclear Properties (1959).

The β and γ transitions in the decay of curium-242 were investigated using a β -spectrometer.

380

A STUDY OF THE RADIOACTIVE DECAY OF CURIUM-242 AND CURIUM-244. G. G. Akalaev, N. A. Vartanov, and P. S. Samoilov; NP-14688

(1963).

Electron and γ spectra of Cm isotopes were studied using a 1.5×30 mm strip placed on a 0.1μ celluloid film which permitted the recording of electrons starting at 1 keV. The general spectra for 0.8 to 120 keV electrons exhibited 15 electron lines with a strong burst of Auger electrons appearing in $M_i \rightarrow N_j X_k$ transitions. The mean-energy of the electron transitions was 44.09 keV. The L and M lines were found and estimated.

D. Gamma Decay

381

GAMMA RADIATION FROM THE DECAY OF PLUTONIUM-238, CURIUM-242, AND CURIUM-243. J. O. Newton, B. Rose, and J. Milsted. *Phil Mag.* (8), 1, 981-1002 (1956).

Accurate energy measurements on the γ rays from the decay of curium-242 has been made. Values of 44.03 ± 0.06 , 101.80 ± 0.17 and 157.61 ± 0.3 keV were found for curium-242. Gamma rays having energies of 210 ± 1.5 , 228 ± 2 and 277 ± 2 keV and K-X radiation were found from the decay of curium-243.

382

I. NUCLEAR SPECTROSCOPIC STUDIES IN THE HEAVIEST ELEMENT REGION. II. AN ACCELERATING ELECTRON SPECTROGRAPH. R. G. Albridge, Jr.; UCRL-8642 (1960).

Gamma-gamma coincidence techniques were used to study the electron capture decay of curium-241.

383

GAMMA EMISSION FROM CURIUM-243 AND CURIUM-242. I. A. Baranov, A. S. Krivokhatskii, and A. N. Silant'ev. *Izv. Akad. Nauk. SSSR, Ser. Fiz.*, 28, 1255-6 (1964).

A gamma spectrometer with a resolving power of 10 percent for 662 keV γ rays was used for the determining of the absolute intensity of curium-243 γ emission per α -decay. The α - γ coincidence method permitted reduction of the γ background to a minimum. The absolute intensity of curium-243 γ emission per α -decay at the γ -ray energy of 100, 200, and 277 keV was (42 ± 6) , (11.3 ± 1.7) , and (11.2 ± 1.7) percent respectively. Investigation of γ -spectra for curium-242 indicated that the number of γ quanta per α -decay at $E_\gamma = 44$ keV was $(2.7 \pm 0.5) \times 10^{-2}$ percent.

E. Fluorescence

384

FLUORESCENCE YIELDS FOR THE L-SHELL OF NEPTUNIUM AND PLUTONIUM. G. G. Akalaev, N. A. Vartanov, and P. S. Samilov; NP-14687 (1963). Mean fluorescence yields were determined for the radioactive decay of americium-241, curium-242, and curium-244. The fluorescence and Auger yields for Np and Pu L_1 , L_2 , and L_3 subshells were found.

385

L-FLUORESCENCE YIELDS IN HEAVY ELEMENTS. J. W. Halley and D. Engelkemeir. *Phys. Rev.*, 134, 124-8 (1964).

L-X-ray fluorescence yields for the Ra, Th, U, Pu, and Cm daughters of even-even alpha emitters were measured by three methods. Internal conversion of E2 gammas from the decay of these nuclides produces approximately equal numbers of L_{II} and L_{III} vacancies and practically no L_I vacancies; the yields reported are therefore averages of the L_{II} and L_{III} shell yields. The value found for Cm is 0.531 ± 0.010 .

XXI. HALF-LIFE : SPECIFIC ACTIVITY

386

PREPARATION AND PROPERTIES OF AMERICIUM-242. L. B. Asprey and W. M. Manning; AECD-2505 (ANL-JJK-14B-171) (1948). Americium-241 was bombarded with thermal neutrons and the growth of curium-242 was observed. From the data obtained the half-life of curium-242 was assigned at 150 days.

387

THE HALF-LIFE OF CURIUM-242. G. C. Hanna, B. G. Harvey, and N. Moss. *Phys. Rev.*, 78, 617 (1950).

The activity of curium-242 was measured in a low geometry proportional counter using a 30-channel pulse analyzer. Activities were measured at intervals of about 200 days. The authors estimate the half-life to be 162.5 ± 2 days.

388

NEW ISOTOPES OF BERKELIUM AND CALIFORNIUM. E. K. Hulet, S. G. Thompson, A. Ghiorso, and K. Street, Jr.; UCRL-1224 (1951). A target containing 100 μ g of curium-242, $\sim 5 \mu$ g

of curium-243, and $\sim \mu\text{g}$ curium-244 was bombarded with 35 MeV He-ions, and 16 MeV deuterons. From this work the half-life of curium-245 was estimated to be at least 500 years.

389

THE HALF LIFE OF CURIUM-242. K. M. Glover and J. Milsted; AERE-C/R-1373 (1954).
The half-life of curium-242 has been redetermined by accurate α counting of a pure Cm source over a period of seven months. A value of 162.4 days was obtained which is in very close agreement with the accepted value of 162.5 ± 2 days but the precision has been greatly improved. The standard deviation in half-life from the present results is ± 0.27 days.

390

A CALORIMETRIC DETERMINATION OF THE HALF-LIFE OF CURIUM-242. W. P. Hutchinson and A. G. White; AERE-C/R-1365 (1954).
A calorimetric measurement on a $2\text{-}\mu\text{g}$ sample of curium-242 confirmed the value of 162.5 days previously published for the half-life of this nuclide.

391

ALPHA HALF-LIVES OF CURIUM-244, CURIUM-245, AND CURIUM-246. A. M. Friedman, A. L. Harkness, P. R. Fields, M. H. Studier, and J. R. Huizenga. *Phys. Rev.*, 95, 1501 (1954).
The alpha half-lives of curium-244, curium-245, and curium-246 measured from mass spectrometric analyses of Cm and its Pu daughters are 18.4 ± 0.5 years, $1.15 \pm 0.5 \times 10^4$ years, and $4.0 \pm 0.6 \times 10^3$ years, respectively.

392

HALF-LIVES AND ALPHA ENERGIES OF CURIUM-248 AND CURIUM-246. J. P. Butler, T. A. Eastwood, H. G. Jackson, and R. P. Schuman. *Phys. Rev.* 103, 965-6 (1956).
The new isotope curium-248, the daughter of californium-252, has been separated from a sample of californium. Curium-248 decays by the emission of a 5.054 ± 0.015 MeV α particle with an α -half-life of $(4.7 \pm 0.4) \times 10^5$ years. The spontaneous fission half-life of curium-248 was found to be $4.6 \pm 0.5 \times 10^6$ years. Curium-246 was also observed in the Cm daughters isolated from the Cf sample; the curium-246 decays by the emission of 5.373 ± 0.010 MeV α particle with a half-life of 6620 ± 320 years.

393

CURIUM-249. T. A. Eastwood and R. P. Schuman. *J. Inorg. and Nuclear Chem.*, 6, 261-2 (1958).
The assignment of the 65 min. β -activity in Cm to curium-249 was confirmed by neutron irradiations of Cm containing 86% curium-248. The half-life and maximum β -particle energy of curium-249 were found to be 64 ± 3 min. and 0.86 ± 0.10 MeV, respectively. The yield of curium-249 from the irradiations corresponds to a capture cross section of about 6 barns for curium-248.

394

ELECTRON CAPTURE HALF-LIFE OF CURIUM-243. G. R. Choppin and S. G. Thompson. *J. Inorg. and Nuclear Chem.*, 7, 197-8 (1958).
A sample containing curium-243 was milked for Am after a known growth period. From the relative activity intensities and mass ratios in the Cm sample and the amount of americium-243 which grew in, a value of $1.0 \pm 0.1 \times 10^4$ years was calculated for the electron capture half-life of curium-243.

395

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 minute per microgram.

396

THE α -HALF-LIVES OF CURIUM-244, CURIUM-245, AND CURIUM-246. W. T. Carnall, S. Fried, and A. L. Harkness. *J. Inorg. and Nuclear Chem.*, 17, 12-14 (1961).
The α -half-life of curium-244, determined from specific activity measurements, and the α -half-lives of curium-245, and curium-246, determined by mass spectrometric analysis of Cm and its Pu daughter, are determined to be 17.59 ± 0.06 years, 9320 ± 180 years, and 5480 ± 170 years, respectively.

397

LIFETIME OF THE FIRST $2+$ LEVEL IN CURIUM-244. P. R. Christensen. *Nucl. Phys.*, 37, 482-5 (1962).
The half life of the 42.9 keV $2+$ level in curium-244 is measured using the delayed coincidence method. An exponential decay is directly observed in the

time spectra. The result obtained is $T_{1/2} = (0.97 \pm 0.05) \times 10^{-10}$ seconds.

398

HALF-LIFE DETERMINATIONS BY DIRECT DECAY. K. F. Flynn, L. E. Glendenin, and E. P. Steinberg. *Nucl. Sci. Eng.*, 22, 416-19 (1965). The half-life of curium-242 was measured by direct decay. The method of least squares was used to obtain the best straight-line fit to the data. The results are compared with values in the literature, and average values of existing determinations are given.

