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May 13, 1953

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The present communication aims to bring out some definite regularities in the spectra of even-even alpha emitters without elaborating particularly on the possible significance of these findings regarding alpha decay theory and spectroscopic states of heavy nuclei. Most of the data to be discussed were obtained over the range of elements from curium (96) to radium (88) since it is inherently difficult to make the necessary measurements for elements below radium.

We shall first suggest some means to identify the energy states which seem to recur generally and to designate the alpha transitions leading to these states. The first rule for even-even alpha emitters is that the most prominent alpha group leads to the ground state of the product nucleus as would be expected from previous alpha decay theory. (This is not the case for nuclear types having odd nucleons.) In addition, an alpha group is invariably found which leads to a level with spin 2 and even parity and the abundance of this group likewise conforms in first approximation with the expectations from unadorned alpha decay theory. The energy level of this excited state will be termed the first even spin state and lies about 40 kev above the ground state at plutonium, increasing with decreasing mass number as already described^(1, 2) In low abundance are found alpha groups leading to other

levels which we shall term second and third even spin states. In the few cases for which gamma ray data are available it seems probable that these levels have even parity as well as even spin and may very well be $4+$ and $6+$ states. There is some fragmentary evidence in our work that an odd spin-odd parity state is appearing in a limited region, but this will not be discussed further at present.

Bohr and Mottelson⁽³⁾ have suggested that nuclides well beyond a closed shell have states in which the nucleus acts as a rigid rotator. Such rotational levels should be proportional to $J(J + 1)$ where J is the total angular momentum quantum number. If we consider the $2+$ and $4+$ states to be rotational states, the ratio of the energies should be 3.3. Fig. 1 shows experimental ratios for 10 nuclei in the heavy element region plotted against neutron number. It is fairly certain that corresponding states are compared here although in only one case, Cm^{242} , have the necessary measurements been made to establish this state as $4+$.⁽⁴⁾ The heaviest nuclei show remarkably close agreement with the expectations for the postulated rotational states and there appears to be a progressive departure from the ratio 3.3 toward lighter nuclei. (There is no convincing justification for plotting these data strictly with respect to neutron number as is done here; in fact, it is not to be expected that the nuclear deformation which defines these levels is simply a function of the neutron number.)

Gamma ray data have been used to infer the existence of the third even-spin state for three species. The ratios of the third to the first levels are indicated in Fig. 1 in relation to the theoretical value 7 for the third rotational state, $J = 6$.

In the study of the alpha spectra of most of the nuclides shown in Fig. 1, it became clear that the alpha transitions leading to the second even spin states were highly hindered. That is, the measured partial half-lives were much longer than expected simply from the energy and nuclear charge. (It will be remembered that the ground state transitions and those leading to the first even spin states are in first approximation unhindered.) The Cm²⁴² alpha group leading to the second even spin state, as an example, has a half-life almost 400 fold longer than expected from theory. On examining this relationship for alpha emitters of lower elements, it was found that as the energy of the second even spin state increased, the hindrance factor decreased. For the species examined so far, the logarithm of the hindrance factor varies linearly with the atomic number (Fig. 2). There is no quantitative explanation yet known for the close agreement of this function. (It will be noted that a few points lie off the curve.)

If we assume that the same spin change is involved in each of these transitions, an explanation cannot lie in simple fashion in this direction both because of the large hindrance factors in some cases and because of the wide variation. A possible explanation lies in the assumption of a progressive change in charge asymmetry on leaving the closed shells in the vicinity of lead. The potential barrier will then be spherically non-symmetrical and if the alpha particles of a type have a preferred direction of emission, any progressive change in charge distribution will be reflected in a progressive change in the ease with which the alpha particle can leave.

¹F. Asaro and I. Perlman, Phys. Rev. 87, 393 (1952).

- ²S. Rosenblum and M. Valadares, Compt. rend. 235, 711 (1952).
- ³A. Bohr and B. Mottelson, Phys. Rev. 89, 316 (1953).
- ⁴Asaro, Thompson, and Perlman, "The Alpha Spectra of Cm^{242} , Cm^{243} , and Cm^{244} ," Phys. Rev., submitted for publication.

