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Berkeley, California

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INVESTIGATIONS OF COMPLEX STRUCTURE IN ALPHA EMISSION WITH NUCLEAR EMULSIONS*

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April 25, 1952

A study has been made, utilizing the method of photographic emulsions, of the conversion electrons accompanying the complex alpha group structure in a number of nuclides. These conversion electrons, coincident in origin with the alpha particles, were identified in Ilford G-5 nuclear emulsions. Energies of the electrons were approximated from their range and this, together with postulation of the shell of conversion (or binding energy) of the electrons, allows calculation of the gamma ray energy or nuclear energy level separation. The percentage of alpha particles having such conversion electrons associated with them represent a lower limit to the alpha decay leading to the corresponding nuclear energy level since the unconverted gamma rays are not measured by this technique.

Fresh plates were ordered frequently and used within three to eight weeks after the time of manufacture in order that no eradication of electron background (with associated desensitization of the emulsion) would be required. Because of residual acidity left in the emulsion with the radioactivity through use of citrate or acetate complexing agents (to aid penetration of the radioactivity into the emulsion), a 30 minute presoaking of the plates in dilute Na_2CO_3 solution preceded normal development with Eastman D-19 solution. The customary period of exposure was 66 hours; where the daughter was a beta emitter of sufficiently short half-life, appropriate corrections were made in the percentages

*This work was performed under the auspices of the AEC.

of electron abundance. Alpha particle emitting contaminants were negligible (0-1 percent) in all cases except U^{238} for which an isotopically enriched sample was used and appropriate corrections made for U^{234} and U^{235}. Close agreement was found between the present results and those of Asaro and co-workers in earlier work on the two nuclides Cm^{242}[1] and Pu^{238}[2] using the alpha magnetic spectrometer; this was regarded as indicating satisfactory efficiency of the emulsion method in estimating both electron abundances and energies.

The results are summarized in Table I where the gamma ray energies are probably accurate to about 5 kev. As can be seen, in the case of the even-even emitters the alpha decay in every case divides between the ground state and one higher energy level of the daughter nucleus. Since the conversion coefficient for the gamma ray seems to be high for all such daughter nuclei of the even-even type where this has been measured, it seems reasonable to assume that the percentages of conversion electrons listed in Table I correspond essentially to the percentages of the alpha decays to the level above the ground state. For all the even-even nuclides both the low and high energy alpha particle groups obey the relationship between energy and half-life quite well; that is, neither group exhibits appreciably the hindered decay characteristic of nuclides containing odd nucleons.[3,4] On the other hand, each of the nuclides with odd nucleons exhibits alpha decay to several energy levels with widely varying percentages; for these, the decay to one of the excited states is in each case less hindered than the corresponding decay to the ground state, in agreement with the view that the conditions for the assembly of the outgoing alpha particle can be

Table I. Conversion electrons accompanying alpha decay.

Isotope	Alpha events observed	% having conversion electrons	Electron energies (kev)	Shell of conversion	Gamma energy (kev)
Cm^{242}	5250	23 ± 3	25 ± 5 (19%) 40 ± 5 (4%)	L M	~45 ~45
Am^{241}	2600	56 ± 5	≤20 (12%) 20-35 (31%) 35-60 (9%) two electron coincidences (4%)		several levels, highest at least 65 kev above the ground level
Pu^{239}	8100	12 ± 2	30 ± 5 45 ± 5 20 ± 5 30 ± 5 100 ± 20 (0.5%)	L M L M	~50 ~50 ~35 ~35 origin uncertain
Pu^{238}	5700	23 ± 3	20 ± 5 35 ± 5	L M	~40 ~40
Pu^{236}		23 ± 5	25 ± 5 40 ± 5	L M	~45 ~45
Np^{237}	3500	80 ± 5	≤20 (10%) 20-40 (38%) 40-65 (20%) two electron coincidences (11%) three electron coincidences (1%)		several levels, highest at least 65 kev above the ground level
U^{238}	6300	22 ± 3	25 ± 5 40 ± 5	L M	~45 ~45
U^{236}	9700	27 ± 3	30 ± 5 (23%) 45 ± 5 (4%)	L M	~50 ~50
U^{232}	8000	30 ± 3	40 ± 5 55 ± 5	L M	~60 ~60
Th^{232}	5100	24 ± 3	35 ± 5 50 ± 5	L M	~55 ~55
Sm^{147}	7500	0			

more favorable in certain instances when the highest lying odd nucleon need not be included.(3)

Results similar to those presented here have been reported for U^{238}(5,6) and Pu^{239}(7) using the same technique.

This work will be reported in more detail in a forthcoming publication.

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