399

FISSION PROPERTIES AND CROSS SECTION DATA. R. Avery; ANL-7110 (1965).

The scattering of fast neutrons from a number of elements was investigated; an attempt was made to obtain a theoretical description of the experimental results. The half-lives of americium-241, curium-242, and curium-244 were measured.

XXII. NUCLEAR SPIN

400

HYPERFINE-STRUCTURE MEASUREMENTS ON SOME TRANSURANIC ELEMENTS. R. Marrus; UCRL-8547 (1958).

Hyperfine structure measurements were made on four isotopes in the transuranic region by means of the atomic beam flop-in method. These measurements yielded values of J and g_J of the low lying electronic states of each element and values for nuclear spin of each isotope. The energy separations of the four observed states of curium-242 were determined.

401

CHEMISTRY DIVISION SEMIANNUAL REPORT (for) DECEMBER 1957 THROUGH MAY 1958; UCRL-8369 (1958).

Nuclear spins and magnetic moments are presented for curium-242. Electronic ground states are presented for Cm and fluorescent studies of Cm in LaCl_3 matrix are described.

402

ATOMIC BEAM RESEARCH ON RADIOACTIVE ATOMS. W. A. Nierenberg; UCRL-8553 (1958). The study of nuclear structure by the combined

use of atomic beams and particle detection techniques is discussed. Data are given on the spins of isotopes of Cm and the electronic coupling in Cm.

403

ZEEMAN INVESTIGATIONS OF CURIUM-242.

J. C. Hubbs, R. Marrus, and J. O. Winocur. *Phys. Rev.*, 114, 586-9 (1959).

The atomic beam magnetic-resonance method has been used to investigate 163-day curium-242. The spin of this even-even nuclide is found to be zero. Four low-lying electronic energy levels are found, and the Lande g -factors are measured to be

$$g_{J2} = 2.561 \pm 0.003$$

$$g_{J3} = 2.000 \pm 0.003$$

$$g_{J4} = 1.776 \pm 0.002$$

$$g_{J5} = 1.671 \pm 0.003$$

No direct measurement can be made of the angular momenta of these levels, but other considerations make highly probable the J values indicated in subscripts and arising from the electronic configuration

$$5f^6d^17s^2$$

404

EXCITATION STATE OF ODD NUCLEI WITH SMALL NON-AXIALITY. A. S. Davydov and R. A. Sardaryan. *Vestn Mosk. Univ., Ser. III*, No. 4, 72-82, July-August 1962.

The spin sequence and energy ratio of excited odd nuclei with small non-axiality were calculated using a simple nuclear model without separating the one dimensional and collective excitations. The results are correlated with experimental data. Spins and energies of nuclei with ground state spins of 5/2, and 7/2 uranium-233, thorium-231, curium-245, berkelium-240, and neptunium-237 are tabulated. It was concluded that certain odd-nuclei excitation states (3/2 and 1/2) that ordinarily are interpreted as one dimensional excitations are in reality complex combinations of one dimensional, rotational, and oscillatory excitations.

XXIII. MAGNETIC MOMENTS

405

NUMERICAL SOLUTION OF THE CURIUM-242 ALPHA DECAY WAVE EQUATION. J. O.

Rasmussen and E. R. Hansen. *Phys. Rev.*, 109, 1656-63 (1958).

Numerical integration of the previously derived alpha-decay wave equation, including electric quadrupole coupling terms, was carried out for curium-242 including $l = 0, 2, 4$, and 6 partial waves. The alpha-wave distributions are calculated for a spheroidal nuclear interaction surface. A discussion is made of conditions for the existence of solutions satisfying boundary conditions imposed by alpha-group intensities, and the quadrupole phase shift problem is considered.

406

DETERMINATION OF NUCLEAR DEFORMATION BY THE FINE STRUCTURE OF α DECAY. V. G. Nosov. *Zhur. Eksperim. i Teoret. Fiz.*, 37, 886-7 (1959).

The previously postulated theory of V. G. Nosov on the determination of the surface deformation of daughter nuclei by the fine structure of α -decay was verified by calculations and analysis of quadrupole deformation α_2 for 22 even-even daughter nuclei.

407

ENERGIES OF THE OCTUPOLE COLLECTIVE STATES OF EVEN-EVEN NUCLEI IN THE REGION $228 \leq A \leq 254$. V. G. Soloviev and P. Vogel. *Phys. Letters*, 6, 126-8 (1963).

The energies of the octupole collective oscillations of even-even nuclei in the region $228 \leq A \leq 254$ are calculated in the framework of the superfluid nuclear model using the method of approximate second quantization.

408

ENERGY OF QUADRUPOLE STATES OF STRONGLY DEFORMED EVEN-EVEN NUCLEI. Y. Liu, V. G. Soloviev, and A. A. Korneichuk. *Zhur. Eksperim. i Teoret. Fiz.*, 47, 252-61 (1964).
Energies of the β - and γ -vibrational states of even-even strongly deformed nuclei for $152 \leq A \leq 186$ and $228 \leq A \leq 254$ are calculated.

409

ENERGIES OF EVEN-EVEN STRONGLY DEFORMED NUCLEI IN THE REGION $228 \leq A \leq 254$. V. G. Soloviev and T. Shiklosh; (JINR-P-1568) (1964).

The energies of the two quasi particle excited states of even-even nuclei in the range $228 \leq A \leq 254$ were calculated. The obtained

energies of some collective non-rotational excited states and those of two quasi-particle neutron and proton states up to 2 MeV are tabulated. Data on the structures of gamma vibrational and octupole states are given.

410

STUDY OF THE OCTUPOLE STATES OF EVEN-EVEN STRONGLY DEFORMED NUCLEI. V. G. Soloviev, P. Vogel, and A. A. Korneichuk; (JINR-E-1561) (1964).

Octupole states of even-even nuclei with $\lambda = 3$, $\mu = 0, 1, 2, 3$, in the regions $150 \leq A \leq 186$ and $228 \leq A \leq 254$ are systematically investigated. The energies of states are calculated, and the structure is studied. Comparison with experimental data is made.

XXIV. NUCLEAR RADII

411

THE CONSISTENCY OF NUCLEAR RADII OF EVEN-EVEN NUCLEI FROM ALPHA-DECAY THEORY. I. Perlman and T. J. Ypsilantis. *Phys. Rev.*, 79, 30-4 (1950).

It is possible to obtain a consistent function for nuclear radii if the quantitative treatment of the α -decay process is applied to even-even isotopes of the heavy elements. The nuclear radii so calculated for even-even isotopes of Cm conform to the expression $R = 1.48 A^{1/3} \times 10^{-13}$ cm which defines the normal nuclear radii.

412

CALCULATIONS OF NUCLEAR RADII FROM ALPHA DECAY THEORY TAKING INTO ACCOUNT PAIR CORRELATIONS OF THE SUPERCONDUCTING TYPE. T Veresh. *Izv. Akad. Nauk. SSSR, Ser. Fiz.*, 27, 891-4 (1963).

The influence of pair correlations of the superconducting type on the radii derived from α decay was investigated. Nuclear radii were calculated for heavy element α -emitters ranging from thorium-230 to fermium-254. The surface probability (SP) and the reduced width, δ_0^2 were also determined for these nuclei. Calculations made in this manner led to a decrease of about 2f in nuclear radii and thus did away with the disagreement existing between calculated and experimental nuclear radii determined from α decay. It was found that the α -decay radii can be described by a formula of the type $R = R_0 A^{1/3}$ where R_0 is approximately 1.19 Fermis.

XXV. NUCLEAR CROSS SECTION

413

NUCLEAR DATA SERIES, PART II. J. S. Story; AERE-T/M-97, NRDC-33 (1954).

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

414

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 thermal neutron fission cross sections for curium-243, curium-245, and a few other actinides were measured in the MTR. The cross sections presented for Cm are as follows:

$$^{243}\text{Cm} \quad 690 \pm 50b$$

$$^{245}\text{Cm} \quad 1880 \pm 150b$$

415

DIFFERENTIAL AND INTEGRAL CROSS SECTIONS FOR THE TRANSURANIUM ELEMENTS. S. Pearlstein; BNL-10083 (1964).

Cross sections useful for determining the production of transuranium elements are evaluated using the Breit-Wigner single level formula. Thermal cross sections are presented for several actinides including curium-244.

416

TOTAL NEUTRON CROSS SECTION OF CURIUM-244. R. E. Coté, R. F. Barnes, and H. Diamond. *Phys. Rev.*, 134, B 1281-4 (1964).

The total neutron cross section of curium-244 was studied from 0.01 to about 900 eV with a fast chopper. Resonance parameters are given for many of the approximately 20 resonances observed below 500 eV. Three resonances were assigned to curium-246, but none to curium-245. Although this isotope was about as abundant as the curium-246 in one of the samples studied. The value of the strength functions of curium-244 and curium-246 when combined with other measured values, suggests that this quantity has a maximum near $A = 239$.

417

SURVEY OF NEUTRON CROSS SECTIONS REPORTED FOR $Z \geq 93$. I. Sin-iti, Y. Masaaki; JAERI-4032 (1965).

