

TABLE II.

Nuclear reaction	Q-value (MeV)	Threshold (MeV)	Coulomb Barrier (MeV)
235-U(p,n)235-Np	-0.91	0.91	12.9
235-U(p,2n)234-Np	-8.98	9.02	12.9
235-U(p,3n)233-Np	-13.90	13.96	( )
234-U(p,n)234-Np	-2.60	2.61	12.9
234-U(p,2n)233-Np	-8.63	8.67	12.9
238-U(p,n)238-Np	-0.90	0.90	12.9
238-U(p,2n)237-Np	-6.33	6.35	12.9
238-U(p,3n)236-Np	-13.06	13.12	( )
238-U(p,4n)235-Np	-18.74	18.82	( )
238-U(p,5n)234-Np	-25.70	25.81	( )
283-U(p,6n)233-Np	-31.73	31.86	( )
235-U(d,n)236-Np	2.54	0.00	12.5
235-U(d,2n)235-Np	-3.13	3.16	12.5
235-U(d,3n)234-Np	-10.09	10.18	12.5
235-U(d,4n)233-Np	-16.12	16.26	( )
234-U(d,n)235-Np	2.14	0.00	12.5
234-U(d,2n)234-Np	-4.82	4.87	12.5
234-U(d,3n)233-Np	-10.86	10.95	12.5
237-Np(p,n)237-Pu	-1.01	1.01	13.0
237-Np(p,2n)236-Pu	-7.00	7.03	13.0
237-Np(p,3n)235-Pu	-14.32	14.38	( )
237-Np(d,n)238-Pu	3.71	0.00	12.6
237-Np(d,2n)237-Pu	-3.23	3.26	12.6
237-Np(d,3n)236-Pu	-9.23	9.31	12.6
237-Np(d,4n)235-Pu	-16.55	16.69	( )
235-U( $\alpha$ ,n)238-Pu	-10.83	11.02	24.1
235-U( $\alpha$ ,2n)237-Pu	-17.77	18.08	24.1
235-U( $\alpha$ ,3n)236-Pu	-23.77	24.18	( )
235-U( $\alpha$ ,4n)235-Pu	-31.09	31.62	( )
234-U( $\alpha$ ,n)237-Pu	-12.51	12.72	24.1
234-U( $\alpha$ ,2n)236-Pu	-18.50	18.82	24.1
234-U( $\alpha$ ,3n)235-Pu	-25.82	26.26	( )
238-U( $\alpha$ ,n)241-Pu	-11.18	11.37	25.4
238-U( $\alpha$ ,2n)240-Pu	-16.59	16.87	25.4
238-U( $\alpha$ ,3n)239-Pu	-23.05	23.43	25.4
238-U( $\alpha$ ,4n)238-Pu	-28.66	29.14	( )
238-U( $\alpha$ ,5n)237-Pu	-35.60	36.20	( )
238-U( $\alpha$ ,6n)236-Pu	-41.60	42.30	( )
235-U( $\tau$ ,n)237-Pu	2.78	0.00	24.5
235-U( $\tau$ ,2n)236-Pu	-3.22	3.26	24.5
235-U( $\tau$ ,3n)235-Pu	-10.54	10.67	24.5
235-U( $\tau$ ,4n)234-Pu	-16.80	17.01	24.5
238-U( $\tau$ ,n)240-Pu	3.96	0.00	24.3
238-U( $\tau$ ,2n)239-Pu	-2.49	2.53	24.3
238-U( $\tau$ ,3n)238-Pu	-8.11	8.21	24.3
238-U( $\tau$ ,4n)237-Pu	-15.05	15.24	24.3
238-U( $\tau$ ,5n)236-Pu	-21.05	21.32	24.3

about the ( $\tau$ ,4n) reaction [12]. At the Milan Cyclotron Laboratory the employ of the  $^{237}\text{Np}(p,n)$  reaction has been considered. In principle, if the proton energy is lower than the threshold of the ( $p$ , 2n) reaction which leads to the  $\alpha$ -emitting  $^{236}\text{Pu}$ , the ( $p,n$ ) reaction seems to lead to a  $^{237}\text{Pu}$  with a high radionuclidic purity, higher than that obtained via ( $d,2n$ ) and ( $\alpha,2n$ ) reactions. Only preliminary

irradiations on a 'thin' layer of  $^{237}\text{Np}$  deposited and sealed between Al foils led to a very complicated mixture of  $\gamma$ -emitting products, which made impossible to perform conventional  $\gamma$  measurements without a suitable radiochemical separation.

