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Radiation Laboratory
Berkeley, California

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ABSTRACT

Precise measurements of the energies of first excited states of some heavy even-even nuclei are reported, which indicate that these energies do not decrease monotonically with A but show appreciable variations from the average value (~ 44 kev).

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The systematic behavior of first excited states of even-even nuclei is well known, and indeed the pronounced maxima of the first excited state energies at the "magic numbers" are among the most striking manifestations of nuclear shell structure.^{1, 2} Between the closed shells, in the regions $155 < A < 185$ and $A > 225$, rather flat minima are developed whose constancy and low energy point to the collective nature of the excitations.³ In their review paper on alpha decay, Perlman and Asaro⁴ point out that the first excited states of even-even nuclei in the transuranium region are always between 40 and 50 kev above the ground state and that they follow smooth curves when plotted against neutron number. In Fig. 1 we reproduce a drawing from their paper, which depicts the behavior of these states.

It is the purpose of this note to assemble some recent data which illustrate the "second order" systematics of these excited states. Most of the energies quoted here were obtained from precision measurements of conversion electron spectra in the Berkeley permanent-magnet beta spectrographs. These data are given in Table I, and they are plotted against neutron number in Fig. 2. Although they are as yet fragmentary, these results show that the energies of the first excited states do not decrease monotonically with N or A , but exhibit large variations from the average value (~ 44 kev) which are well outside the experimental errors. The uranium and plutonium curves also show minima.

Since the excitation energy of the first excited state of a rotational band is determined essentially by the nuclear moment of inertia, such measurements allow one to examine the very small changes in nuclear deformation brought about by the addition of pairs of nucleons

to the already deformed core. It may be possible to relate these small changes in shape to the character of the nucleon pairs, specifically to the total angular momentum (or component along the symmetry axis, Ω) of the odd particles which make up the last pair.

The energy values of the first excited states of the curium isotopes are of some interest in view of the existence of small discontinuities in the alpha decay energies at around 152 neutrons, interpreted by Ghiorso et al.⁵ as evidence for a "subshell" closure at $N = 152$. Although the present data indicate that the energies of the first excited states in curium rise as one approaches $N = 152$ (Cm^{248}), the effect is very small and even less than the variations in the uranium and plutonium curves. Thus, as pointed out by Ghiorso et al.,⁵ such a "subshell" at $N = 152$ would have to be of a fundamentally different nature than the major closed shells, especially since the moment of inertia of Cm^{248} does not appear to be substantially lower than that of the neighboring nuclides.

I wish to thank Professor J. O. Rasmussen for his helpful comments, and Dr. W. G. Smith and Mr. R. G. Albridge for their aid in the experimental work.

Table I

Energies of first excited states of heavy even - even nuclei.

Isotope	Energy (kev)	Lines Seen	Measured From	Reference
U ²³⁰	52.8 ± 0.2	L _{II} , L _{III} , M	Pa ²³⁰	a
U ²³²	47.2 ± ?	L _{II} , L _{III} , M, N	Pa ²³²	b
U ²³⁴	43.50 ± 0.04	L _{II} , L _{III} , M _{II} , M _{III} , N, O	Pu ²³⁸	c
U ²³⁶	45.23 ± ?	L _{II} , L _{III} (weak lines)	Np ²³⁶	d
Pu ²³⁶	44.58 ± ?	L _{II} , L _{III} (weak lines)	Np ²³⁶	d
Pu ²³⁸	44.11 ± 0.05	L _{II} , L _{III} , M _{II} , M _{III} , N _{II} , N _{III} , O	Cm ²⁴²	e
Pu ²⁴⁰	42.88 ± 0.05	L _{II} , L _{III} , M _{II} , M _{III} , N _{II} , N _{III} , O	Cm ²⁴⁴	e
Pu ²⁴²	44.50 ± 0.06	L _{II} , L _{III} , M _{II} , M _{III} , N _{II} , N _{III} , O	Am ^{242m}	f
Pu ²⁴²	44.52 ± 0.1	L _I , L _{II} , L _{III} , M _{II} , M _{III} , N, O	Am ^{242m}	g
Cm ²⁴²	42.12 ± 0.06	L _{II} , L _{III} , M _{II} , M _{III} , N _{II} , N _{III} , O	Am ^{242m}	f
Cm ²⁴²	42.18 ± 0.1	L _{II} , L _{III} , M _{II} , M _{III} , N _{II} , N _{III} , O	Am ^{242m}	g
Cm ²⁴⁶	42.9 ± 0.1	L _{II} , L _{III}	Cf ²⁵⁰	h
Cm ²⁴⁸	43.4 ± 0.1	L _{II} , L _{III}	Cf ²⁵²	h

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FIGURE CAPTIONS

Fig. 1. First excited state energies of even-even nuclei in the heavy element region.

Fig. 2. Energies of first excited states of even-even heavy nuclei.