A survey of the experimental data of the neutron cross sections, resonance parameters, etc. for Np, Pu, Am, Cm, Fm, Es, and Cf is presented. Experimental method, energy range, accuracy of data, and remarks are briefly described for each individual reference. The data are also listed in a tabular form, classified by nuclide.

418

NEUTRON CROSS SECTIONS. Vol III. $Z = 88$ to 98. J. R. Stehn, M. D. Goldberg, R. Wiener-Chasman, S. F. Mughabghab, B. A. Magurno, and V. M. May; BNL-325 (2nd Ed.) (Supple. 2) (Vol III) (1965).

Neutron cross sections are tabulated and shown graphically for elements having $Z = 88$ to 98.

419

CROSS SECTIONS FOR TRANSURANIUM ELEMENTS. S. Pearlstein. *Trans. Am. Nucl. Soc.*, 9, 249-50 (1966).

Resonance parameters reported in BNL-325 were used in a single-level formalism to reconstruct the total and partial neutron cross sections as a function of energy for the nuclides uranium-236, neptunium-237, plutonium-238, plutonium-240, plutonium-241; plutonium-242, americium-241, americium-243, and curium-244. New information is reported for the capture integrals of plutonium-241, americium-241, and curium-244.

420

NEED FOR PLUTONIUM-238 AND CURIUM-244 CROSS SECTION DATA. E. H. Ottewitte, V. Keshishian; CONF-660303, pp. 964-70 (1966).

Both plutonium-238 and curium-244 promise to be excellent radioisotope heat sources. The question of criticality arises when either of these materials is assembled in large quantity. The problem, and information required to calculate the criticality of these systems is reviewed.

421

CROSS SECTIONS FOR TRANSURANIUM ELEMENT PRODUCTION. S. Pearlstein; BNL-982 (1966).

An evaluation of cross sections useful for determining the production of transuranium elements is presented.

422

NEUTRON CROSS SECTIONS FOR CURIUM-244 AND PLUTONIUM-238. A. Prince; GEMP-411 (1966).

Neutron cross sections for curium-244 and plutonium-238 were calculated from below thermal to 14 MeV. A discussion is presented for the possible neutron reactions, the theoretical assumptions made along with their justification, and reasons for choosing certain recommended values.

XXVI. FISSION

A. Spontaneous

423

SPONTANEOUS FISSION IN CURIUM-242. G. C. Hanna, B. G. Harvey, N. Moss, and P. R. Tunncliffe. *Phys. Rev.*, **81**, 466-7 (1951). The spontaneous fission rate of curium-242 was measured as 6.2 per min. per 10^8 curium-242 α disintegrations. The fission half-life was determined to be $(7.2 \pm 0.2) \times 10^6$ years.

424

SUMMARY OF THE RESEARCH PROGRESS MEETING OF JULY 31, 1952. S. Shewchuck; UCRL-1952 (1952). FURTHER CONSIDERATIONS ON SPONTANEOUS FISSION. G. Higgins. A recalculation was made of the spontaneous fission rate of curium-240 reported in UCRL-1772. The new values are

$$4.0 \pm 0.2 \times 10^{12} \text{ fission/gm-hr}$$

and

$$7.9 \pm 0.4 \times 10^5 \text{ yr. half-life.}$$

425

SPONTANEOUS FISSION OF URANIUM-234, PLUTONIUM-236, CURIUM-240, and CURIUM-244. A. Ghiorso, G. H. Higgins, A. E. Larsh, G. T. Seaborg, and S. G. Thompson; UCRL-1772 (1952). The spontaneous fission rates of curium-240 and curium-244 were measured and summarized as follows:

Nuclide	Fissions/g hr	Half-life (years)
^{240}Cm	$1.0 \pm 0.2 \times 10^{11}$	$1.9 \pm 0.4 \times 10^6$
^{244}Cm	$1.4 \pm 0.2 \times 10^{10}$	$1.4 \pm 0.2 \times 10^7$

A graph also shows the exponential dependence of spontaneous fission rate on Z^2/A .

426

CHEMISTRY DIVISION, SECTION C-II SUMMARY REPORT FOR JULY, AUGUST, AND SEPTEMBER

1952. J. R. Gilbreath and O. C. Simpson; ANL-5000 (1953).

The progress of the work on the mass distribution in the spontaneous fission of curium-242 is reported.

427

RADIOCHEMICAL INVESTIGATION OF THE SPONTANEOUS FISSION OF CURIUM-242. E. P. Steinberg and L. E. Glendenin; AECD-3520, ANL-OCS-329 (1953).

The distribution of mass in the spontaneous fission of curium-242 has been investigated by a radiochemical determination of the fission yields of 21 nuclides ranging in mass from 91 to 140. The products of spontaneous fission were isolated by standard radiochemical procedures from a solution of 1.0 to 1.5 mg of 162.5 day curium-242 emitting 7.37×10^{12} α -d/m/mg and providing 4.66×10^5 spontaneous fission/min/mg.

428

CHEMISTRY DIVISION SECTION C-II SUMMARY REPORT FOR OCTOBER, NOVEMBER, AND DECEMBER 1952. J. R. Gilbreath and O. C. Simpson; ANL-5024 (1953).

Progress is reported on the spontaneous fission yields of curium-242.

429

CHEMISTRY DIVISION, SECTION C-II SUMMARY REPORT FOR JULY, AUGUST, AND SEPTEMBER 1952. J. R. Gilbreath and O. C. Simpson; ANL-5000 (1953).

Progress is reported on the work on mass distribution in the spontaneous fission of curium-242.

430

THE AVERAGE NUMBER OF NEUTRONS EMITTED IN THE SPONTANEOUS FISSION OF CURIUM-242. F. R. Barclay and W. J. Whitehouse. *Proc. Phys. Soc. (London)*, **A66**, 447-53 (1953).

The average number ν of neutrons emitted in the spontaneous fission of curium-242 is reported to be 3.0 neutrons per fission.

431

RADIOCHEMICAL INVESTIGATION OF THE SPONTANEOUS FISSION OF CURIUM-242. E. P. Steinberg and L. E. Glendenin. *Phys. Rev.*, **95**, 431-9 (1954).

Spontaneous fission of curium-242 has been investigated by radiochemical determination of the yields of 21 fission products ranging in mass number

from 91 to 140. Fission is observed to be asymmetric. Prominent fine structure is observed in the mass distribution, and an analysis of this phenomenon is made. The distribution of nuclear charge in spontaneous fission appears to be essentially the same as that in low energy induced fission.

432

AVERAGE NUMBER OF NEUTRONS PER SPONTANEOUS FISSION OF CURIUM-244. G. H. Higgins, W. W. T. Crane, and S. R. Gunn. *Phys. Rev.*, 99, 183 (1955).

The average number of neutrons per fission, $\bar{\nu}$, for curium-244 has been measured by the manganous sulphate moderator-absorber system. The value 2.60 ± 0.11 has been determined.

433

SPONTANEOUS FISSION NEUTRONS OF CALIFORNIUM-252 AND CURIUM-244. D. A. Hicks, J. Ise, Jr., and R. V. Pyle. *Phys. Rev.*, 98, 1521-3 (1955).

Further measurements of the multiplicities of prompt neutrons from the spontaneous fission of californium-252 and curium-244 have been made with improved apparatus. In a previous paper [*Phys. Rev.*, 97, 564 (1955)] the calculated multiplicity distribution is incorrect because of an error in the published value $\bar{\nu}$ (californium-252). The corrected results are presented.

434

SPONTANEOUS FISSION HALF-LIFE OF CURIUM-246. S. M. Fried, G. L. Pyle, C. M. Stevens, and J. R. Huizenga. *J. Inorg. and Nuclear Chem.*, 2, 415-16 (1956).

A value of $2.0 \pm 0.8 \times 10^7$ years has been obtained for the spontaneous fission half-life of curium-246.

435

MULTIPLICITIES OF FISSION NEUTRONS. B. C. Diven, H. C. Martin, R. F. Taschek, and J. Terrell. *Phys. Rev.*, 101, 1012-15 (1956).

The average number of neutrons per fission, $\bar{\nu}$, and the respective probabilities of 0, 1, 2 --- neutrons per fission, for spontaneous fission of curium-244 are reported here. The value of $\bar{\nu}$ for curium-244 is 2.810 ± 0.059 .

436

PROBABILITIES OF PROMPT-NEUTRON EMISSION FROM SPONTANEOUS FISSION. D. A. Hicks, J. Ise, Jr., and R. V. Pyle. *Phys. Rev.*, 101, 1016-20

(1956).

The neutron number distributions from the spontaneous fission of seven isotopes have been measured by use of a Cd loaded liquid scintillation tank. The average number of neutrons per spontaneous fission have been found to be 2.65 ± 0.09 for curium-242 and 2.84 ± 0.09 for curium-244.

437

AVERAGE NUMBER OF NEUTRONS PER FISSION FOR SEVERAL HEAVY-ELEMENT NUCLIDES.

W. W. T. Crane, G. H. Higgins, and H. R. Bowman. *Phys. Rev.*, 101, 1804-5 (1956).

The relative average number of neutrons per fission, $\bar{\nu}$ of several spontaneous fissioning nuclides has been measured by making use of the coincidence between fission events and neutrons detected in a LiI(Eu) crystal.