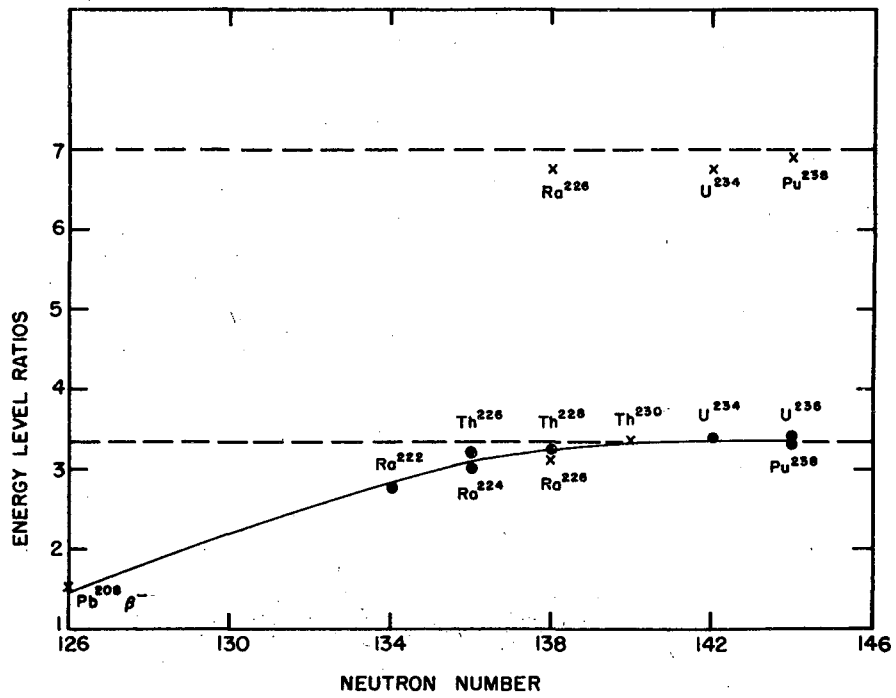


FIG 1

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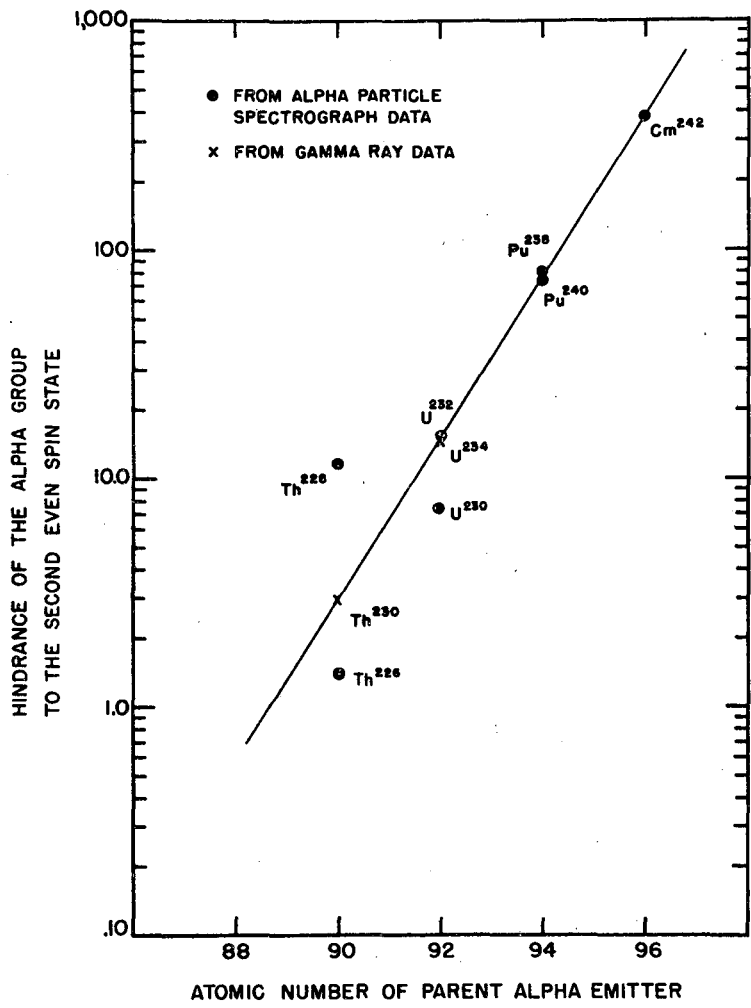


FIG 2

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