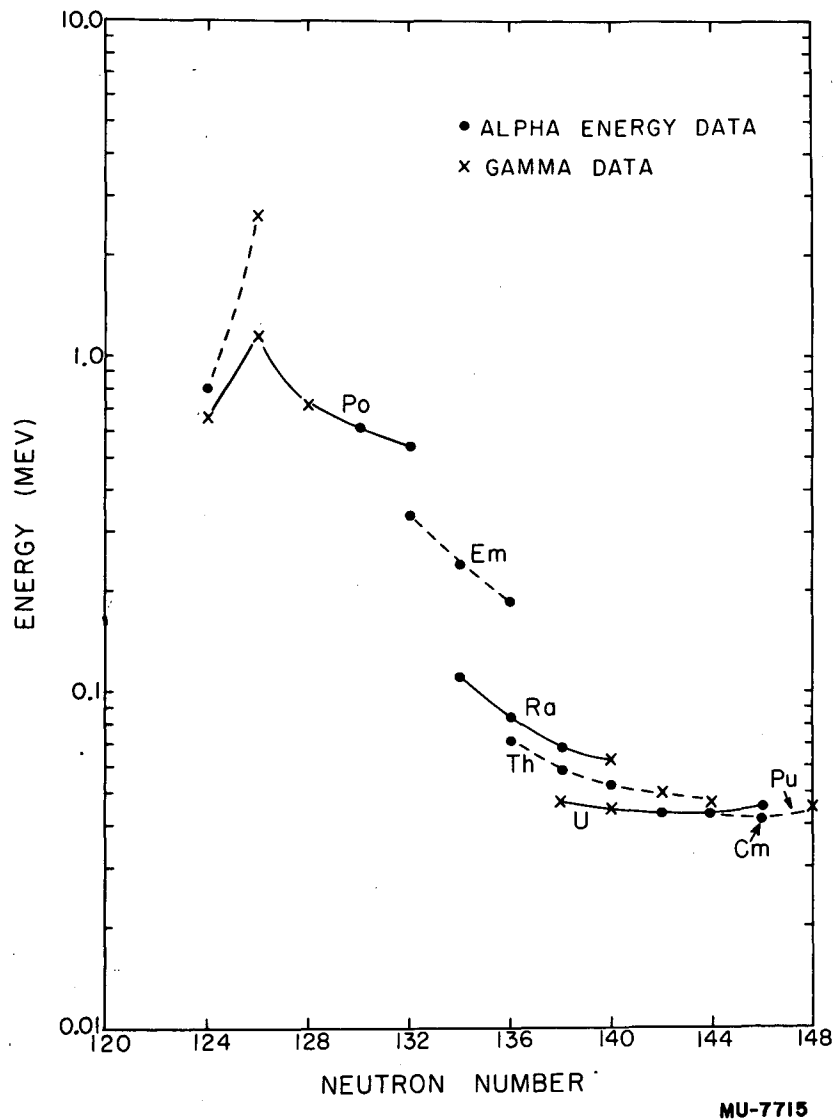
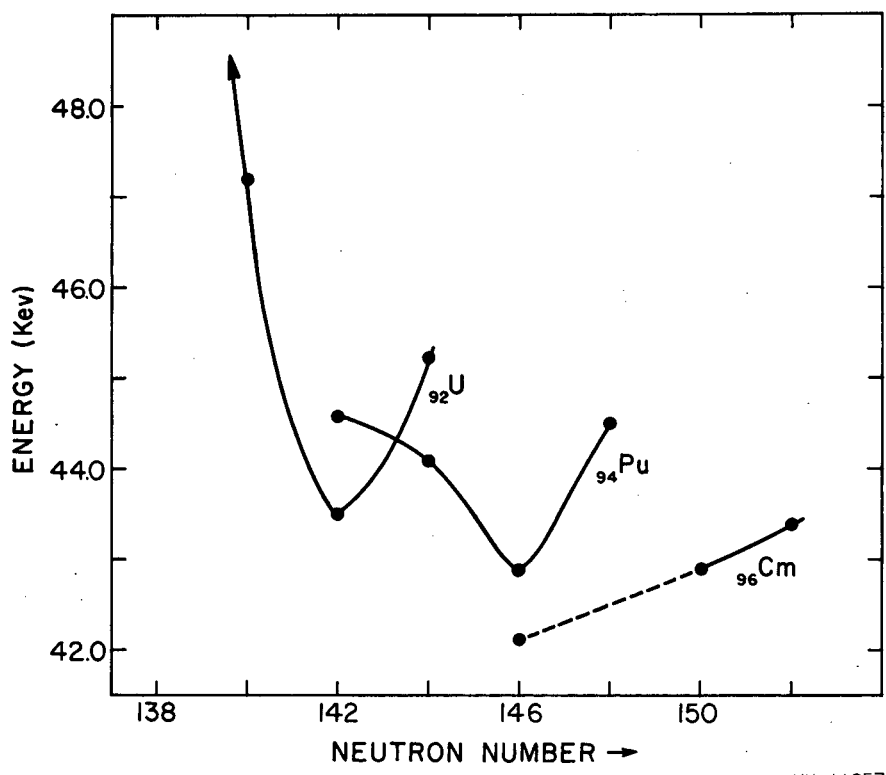


Fig. 1



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Fig. 2