438

TRANSPLUTONIUM ELEMENTS IN THERMONUCLEAR TEST DEBRIS. P. R. Fields, M. H. Studier, H. Diamond, J. F. Mech, M. G. Inghram, G. L. Pyle, C. M. Stevens, S. Fried, and W. M. Manning. *Phys. Rev.*, 102, 180-2 (1956).

The isotopes of Cm, Bk, and Cf found in the thermonuclear debris of the November, 1952, thermonuclear test are discussed. The α -particle energy (5.4 MeV) and the spontaneous fission half-life ($< 1.2 \times 10^7$ years) of curium-246 are reported.

439

SPONTANEOUS-FISSION HALF-LIVES OF CALIFORNIUM-254 AND CURIUM-250. J. R. Huizenga and H. Diamond. *Phys. Rev.*, 107, 1087-90 (1957).

An approximate spontaneous-fission half-life of 2×10^4 years for curium-250 is deduced from a curium sample produced in the November 1952, thermonuclear test.

440

ON SPONTANEOUS FISSION RATES. S. A. E. Johansson. *Nuclear Phys.*, 12, 449-64 (1959).

An attempt is made to explain the irregular behavior of the spontaneous fission half-lives. Predictions of spontaneous fission half-lives are made for the heavier nuclei and the application of these predictions to some problems is discussed.

441

TRIPLE SPONTANEOUS DIVISION OF CURIUM. N. A. Perfilov, Z. I. Solov'eva, R. A. Filov, and

G. I. Khlebnikov. *Doklady Akad. Nauk SSSR*, 136, 581-2 (1961).

A spontaneous triple fission of curium-242 was recorded in fine-grain emulsion. Only long-track α particles were recorded in the photolayer. Calculations of the energy distribution of 182 α -particles with tracks $>30 \mu$ and considering the losses in the filter, $E_{\alpha_{\min}} = 11 \text{ MeV}$.

442

SPONTANEOUS NUCLEAR FISSION. K. A. Petrzhak and G. N. Flerov. *Uspekhi Fiz. Nauk*, 73, 655-83 (1961).

The history of the early work on spontaneous fission in Kurchatovs' laboratory is related. Results are reviewed on the systematics of spontaneously fissioning nuclides such as the plots of half-life vs. Z^2/A for even-even nuclei and half-life vs. neutron number. Mass distributions of fission fragments are given for uranium-238, curium-242, and californium-252. The theory of spontaneous fission is reviewed from the point of view of a deformable liquid drop. Spontaneous fission applications in astrophysics and geophysics are given. The californium-254 spontaneous fission half-life in supernovae is discussed, as is the presence of fission produced xenon in old rare earth minerals. A discussion of transuranic elements is given in which it is pointed out that spontaneous fission of very heavy elements is responsible for the limit of the atomic table. Spontaneous fission competes successfully with other modes of decay and makes production of very heavy elements difficult.

443

SPONTANEOUS FISSION RATES AND THE ROLE OF THE "EXCESS" NEUTRONS IN HEAVY NUCLEI. N. Feather. *Proc. Roy. Soc. A*, 66, 20-32 (1961-62).

Empirical regularities are sought among the experimental data relative to the spontaneous fission rates and the nucleon-pair binding energies of the heavy even-even nuclei. Certain regularities are found; in particular, it appears that the isotopic number D is a significant parameter in relation to these various quantities.

444

LONG-RANGE PARTICLES FROM NUCLEAR FISSION. R. A. Nobles. *Phys. Rev.*, 126, 1508-13 (1962).

A measurement of the probability of emission of

long range particles, which are known to be predominantly alpha particles, gave the following results for spontaneous fission: curium-242, 257 ± 17 ; curium-244, 314 ± 20 fissions per long range particle. The data given indicate a trend of increasing probability of emission of long-range particles with increasing Z^2/A values and decreasing probability with increasing excitation energy in a given nuclide. Present explanations of these apparently contradictory results seem inadequate.

445

SPONTANEOUS FISSION OF SOME HEAVY ISOTOPES. R. Brandt; UCRL-10481 (1962).

A back to back semiconductor counter system was used to study the energy and mass distributions of the fragments in the spontaneous fission of fermium-254, einsteinium-253, californium-254, californium-250, and curium-248.

446

LONG-RANGE ALPHA PARTICLES IN THE SPONTANEOUS FISSION OF TRANSURANIC ELEMENTS. N. A. Perfilov, Z. I. Solov'eva, R. A. Filov, and G. I. Khlebnikov; pp. 145-50 of "Fizika Deleniya Atomnykh Yader" Moscow, Gosatomizdat (1962).

Investigations were made of spontaneous fission in the transuranic region accompanied by the emission of long range alpha particles. The maximum alpha energy observed for curium-242 is $15.5 \pm 1.0 \text{ MeV}$. The ratio determined for the probability of fission accompanied by alphas as compared to the probability for ordinary binary fission is $1/280 \pm 50$ for curium-242.

447

MASS AND ENERGY DISTRIBUTIONS IN THE SPONTANEOUS FISSION OF SOME HEAVY ISOTOPES. R. Brandt, S. G. Thompson, R. C. Gotti, and L. Phillips. *Phys. Rev.*, 131, 2617-24 (1963); UCRL-10506.

A back-to-back semiconductor counter system was used to study the energy and mass distributions of the fission fragments in the spontaneous fission of fermium-254, einsteinium-253, californium-254, and curium-248.

448

THE ENERGY DISTRIBUTION OF FRAGMENTS RESULTING FROM THE SPONTANEOUS FISSION OF CURIUM-244. L. Z. Malkin, I. D. Alkhazov, A. S. Krivokhatskii, K. A. Petrzhak, and L. M. Belov. *At. Energ. (USSR)*, 15, 249-50 (1963).

A gas scintillation counter was used for measurements that were carried out on curium-244, curium-242, and plutonium-238. On the basis of a spontaneous-fission half-life of 7.2×10^6 years it was found that the most probable values for the energy of the light and heavy fragments resulting from the spontaneous fission of curium-244 are (11 ± 4) and (86 ± 3) MeV, respectively.

449

THE SPONTANEOUS FISSION OF CURIUM-244 WITH EMISSION OF A LONG-RANGE α -PARTICLE. L. Z. Malkin, I. D. Alkhazov, A. S. Krivokhatskii, K. A. Petrzhak, and L. M. Belov. *At. Energ. (USSR)*, 16, 148-9 (1964).

The spontaneous fission fragments from curium-244 were counted on a Xe scintillation detector whose walls were covered with a layer of sodium salicylate to convert the UV emission of Xe to visible light. Long range α -particles were counted on a CsI crystal 0.8 mm thick. The curium-244 was purified from lanthanide by elution from a Dowex-50 column with 0.25 M α -hydroxyisobutyrate at a pH of 4. The curium-244 was mounted on an oxidized Al foil with a surface density of 7.1 mg/cm² to discriminate against the 6.15 MeV α -particles of curium-244. The ternary fission of curium-244 was measured continuously for a period of 8 days. A total of 400 spontaneous fission events was recorded with emission of long range α -particles. One ternary fission occurred for each 318 ± 25 binary. The most probable energy of the long range α -particle is 15.8 ± 1.1 MeV, and the maximum energy is 29.0 ± 1.9 . The most probable energy is 100 MeV for the lightest fission fragments and 77 MeV for the heavier fission fragments.

450

SEARCH FOR A SPONTANEOUS FISSION BRANCH IN A METASTABLE STATE OF CURIUM-244. R. Vandenbosch, P. R. Fields, S. E. Vandenbosch, and D. Metta. *J. Inorg. Nucl. Chem.*, 26, 219-34 (1964).

The partial spontaneous fission half-life of the 0.034 second ($I = 6+$) metastable state of curium-244 was found to be $\geq 1.4 \times 10^2$ years. The lifetime is not reduced as much as might be expected from the 1.04 MeV excitation energy of the isomeric state. This hindrance may be due to the intrinsic structure of the metastable state.

451

SPECTRUM OF α PARTICLES IN THE CURIUM-244 SPONTANEOUS TERNARY FISSION. N. A.

Perfilov, Z. I. Solov'eva, and R. A. Filov. *Zhur. Eksperim i Teor. Fiz.*, 46, 2244-5 (1964).

The energy spectra of α -particles in the curium-244 spontaneous ternary fission were measured by means of photographic emulsions and photographic plates. The energy spectra have a Gaussian distribution with a maximum at ~ 15.5 MeV.

452

SPECIFIC IONIZATION ALONG THE TRACK OF URANIUM-235 AND CURIUM-244 FISSION FRAGMENTS. F. NasYROV. *At. Energy. (USSR)*, 16, 449-51 (1964).

A study was made of specific ionization in a mixture of Ar and 5% CH₄ by fission fragments from thermal neutron fission of uranium-235 and spontaneous fission of curium-244. Ion pairs formed per unit path length and energy loss per unit length for light and heavy fission fragments are given for both cases. The specific ionization energy loss dependence on velocity of fragments is presented for uranium-235 fission. The obtained value of W, energy per ion pair, coincides for both light and heavy groups of fragments.

