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April 25, 1952

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FIRST EXCITED STATES OF EVEN-EVEN NUCLIDES
IN THE HEAVY ELEMENT REGIONFrank Asaro and I. Perlman
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April 25, 1952

This communication aims to amplify some observations on regularities of the complex spectra of even-even alpha emitters particularly as they apply to the location of nuclear energy levels.^{1,2} Most of the alpha emitters of this type examined in this laboratory have shown two alpha groups and the ratio of intensities of the two groups for a particular nuclide is, in good approximation, that expected for the energy difference according to simple alpha decay theory. For lack of good evidence to the contrary we have been assuming that the energy level reached by the low energy group is the first excited state and that the laws governing the alpha decay rate are the same as for the ground state transition with only the energy operating to fix its relative abundance. For the few instances in which but a single alpha group has appeared the working hypothesis has been adopted that the first excited state is so high that the correspondingly low abundance of the alpha group has prohibited its detection. To the extent that these assumptions are valid the examination of complex alpha spectra leads to the definition of the first excited states of the even-even nuclides.

The examination with our alpha particle spectrograph of a number of nuclides in the region of uranium and higher atomic numbers yielded the curious result that the energy levels reached were all in a narrow range. For example, the energy differences between the two alpha

groups for each of the nuclides Cm^{244} , Cm^{242} , Pu^{240} , Pu^{238} , U^{234} all fell between 41 and 47 kev. It was also noted that nuclides of lower mass numbers showed higher energies for their first excited states.

The data are summarized in Fig. 1 in which are plotted the energy levels of the "first excited states" against neutron numbers with isotopes of each element joined. Most of the data were obtained from alpha spectra taken in this laboratory, others were obtained by Rosenblum and co-workers, and some were measured by conversion electron ranges in photographic emulsions both in this laboratory and elsewhere. Data for excited states of polonium and lead were taken from the literature concerning principally beta decay processes leading to these states. For the sake of brevity, references are omitted for both the published and unpublished data but these will be included in a later paper.

It is seen that the levels for plutonium, uranium and the heaviest thorium isotopes are all bunched within a range of about 10 kev. The progressively higher energy for lower elements is consistent with the experienced difficulty of finding such states in alpha spectra because of the low abundance which would accordingly be expected for the low energy alpha groups. For example Em^{222} , Em^{220} , and Em^{218} have not yet revealed low energy groups which, according to our present expectations for the energies of the excited states of the corresponding polonium isotopes, would have abundances in the range $\sim 0.03 - 1$ percent.

The wide level spacing encountered at the region of 126 neutrons is obvious and it is interesting to note that lead isotopes show a decrease going away from 126 neutrons on the low mass side. It is

possible that all of these correlations may be based primarily on departures from closed neutron and proton shells. Recently, there have been communications from several sources pointing out this same relationship surrounding closed shells.^{3,4}

It is difficult to interpret these data on the single particle model which has been so successful in correlating transitions and energy states of nuclides having odd nucleons. The marked regularity of the first excited states and their low energies suggests some type of excitation involving the nucleus as a whole.

There are a number of apparent steps which may be taken in pursuing further these correlations and their interpretation. One of these, of course, is to extend the data to a wider range and, as one example, to see if energy level spacings increase at still higher mass numbers as might be expected for the approach to a new closed shell. Another point is the examination of the lifetimes of these states and the measurement of conversion coefficients and angular dependence of the gamma rays. Goldhaber and Sunyar⁵ have concluded that the first excited states of most even-even nuclides have spin 2 and even parity. With the low energies encountered for most of these transitions the lifetimes should be in the measurable range.

References

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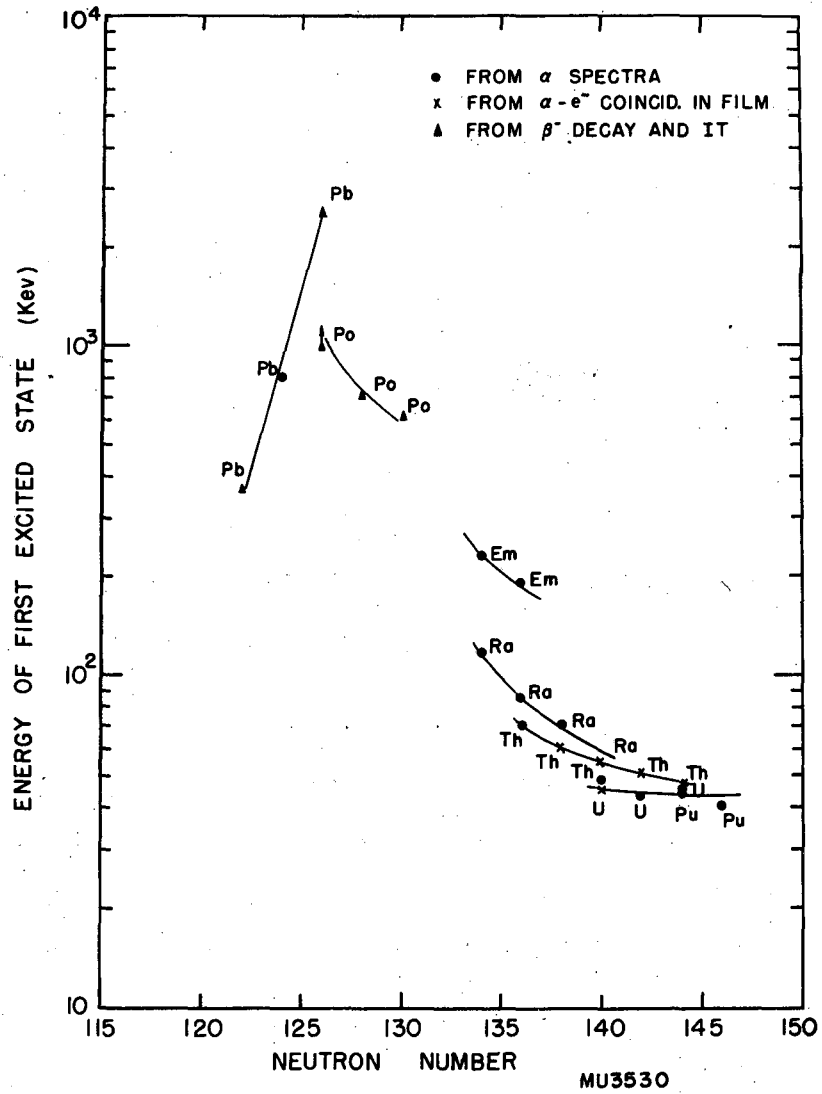


Fig. 1

First excited states of even-even nuclides.