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## E36

Comparative Study of Self-Diffusion of the Trivalent Ions  $\text{Eu}^{3+}(4f)$  and  $\text{Am}^{3+}(5f)$  in Aqueous Solutions

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The self diffusion coefficients of the  $^{152}\text{Eu}^{3+}$  ion aqueous nitrate solution and the  $^{241}\text{Am}^{3+}$  ion in neodymium perchlorate solution are determined by the open end capillary method (OCM). The aim of this work is as follows: Verification of the Onsager

limit law concerning the relative variation of the self diffusion coefficient with the ionic strength. Comparison of the behaviour of the europium ion  $^{152}\text{Eu}^{3+}$  with that of the americium ion  $^{241}\text{Am}^{3+}$  from the point of view of ionic transport. This work would be useful in elucidating the electrolytic behaviour of actinide and lanthanide ions, especially with respect to ion-ion and ion-solvent interactions under equilibrium and non-equilibrium conditions.

The data show that there is a similarity in the ionic transport processes of the  $^{152}\text{Eu}^{3+}$  and  $^{241}\text{Am}^{3+}$  ions.

Diffusion coefficient of lanthanide ion at infinite dilution:  $D_i^\circ \times 10^6 \text{ cm}^2 \text{ s}^{-1}$ :  $6.10 (^{152}\text{Eu}^{3+})$  [1].

Diffusion coefficient of actinide ion at infinite dilution:  $D_i^\circ \times 10^6 \text{ cm}^2 \text{ s}^{-1}$ :  $6.19 (^{241}\text{Am}^{3+})$  [1].

The present work shows that the electrostatic relaxation effect for  $^{152}\text{Eu}^{3+}$  in an aqueous solution of  $\text{Eu}(\text{NO}_3)_3$  is responsible for a relatively important variation (20%) in the concentration range 0 to  $10^{-3} \text{ M}$  for the self-diffusion of these ions.

On the other hand, our results show that the ionic transport process for  $^{152}\text{Eu}^{3+}$  is similar to that for  $^{241}\text{Am}^{3+}$  at pH 2.5. Moreover, it may be provisionally argued that the  $\text{Eu}^{3+}$  ion in solution at  $\text{pH} \geq 6$  has essentially the same structure as a tripositive 5f ion.

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### E37

#### Removal of Thorium and Uranium from Surfaces by Attapulgus Clay Suspensions

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In the operations connected to the nuclear fuel cycle, equipments and surfaces can undergo radiological contamination for accidental causes or consequently to their use; among radionuclides, Uranium and Thorium are often present and in a large amount.

Protection of the operators requires the removal of radioactive substances from the materials involved in the working especially in the case of alpha emitters, whose effects on man are very dangerous. Severe limits to the contamination levels are imposed in the various countries: generally, alpha activity on the working surfaces must be below  $1.85 \text{ Bq cm}^{-2}$ .

Radioactivity elimination current techniques involve the use of physical and chemical methods. The

physical or abrasive methods can change in some degree treated materials and are not suited for a lot of instruments; chemical methods produce large quantities of radioactive wastes which often show some difficulties in handling. Both decontamination techniques can introduce some irradiation and contamination hazards for the operators.

In order to reduce these disadvantages, there is arising a certain interest in the use of solid decontaminating agents as easily applicable pastes or gels. At C.A.M.E.N. we have used a suspension of a particular clay. The basic constituent of these decontaminating media is attapulgite, a widely used material utilized to remove resisting dirt present on artworks; its aqueous suspensions show high chemical inertness and thixotropic and non-newtonian properties.

The present work describes some decontamination experiments of materials frequently used in the actinides technology, previously contaminated with uranyl nitrate and thorium nitrate. This decontamination is carried out by attapulgus clay aqueous suspensions. Samples, cured by B.S. 4247 specification, of the following materials, stainless steel AISI 304, mild steel UNI Aq 42, aluminium alloy UNI P-Al-Mg 3.5, lead, polymethylmetacrylate, polyvinylchloride, polytetrafluoroethylene, polypropylene, have been contaminated with 0.2 ml of 2% solutions of uranyl nitrate and thorium nitrate ( $\text{pH} = 3.0$ ) respectively. The suspension, obtained on mixing attapulgitic clay and water in predetermined proportions, was laid by a spatula with a 10–12 mm thickness, corresponding to  $1.0\text{--}1.2 \text{ g cm}^{-2}$ . The samples were kept for 48 hours at room temperature; the suspension dries up and severs spontaneously. A light halo eventually remained on the samples and can be removed by wiping delicately surfaces with a lightly wet flock of cotton. The samples have been measured by an alpha scintillator, with ZnS(Ag) detector, after contamination and after each decontamination process; the efficiency of the instrument was determined with uranyl nitrate and thorium nitrate standard.

Results obtained in experiments are reported as decontamination factor  $D_F$  (logarithm), where  $D_F$ :

$$D_F = \frac{\text{activity before decontamination}}{\text{activity after decontamination}}$$

In Tables I–II values of logarithm of  $D_F$  found for uranyl nitrate and thorium nitrate for repeated applications of attapulgus clay aqueous suspensions are reported.

From the data it appears that:

– For most of the examined materials a high removal has been obtained: more than 95% of the initial activity, except for mild steel, where removal