453

NUCLEAR CONSTANTS OF NINE TRANSPLUTONIUM NUCLIDES. D. Metta, H. Diamond, R. F. Barnes, J. Milsted, J. Gray, Jr., D. J. Henderson, and C. M. Stevens. *J. Inorg. Nucl. Chem.*, 27, 33-9 (1965).

The ratios of α -emission to spontaneous fission for isotopes of Cf, Es, and curium-244 are presented. The value for curium-244 was found to be $(7.43 \pm 0.01) \times 10^5$. The partial spontaneous fission half-life of curium-246 is $(1.66 \pm 0.10) \times 10^7$ years.

454

ENERGY SPECTRA OF NEUTRONS AND GAMMA RAYS FROM SPONTANEOUS FISSION OF CURIUM-244. H. T. Richard; DP-949 (1965).

The energy spectrum of the neutrons from the spontaneous fission of curium-244 was measured from 0.5 to 6 MeV. The spectrum shows a maximum of about 0.75 MeV and decreases exponentially above 2 MeV. The energy spectrum of the gamma rays that were emitted within 180 nanoseconds of the spontaneous fission neutrons was measured from 0.1 to 2.5 MeV. The gamma ray spectrum shows a dual-peak maximum at about 200 keV and decreases exponentially above 800 keV.

455

FISSION BARRIERS AND HALF-LIVES OF THE TRANS-RADIUM ELEMENTS. V. E. Viola, Jr. and B. D. Wilkins. *Nucl. Phys.*, 82, 65-90 (1966). Spontaneous fission half-lives and fission barriers are calculated for the elements with $88 \leq Z \leq 108$. The method is semi-empirical. Spontaneous fission stability is predicted to decrease for nuclei just beyond the $N = 152$ neutron subshell but should increase regularly for neutron numbers greater than 160. This effect should become quite strong as the $N = 184$ neutron subshell is approached, resulting in a number of experimentally observable isotopes in the mass region $A \approx 270 - 290$. The results are discussed briefly with regard to problems of nucleosynthesis and heavy element generation in stellar reactions.

B. Induced

456

THE CRITICALITY OF CURIUM-244. V. Keshishian, E. H. Ottewitte and C. L. Dunford. *Trans. Amer. Nucl. Soc.*, 8, 549-50 (1965). Curium-244 promises to be an excellent radio-isotope heat source. The question of criticality arises for large quantities of curium-244. The critical mass of curium-244 was calculated as a function of its density. The number of neutrons emitted in the induced fission of curium-244 is equal to $\nu(E) = 3.23 + 0.13 E$ (MeV). The critical mass of an unreflected curium-244 sphere is approximately one-half that of plutonium-238 which is about equal to that of plutonium-239.

457

DEFORMATION OF THE TRANSITION-STATE NUCLEUS IN ENERGETIC FISSION. R. F. Reising, G. L. Bate, J. R. Huizenga. *Phys. Rev.*, 141, 1161-6 (1966). Fission-fragment anisotropy ratios, $W(170^\circ)/W(90^\circ)$, from fission induced by 42.8 MeV helium ions were measured for the targets, thorium-230, thorium-232, protactinium-231, uranium-233, uranium-234, uranium-235, uranium-236, uranium-238, neptunium-237, plutonium-239, plutonium-240, plutonium-242, americium-241, americium-243, curium-244, and californium-249. By modifying values of the fission-to-neutron level-width ratio Γ_f/Γ_n from the literature, first chance anisotropies were calculated to permit comparison of the targets at nearly uniform and rather high excitation energies.

C. General

458

DYNAMIC TREATMENT OF THE FISSION OF HEAVY NUCLEI. S. Flügge and K. Woeste. *Sitzber. Ges. Beförder. ges. Naturw. Marburg*, 75, 46-53 (1952). The fission of heavy nuclei is described on the basis of the drop model. The potential energy terms E_C and E_S of the deformed drop are derived from a development of the spherical function in a purely statistical manner. The kinetic energy of the system and the motion equation are derived dynamically. The constants are expanded to terms of the 4th order. The threshold energies of a few of the actinides, including curium-242, are tabulated.

459

AN EXPERIMENTAL STUDY OF FISSION IN THE ACTINIDE ELEMENTS. A. Smith, P. Fields, A. Friedman, S. Cox and R. Sjöblom; A/CONF. 15/P/690 (1958). The results of a recent experimental study of the fission properties of some actinide elements are presented. The study includes: fission fragment kinetics, fission neutron spectra, prompt gamma rays from fission, and delayed neutrons from fission. The kinematic distribution of the fission fragment modes of curium-242, curium-244, and other actinides were determined.

460

AN EMPIRICAL FORMULA FOR THE AVERAGE NUMBER OF FISSION NEUTRONS. L. D. Gordeeva and G. N. Smirenkin. *At. Energy, (USSR)*, 14, 530-4 (1963).

The instantaneous fission energy E_F , which is equal to the difference in energies between the fissioning nucleus and the fission fragments which in turn is distributed between the kinetic energy of the fission fragments E_K and the excitation energy E_X of the fission fragments which in turn is distributed between the prompt neutrons and prompt γ quanta. $E_K + E_X = E_K + \nu E_v + E_\gamma$. Here, ν is the number of neutrons; E_v is the average energy for the removal of a neutron from the fission fragment, and E_γ is the total energy of the prompt γ -quanta. Values of $\bar{\nu}_T$ were computed for the isotopes of Th, Pa, U, Np, Pu, Am, and Cm, and agree within 3 percent when compared with known experimental values of $\bar{\nu}_T$.

461

SYSTEMATICS OF FISSION ASYMMETRY WITH RESPECT TO NUCLEAR CHARGE AND NEUTRON CONTENTS. M. Talat-Erben and B. Gueven; CNAEM-12 (1963).

Swiatecki's asymmetry formula was applied to charge and neutron asymmetry in fission. The average proton and neutron contents were determined from the asymmetry equations for the fission fragments of the compound nuclei thorium-233, uranium-234, uranium-238, uranium-239, curium-242, and californium-252. Predictions can be made concerning the average charge and neutron contents of the two fragments for any fissile nuclide, if these quantities are known for any other reference nuclide.

462

QUASI-CLASSICAL MODEL OF TRIPLE FISSION. B. T. Geilikman and G. I. Khlebnikov (USSR Sovet Ministrov. Gosudarstvennyi Komitet po Ispol'zovaniyu Atomnoi Energii. Institut Atomnoi Energii im Kurchatova, Moscow); IAE-562 (1964); ANL-Trans-68.

The classical model of triple fission with departure of α -particles, which considers the distribution of α -particles over energies in the fissioning nucleus, was studied. The energies and angular distributions of the departing α -particles were calculated. The theoretical distributions agree satisfactorily with the experimental data.

XXVII. ISOTOPE PRODUCTION

463

NUCLEAR PROPERTIES OF TRANSPLUTONIUM ISOTOPES. G. T. Seaborg; AECD-2376 (ANL-JJK-14A-161) (December 1947).

The radioactive properties of the transplutonium isotopes Am and Cm are discussed and the ways in which they are produced are given. The curium isotopes considered include curium-238, 239, 240, 241, 242, 243, 244, 245, 246, and 247.

464

THE NEW ELEMENT CURIUM (ATOMIC NO. 96). G. T. Seaborg, R. A. James, and A. Ghiorso; AECD-2182 (January 1948).

Two isotopes of the element, atomic number 96, were produced by the He-ion bombardment of plutonium-239. These isotopes are:

1. $^{96}_{242}$ which emits α -particles with a range 4.75 ± 0.1 cm in air (6.1 MeV) and decays with a half-life of 5.0 ± 0.1 mo;

2. $^{96}_{240}$ which emits alpha particles with a range of 4.95 ± 0.1 cm in air (6.3 MeV) and decays with half-life of 26.8 ± 0.3 days.

This element was also produced by neutron irradiation of americium-241. The name curium (Cm) is proposed for element 96. Chemical investigations indicate that the most stable state is the III state.

465

ISOTOPES OF THE NEW ELEMENT, CURIUM (ATOMIC NO. 96). R. A. James (thesis); AECD-2224 (UCRL-99) (1948).

Three isotopes of element 96 were produced by the He-ion bombardment of Pu. The tracer chemistry reveals only a very stable trivalent oxidation state. The isotopes produced are:

1. Curium-242; alpha-emitting with range 4.75 ± 0.1 cm in air (6.1 MeV) $T_{1/2} = 5.0 \pm 0.1$ mo.;

2. Curium-240; alpha emitting with range 4.95 ± 0.1 cm in air (6.3 MeV); $T_{1/2} = 26.8 \pm 0.3$ days;

3. Curium-241; orbital electron capture, $T_{1/2} = 55 \pm 15$ days.

466

THE RADIATION CHARACTERISTICS OF CURIUM-240 AND CURIUM-241. G. H. Higgins and K. Street, J.; UCRL-1374 (1951).

The Cm isotopes of mass numbers 240, 241, and 242 were produced in varying ratios by bombarding plutonium-239 with He ions. Activities were observed and assigned as follows:

Isotope	$T_{1/2}$	MeV
^{240}Cm	27 day	6.25 α
^{241}Cm	35 day	5.89 α and K capture
^{242}Cm	162 day	6.08 α

The ratio of the number of electron capture disintegrations to the number of α disintegrations in the 5.89 MeV group was calculated to be between 360 and 460.

467

AN INVESTIGATION OF THE ISOTOPES OF AMERICIUM AND CURIUM. G. H. Higgins (thesis);

UCRL-1796 (1952).

Isotopes of Cm with mass numbers less than 242 have been produced by cyclotron bombardment techniques, and several of their nuclear properties have been investigated. The partial alpha half-lives of curium-241, and curium-240 and the partial half-life for spontaneous fission of curium-240 were measured. The α -decay daughter of curium-238 was found and evidence for curium-239 (~10 hour electron capture activity) has been presented. Conditions for the separation of the plus three actinides by selective elution from ion exchange resin with citric acid has been included.

468

THE COMPOSITION OF PLUTONIUM, AMERICIUM, AND CURIUM RESULTING FROM IRRADIATION OF AMERICIUM-241 IN A HIGH NEUTRON FLUX. P. Fields and M. A. Weiss; ANL-WMM-1140 (1953). The isotopic composition of americium and the conversion of americium-241 to curium-242 as a function of time of irradiation in a high neutron flux has been calculated using the known cross sections.

469

ISOTOPES OF CURIUM, BERKELIUM, AND CALIFORNIUM. E. K. Hulet, S. G. Thompson, and A. Ghiorso. *Phys. Rev.*, 95, 1703-4 (1954). A general discussion and review of production methods, half-lives, and radioactivity of the new isotopes californium-247, californium-248, curium-245, and berkelium-246 are presented.

470

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). Mass spectrometric analyses show the presence of curium-246 and curium-247 in Cm samples produced from neutron irradiated plutonium. The pile neutron capture cross sections of americium-243, curium-244, curium-245, curium-246 are 115 ± 20 , 25 ± 10 , 200 ± 100 , and 15 ± 10 barns, respectively. The alpha-disintegration half-life of curium-244 is calculated to be 19.2 ± 0.6 years.

471

THE ISOTOPE OF CURIUM HAVING A MASS NUMBER OF 238. G. T. Seaborg and K. Street, Jr. U. S. Patent 2,698,290 (December 28, 1954). A method of producing curium-238 by bombarding

plutonium-239 with 80 MeV α -particles from a cyclotron and chemically separating the Cm from the complex mixture of products including several Cm isotopes, the original target material, and a variety of lanthanide fission products are described.

472

REVIEW OF THE JOINT AECL-KAPL STUDIES OF THE TRANSURANIUM ELEMENTS. J. P. Butler, T. A. Eastwood, H. G. Jackson, T. L. Collins, M. E. Jones, F. M. Rourke, and R. P. Schuman; KAPL-1781 (1957).

A nuclear study has been made of the transuranium elements produced by the long-term irradiation of Pu in the MTR. Data are given on several of the actinide elements including curium-243, curium-244, curium-245, curium-246, curium-247, curium-248, and curium-249.

473

TRANS-PLUTONIUM ISOTOPE BUILDUP BY NEUTRON IRRADIATION OF PLUTONIUM. F. P. Brauer and H. H. Burley; HW-58596 (1958).

Graphs suitable for estimating the plutonium and trans-plutonium isotopic content of irradiated plutonium reactor fuel of various initial isotopic compositions are presented. The curves were computed for a neutron flux of $5 \times 10^{13} \text{ n/cm}^2/\text{sec.}$ and for irradiation times up to ten years.

474

CROSS SECTION FOR PRODUCTION OF CURIUM-240 BY IRRADIATION OF THORIUM-232 WITH C^{12} AND C^{13} IONS. L. I. Guseva, B. F. Myasoedov, N. I. Tarantin, and K. V. Filippova. *Zhur. Eksperim. i Teoret. Fiz.*, 37, 973-7 (1959).

The dependence of the cross sections of the reactions $^{232}\text{Th} (^{12}\text{C}, 4\text{n}) ^{240}\text{Cm}$ and $^{232}\text{Th} (^{13}\text{C}, 5\text{n}) ^{240}\text{Cm}$ on the energy of the bombarding particles was determined by irradiating a stack of thin foils and subsequently analyzing the reaction products. The curves for the reaction cross sections have distinct peaks characteristic of the reactions of evaporation of neutrons from a compound nucleus. The peak value of the cross sections for the reactions $^{232}\text{Th} (^{12}\text{C}, 4\text{n}) ^{240}\text{Cm}$ and $^{232}\text{Th} (^{13}\text{C}, 5\text{n}) ^{240}\text{Cm}$ are respectively $8 \times 10^{-29} \text{ cm}^2$ and $1.8 \times 10^{-29} \text{ cm}^2$. Cross sections for reactions involving evaporation of neutrons do not depend on Z^2/A in a simple manner.

475

EFFECT OF NON-THERMAL CAPTURE ON CALIFORNIUM PRODUCTION IN THE HIFR.

II. C. Claiborne; CF-59-12-16 (1959).

Non-thermal neutron capture was estimated to enhance the production rate of californium-252 in the HFIR by 50 to 100 percent depending on the curium-248 cross section. The optimum ratio of non-thermal to thermal neutron flux was very dependent on the curium-248 thermal cross section.

476

MTR-ETR TECHNICAL BRANCHES QUARTERLY REPORT FOR PERIOD ENDING JUNE 30, 1959; IDO-16561 (1959).

The amounts of reaction products in high burnout irradiations of several actinides including curium-244 have been calculated and a typical yield curve prepared for each nuclide.

477

CALCULATIONS OF THE COMPOSITION OF REACTOR-IRRADIATED HEAVY NUCLIDES.

R. P. Schuman and R. L. Tromp; IDO-16571 (1959).

Calculations were made of the compositions of reactor irradiated actinides, including curium-244. Thermal fluxes of 5×10^{13} , 2×10^{14} , and 1×10^{15} n/cm²/sec. were assumed. Calculation methods, assumptions concerning cross sections, and possible methods of producing specific nuclides are discussed.

478

STUDIO SULLA PRODUZIONE DI AMERICIUM-243 E CURIUM-244 MEDIANTE IRRAGGIAMENTO DI PLUTONIUM-239 IN REATTORI TERMICI.

(Study of the Production of Americium-243 and Curium-244 by Irradiation of Plutonium-239 in Thermal Reactors) G. Restelli and E. Segré; CNI-89 (1960).

Calculations are carried out for the amounts of plutonium-239, plutonium-240, plutonium-241, plutonium-242, americium-243, and curium-244 produced by long term irradiations of plutonium-239 in thermal reactors with $\phi_{th}^{avg} = 5 \times 10^{13}$, 3×10^{14} , and 5×10^{14} n/s/cm².

479

BUILDUP OF CALIFORNIUM-252 AND INTERMEDIATE ISOTOPES FROM CURIUM-244 IN A HIGH FLUX. S. E. Vandenbosch and P. R. Fields; ANL-6252 (1961).

The amount of californium-252 and intermediate isotopes that could be made from curium-244 in a reactor was calculated. The number of atoms of

heavy Cm isotopes per initial curium-244 atom is given as a function of total flux intervals.

480

IDENTIFICATION OF CURIUM-242 IN IRRADIATED NEPTUNIUM. G. A. Carothers; DP-603 (1961).

Curium-242 was experimentally identified as a minor product of the irradiation of neptunium-237 in a nuclear reactor.

481

CALCULATION OF PRODUCTION AND PRICING OF TRANSURANIUM ISOTOPIC HEAT SOURCES.

D. E. Deonigi, E. T. Merrill, and A. F. McConiga. *Trans. Am. Nucl. Soc.*, 6, 420-1 (1963).

Calculations of production of three heat source transuranium isotopes, plutonium-238, curium-242, and curium-244 are described.

482

CALCULATIONS OF YIELDS OF PRODUCTS IN HIGH-FLUX NEUTRON IRRADIATIONS OF HEAVY ELEMENT SAMPLES. J. Milsted, P. R. Fields, and D. N. Metta; ANL-6756 (1963).

Calculations have been made of the build-up of higher nuclides in samples of various heavy-element starting materials, at neutron fluxes ranging from 4×10^{13} to 1×10^{16} n/cm²/sec., including the flux expected from the HFIR reactor at Oak Ridge (namely, 5×10^{15} n/cm²/sec.).

483

EVALUATION OF THE ISOTOPIC COMPOSITION OF HEAVY ELEMENTS ($Z \geq 92$) IN IRRADIATED BR2 FUEL ELEMENTS. A. Siebertz; BLG-231 (1963).

The amount of heavy nuclides from uranium-234 to curium-245 in the BR2 fuel elements during and after irradiation were estimated. Two typical irradiation cycles were considered. Calculation methods and assumptions concerning the effective cross sections of the heavy nuclides in the BR2 are given.

484

THE PRODUCTION OF CURIUM BY NEUTRON IRRADIATION OF AMERICIUM-241. D. C.

Stewart, R. W. Anderson, and J. Milstead; ANL-6933 (1964).

A computer study was made of the production of curium-242. Calculated yields and compositions of Cm isotope fractions are shown from medium to high fluxes. It is shown that better purity of curium-

242 results if lower fluxes are used. Curium composition data are tabulated for use in short irradiation at two low fluxes. Supplementary irradiation data (α -activity, helium accumulation, neutron emission, heat production) are given for americium-241. The production of very heavy elements from americium-241 is considered.

485

TRANSURANIUM-ELEMENT PRODUCTION IN EPITHERMAL REACTORS. L. G. Epel, J. Chernick, B. Manowitz, and W. C. Winsche. *Trans. Am. Nucl. Soc.*, 8, 57-58 (1965).

The production of curium-244 from the irradiation of plutonium-239 can be achieved more economically in an epithermal neutron flux than in a purely thermal spectrum. Calculations indicate that in an epithermal flux, build up is more rapid, and the equilibrium concentrations are higher.

486

TRANSURANIUM ELEMENT PRODUCTION IN EPITHERMAL REACTORS. L. G. Epel, J. Chernick, B. Manowitz, and W. E. Winsche; BNL-9271 (1965).

An investigation was made of the effects of hardening the neutron spectrum on the yield of the two transuranium nuclides plutonium-238 and curium-244. Three spectra were utilized for each of the two nuclide chains and yields of the desired products were calculated. It was found that a hardened spectrum which took advantage of the resonance capture integrals of some of the isotopes in the chain enhanced the yield significantly. Epithermal reactors will also produce transplutonium elements more economically.

487

PRODUCTION OF VERY HEAVY ELEMENTS IN THERMONUCLEAR EXPLOSIONS-TEST BARBEL. *Phys. Rev. Letters.*, 14, 962-5 (1965); Los Alamos Radiochemistry Group, LA-DC-7064 (1965).

The Barbel device for producing heavy elements contained a uranium-238 target in its high-neutron-flux region. Information was obtained by α - β -, and fission measurements on the individual elements. Data on the abundance of isotopes up through mass 250 were obtained by mass spectrometric measurements on Pu, Am, and Cm fractions. A table of data is included.

488

PRODUCTION OF THE HEAVIEST ELEMENTS BY MULTIPLE NEUTRON CAPTURE. J. Milsted,

P. R. Fields, and D. N. Metta. *Nucl. Appl.*, 1, 136-44 (1965).

Calculations were made showing the build up of higher nuclides in samples of various heavy element starting materials at neutron fluxes ranging from 4×10^{13} to 1×10^{16} n/cm²/s. Attempts were made to estimate the yields of the heavier Fm isotopes and of mendelevium-259 by means of the nuclear properties predicted from systematics.

489

THE COMPOSITION OF TRANSURANIUM ELEMENTS. C. Keller, *Atompraxis*, 12, 13-23 (1966).

Experimental techniques are described for the production of transuranium elements. It was concluded that weighable amounts of the transuranium elements up to fermium can be prepared only by long-time irradiation of U or Pu in high flux reactors. Nuclear reactions with heavy ions and, to a smaller extent, nuclear explosions, appear to be promising for synthesis of transcurium elements and isotopes.

490

RADIOISOTOPE PRODUCTION BY NUCLEAR EXPLOSION. M. Gerrard. *Isotop. Radiat. Technol.*, 3, 315-16 (1966).

The distribution of curium-242, americium-241, plutonium-239, thorium-228, polonium-210, thallium-204, and hydrogen-3 from a nuclear explosion in a salt bed and the means by which these nuclides might be recovered are discussed.

491

ADDITIONAL YIELD DATA FOR TRANSPLUTONIUM ELEMENT PRODUCTION IN THERMAL REACTORS. J. Milsted, E. S. Marcias, L. J. Basile, R. W. Andersen, D. C. Stewart; ANL-7096 (1966).

Calculated yields of the heaviest nuclides as formed in various Pu targets by multiple neutron capture in thermal reactors are presented. Yields of plutonium-242, americium-243, curium-244, curium-246, curium-252 are given for neutron fluxes of 7×10^{13} , 3×10^{14} , 2×10^{15} , and 1×10^{16} n/cm²/sec.

492

YIELD OF CURIUM-244 IN THE SRP HIGH FLUX REACTOR. E. K. Dukes, R. L. Folger, G. G. Carothers, C. J. Banick, and M. Y. Donnan; DP-1046 (1966).

Comprehensive destructive analysis of a plutonium-

242 target slug that was irradiated to 3.7×10^{22} n/cm² in the Savannah River Plant high flux reactor confirmed the predicted Cm yield. The measured Cm yield was 0.276 g for each gram of plutonium-242 irradiated.

XXVIII. INSTRUMENTS.

493

PART A. AN X-RAY SPECTROMETER FOR USE IN RADIOACTIVITY MEASUREMENTS. THE L X-RAYS OF NEPTUNIUM AND PLUTONIUM. PART B. SOME LIGHTER ISOTOPES OF ASTATINE. G. W. Barton; AECD-3010. UCRL-670 (1950).

The plutonium L-X-rays from curium-242 have been measured.

494

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. From data obtained with this apparatus, a decay scheme is postulated for curium-242.

495

AN ELECTROSTATIC METHOD FOR THE RECOIL MEASUREMENT OF SUB-NANOSECOND NUCLEAR LIFETIMES. T. Novakov, J. M. Hollander, and R. L. Graham. *Nucl. Instr. Methods*, 26, 189-200 (1964); UCRL-10875.

The use of a high resolution beta-ray spectrometer to measure short life-times in nuclei recoiling from nuclear reactions on α -decay is described. The 42.8 keV transition in plutonium-240 following α -decay of curium-244 was studied in detail as an illustrative example.

496

NEUTRON COUNTER FOR ANALYTICAL APPLICATIONS. T. R. Herold and H. P. Holcomb; DP-1035 (1966).

A neutron counter was developed to assay rapidly and non-destructively such radio nuclides as curium-244 and californium-252 by counting the spontaneous fission neutrons that these isotopes emit. The counting efficiency is 4 percent. The reliable detection limit is 4×10^{-7} g for curium-244 and 1.2×10^{-12} g for californium-252.

XXIX. MISCELLANEOUS

497

MASS-SPECTROGRAPHIC IDENTIFICATION OF CURIUM-243 AND CURIUM-244. F. L. Reynolds, E. K. Hulet, and K. Street, Jr.; AECD-2899 (1950). The isotopes curium-243 and curium-244 have been identified mass-spectrographically. From the energy balances involved, curium-243 is expected to be slightly unstable with respect to orbital electron capture, or possible β -stable. The α -decay systematics predicts that curium-244 is stable with an α -decay half-life of years.

498

SUMMARY OF THE RESEARCH PROGRESS MEETING-JULY 6, 1950. H. P. Kramer; UCRL-858 (1950).

Experimental work concerning X-rays of Cm was discussed.

499

SUMMARY OF THE RESEARCH PROGRESS MEETING OF SEPTEMBER 13, 1951. S. Shewchuck; UCRL-1479 (1951).

Data on the neutron-deficient isotopes of Cm are presented.

500

INVESTIGATIONS OF ALPHA RADIOACTIVITY USING NUCLEAR EMULSIONS. D. C. Dunlavey, (thesis); UCRL-1911 (1952).

Methods are described for using nuclear emulsions for α particle counting and for the observation of α -electron coincidences. A discussion is given of investigation of α emitters by means of nuclear emulsions. The assignment of a Cm isotope having an α energy of 6.5 MeV has been corroborated as curium-238 by showing it to be the parent of plutonium-234.

501

NEUTRON YIELDS FROM ACTINIDE-BERYLLIUM ALLOYS. O. J. C. Runnalls and R. R. Boucher. *Can. J. Phys.*, 34, 949-58 (1956).

The neutron yields from the reaction $^9\text{Be}(\alpha, n)^{12}\text{C}$ have been measured for several actinide-beryllium alloys. The values for the Be thick target neutron yield derived from the measurements on alloys containing plutonium-238, americium-241, and curium-242, are 60 ± 2 , 74 ± 2 , and 112 ± 3 neutrons per million α particles, respectively.

502

LIGHT ISOTOPES OF BERKLIUM AND CALIFORNIUM. A Chetham-Strode, Jr., (thesis); UCRL-3322 (1956).

An experimental study has been made of the light isotopes of Bk and Cf. The new isotopes berkelium-244, berkelium-247, berkelium-248, and californium-244 were identified and their properties studied. Further 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.

503

REPORT OF THE CHEMISTRY AND CHEMICAL ENGINEERING SECTION FOR NOVEMBER, DECEMBER 1955, JANUARY, 1956; KAPL-1491 (1960).

Information is given on some nuclear properties of curium-246 and curium-247.

504

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

Calculation of barrier penetrabilities, reduced widths, and hindrance factors for odd-mass α particle emitters (curium-241, curium-243, and curium-245) is made by using the diffuse exponential nuclear potential derived from optical-model analysis of alpha elastic-scattering data. The calculations are made on the same basis as for even-even alpha emitters.

505

RECOIL STUDIES OF HEAVY ELEMENT NUCLEAR REACTIONS. PART II. B. G. Harvey, W. H. Wade, and P. F. Donovan. *Phys. Rev.*, 119, 225-9 (1960).

Angular distributions and ranges of recoils from the reaction curium-244 ($\alpha, 2n$) californium-246 were measured.

506

PERTURBATION OF ALPHA-GAMMA ANGULAR CORRELATIONS IN TRANSURANIUM ISOTOPES. E. Flamm; UCRL-9325 (1960).

The perturbation of α - γ angular correlations was studied in americium-241, americium-243, and

curium-243 by observing α -particles in coincidence with γ rays from daughter nuclei recoiling into vacuum, air, Al, Ag, Fe, Mylar, H₂O, and C₆H₆. From the observed correlations in curium-243, and lower limit can be set for the E2/M1 mixing ratio S^2 of the 278 keV γ ray in plutonium-239 and the sign of δ is determined.

507

NUMERICAL SOLUTIONS OF THE "SUPERCONDUCTIVITY EQUATIONS" FOR NUCLEI IN THE TRANSURANIC REGION. Z. Szymanski; (PAN-230/VII) (1961).

The variational formalism of superconductivity theory is applied to nucleon-nucleon interactions in nuclei. The formalism is used to calculate the equilibrium deformation of even-even nuclei with proton number Z and neutron number N such that $86 \leq Z \leq 98$ and $130 \leq N \leq 150$.

508

RADIOACTIVITY AND NUCLEAR STRUCTURE. NUCLEAR CHEMISTRY DIVISION ANNUAL REPORT 1965. I. Perlman, J. M. Hollander, F. Reynolds, and B. B. Cunningham; UCRL-16580 (1966).

Research progress is reported on curium-246 odd-parity rotational bands, wave functions for nuclear pairing-force problems, etc.

509

WESTCOTT PARAMETERS DERIVED FROM THE RBU BASIC LIBRARY FOR A Δ -4 CUTOFF. R. C. Liikala; HW-77389 (1966).

Westcott parameters were derived for the following isotopes: uranium-235, uranium-236, uranium-238, plutonium-239, plutonium-240, plutonium-241, plutonium-242, americium-241, americium-242, americium-243, curium-242, curium-243, and curium-244. Results are presented in tabular form.

510

THE NUCLEAR PROPERTIES OF THE HEAVY ELEMENTS. E. K. Hyde, I. Perlman, and G. T. Seaborg. Vol. I, II, III. Prentice-Hall, Englewood Cliffs, N. J. (1964).

A comprehensive treatment of the nuclear properties of the actinide elements including decay schemes, half lives, nuclear systematics, and fission phenomena.

ORGANIZATION SYMBOLS

SYMBOL	FULL TITLE OF ORGANIZATION		
A	Calif. Univ., Berkeley, Radiation Lab.	CL	University of Chicago, Metallurgical Laboratory.
AE	Aktiebolaget Atomenergi, Stockholm.	CN	University of Chicago, Metallurgical Laboratory.
AECD	U.S. Atomic Energy Commission Declassified Document.	CONF	Serial number assigned to conference cataloged by the AEC Division of Technical Information Extension.
AECL	Atomic Energy of Canada Ltd., Chalk River, Ontario.	COO	Chicago Operations Office, AEC.
AEC-tr	Division of Technical Information Extension, AEC.	CRC	National Research Council of Canada, Atomic Energy Project, Chalk River, Ontario.
AECU	Division of Technical Information Extension, AEC.	CRDC	National Research Council of Canada, Atomic Energy Project, Chalk River, Ontario.
AEDC	Arnold Engineering Development Center, Arnold AF Station, Tenn.	CRP	National Research Council of Canada, Atomic Energy Project, Chalk River, Ontario.
AEEW	United Kingdom Atomic Energy Authority, Research Group, Atomic Energy Establishment, Winfrith, Dorset, England.	CRRP	National Research Council of Canada.
AERE	United Kingdom Atomic Energy Authority, Atomic Energy Research Establishment, Harwell, Berkshire, England.	CT	University of Chicago, Metallurgical Laboratory.
AFSWC	Air Force Special Weapons Center, Kirtland AFB, New Mexico.	DASA	Defense Atomic Support Agency, Washington, D.C.
ANL	Argonne National Laboratory, Argonne, Ill.	DEG-Report	United Kingdom Atomic Energy Authority, Development and Engineering Group, Risley, Lanes, England.
BC	Calif. Univ., Berkeley, Radiation Lab.	DP	DuPont de Nemours (E.I.) and Co., Wilmington, Del.
BMI	Battelle Memorial Inst., Columbus, Ohio.	ERDL	Engineer Research and Development Labs., Fort Belvoir, Va.
BNL	Brookhaven National Laboratories, Upton, N. Y.	EUR	European Atomic Energy Community, Nuclear Research Center, Ispra, Italy.
CAPE	Division of Technical Information Extension, AEC (to identify engineering materials).	EURAEC	United States - Euratom Joint Research and Development Program.
CC	University of Chicago, Metallurgical Laboratory.	GEAP	General Electric Co.
CEA	France. Commissariat a-l'Energie Atomique, Paris.	HW	General Electric Co. Hanford Atomic Products Operation, Richland, Wash.
CEI	National Research Council of Canada, Atomic Energy Project, Chalk River, Ontario.	HW-SA	General Electric Co. Hanford Atomic Products Operation, Richland, Wash.
CF	University of Chicago, Metallurgical Laboratory.	IA	Israel Atomic Energy Commission, Rehovath, Israel.
CF-(yr-mo)	Oak Ridge National Laboratory, Tennessee.	IDO	Idaho Operations Office, AEC.
CH	University of Chicago, Metallurgical Laboratory.	IGO	Gt. Britain, Windscale Works, Sellafield, Cumb., England, Industrial Group Report.
CI	National Research Council of Canada.	IGR	Gt. Britain, Windscale Works, Sellafield, Cumb., England, Industrial Group Report.
CK	University of Chicago, Metallurgical Laboratory.	IS	Ames Laboratory, Ames, Iowa.
		ISC	Iowa State College, Ames, Iowa.

JENER	Joint Establishment for Nuclear Energy Research, Kjeller, Norway.	GRNL	Oak Ridge National Laboratory, Tenn.
JINR-P	Joint Institute for Nuclear Research, Laboratory of Nuclear Problems, Dubna, USSR.	ORNL-TM	Oak Ridge National Laboratory, Tenn.
JPRS	Joint Publications Research Service, New York.	PAN	Polish Academy of Sciences, Inst. of Nuclear Research, Warsaw.
JUL	Kernforschungsanlage, Julich, Germany.	PG	United Kingdom Atomic Energy Authority, Production Group.
K	Carbide and Carbon Chemicals Corp., K-25 Plant, Oak Ridge, Tenn.	PGR	United Kingdom Atomic Energy Authority, Production Group.
KAPL	Knolls Atomic Power Lab., Schenectady, New York.	RDB(W)	United Kingdom Atomic Energy Authority, Industrial Group, Windscale Works, Sellafield, Cumb., England.
KFK	Kernreaktor Bau-und Betrieb-Gesellschaft, M.H., Karlsruhe, Germany.	RFP	Rocky Flats Plant - Operated by The Dow Chemical Co. for USAEC.
KR	Norway Institutt for Atomenergi, Kjeller.	SCR	Sandia Corp., Albuquerque, N. M.
LA	Los Alamos Scientific Lab., New Mexico.	SCTM	Sandia Corp., Albuquerque, N. M.
LADC	Los Alamos Scientific Lab., New Mexico.	TID	Division of Technical Information Extension, AEC.
LAMS	Los Alamos Scientific Lab., New Mexico.	TRQ-Report	United Kingdom Atomic Energy Authority, Reactor Group, Atomic Energy Research Establishment, Harwell, Berks., England.
LRL	California Research and Development Co., Livermore Research Lab., Livermore, California.	UAC	Argonne National Laboratory, Lemont, Illinois.
LWS	California Research and Development Co., Berkeley, Calif.	UCLA	California Univ., Los Angeles.
MDDC	Manhattan District, Oak Ridge, Tennessee.	UCRL	Calif. Univ., Berkeley, Lawrence Radiation Lab.
MLM	Mound Laboratory, Miamisburg, Ohio, operated for USAEC.	UK	United Kingdom Atomic Energy Authority, Research Group, Atomic Energy Research Establishment, Harwell, Berks., England.
MND	Martin Co., Nuclear Division, Baltimore.	UR	Rochester, N. Y. University.
Mon (Letter)	Clinton Labs., Oak Ridge, Tennessee.	USNRDL	U.S. Naval Radiological Defense Laboratory, San Francisco, Calif.
N	Argonne National Laboratory, Argonne, Ill.	WAPD	Westinghouse Electric Corp., Atomic Power Division, Pittsburgh.
NAA	North American Aviation, Inc., Downey, California.	WASH	Atomic Energy Commission, Washington, D. C.
NAA-SR	North American Aviation, Inc., Downey, California.	WCAP	Westinghouse Electric Corp., Commercial Atomic Power Activity, Pittsburgh.
NAS	National Academy of Sciences.	WSL	United Kingdom Atomic Energy Authority, Windscale Works, Sellafield, Cumb., England.
NBL	New Brunswick Lab., AEC, N. J.	WT	Assigned to reports to the Scientific Director of Joint AEC-DOD weapons tests.
NDA	Nuclear Development Associates, Inc., White Plains, N. Y.		
NP	Division of Technical Information, AEC. Non-AEC Report.		
NRDC	Nuclear Reactor Data Committee, Harwell, Berks, England.		
NUMEC	Nuclear Materials and Equipment Corp., Apollo, Pennsylvania.		
NYO	New York Operations Office, AEC.		

AUTHOR INDEX

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