THE PUZZLE OF UNIDENTIFIED PARTICLE GROUPS IN ACTINIDE SOURCES.

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Recently[1] a consistent interpretation has been given to secondary reaction experiments in W targets which were irradiated with 24 GeV protons. The interpretation was based on the assumption that the production of neutron-deficient superheavy isotopes is not impossible. This assumption was based on a study of actinide sources, separated from the same W targets, which gave evidence for production of long-lived isomeric-states in neutron-deficient ^{236}Am and ^{236}Bk nuclei[2]. In the present contribution we discuss other aspect of the study of the actinide sources, namely, the observation[2-4] of some unidentified particle groups which may be abnormal alpha particles or perhaps delay proton groups.

Particle spectra from the actinide sources were given before[2,3]. The most prominent unidentified groups are the 5.14-MeV group in the Bk source and the 5.53-MeV group in the Lr-No source. Two coincidence groups between 3.0 and 4.04 MeV particles and 13.7±1 and 15.0±1 keV X- or gamma-rays respectively, were observed in Am, and a coincidence group between 5.19 MeV particles and 115±15 keV X- or gamma-rays were observed in Cm[3]. 13.7 and 15 keV are characteristic energies of L X-rays of actinides, and 115 keV are in the region of K X-rays of actinides. A statistical analysis[5] shows that the probabilities that these coincidence groups are accidental are very small.

The groups mentioned above could not be identified with any known activities. Earlier, we had thought[3] that the 5.14-MeV group in Bk may be attributed to ^{239}Pu. However further measurements taken about 7.2 and 14.4 years after chemical separation showed that this is incorrect since its intensity decayed with a half-life of 3 to 5 years. This group could also not be due to ^{208}Po because initially its intensity grew with a half-life of about 1.5y, and all known decay chains to ^{208}Po have much shorter characteristic lifetimes. The lifetime of the 5.19 MeV group in Cm was not measured but it could also not be due to ^{208}Po because of the coincidence with X- or gamma-rays of about 115 keV.

These groups also do not fit the systematic[6] of alpha particles in the actinides or in the rare-earth regions. As seen in the table their lifetimes are too short if they are due to decay of actinide nuclei, while if they are due to some unknown decays in the rare-earth region their lifetimes are too long. (It should be mentioned that the actinides were separated from the rare-earth elements by several orders of magnitude[3]. Recently[7,8] two oblate isomeric states, at quite low excitation energies, have been predicted in ^{236}Cm by Hartree-Fock calculations. On the basis of the cluster model the state at deformation of $\beta=-0.6$ may be interpreted by one ^{48}Ca and four ^{47}K nuclei clustering on a ring. It was estimated[8] that the barrier penetration factor from such a shape isomer increases by at least three orders of magnitude. The first three groups in the table may perhaps be due to production of such oblate isomeric states.

The very low energy particles of 3.0 and 4.0 MeV need another interpretation. If they are due to alpha particles from actinide nuclei, as indicated from the energies of the X-rays, they may be due to decay from rotating nuclei, namely from a parent nucleus at a high spin state to a daughter nucleus at the same or similar spin state. Quantitative estimates of the barrier reduction are not available at present and may perhaps be obtained by applying the model of Puenaru et al[9] to rotating nuclei.

Another possibility[8] is that the 3.0 and 4.0 MeV groups are due to delay proton emission. Electron capture or alpha decays between shape isomeric states in neutron-deficient nuclei[2,7,8] may lead to a high excitation energy at the daughter nucleus. This state may be well above the proton separation energy, but below or only slightly above the neutron separation energy. Such a state may decay also by emitting a proton. The lifetime for the decay will be determined by the combined lifetimes of the electron capture or alpha processes, which are long, and the proton decay lifetime which is short. However, since the proton decay is from a shape isomeric state to the ground state or low-lying normal states in the daughter nucleus, it will be longer as compared to what is predicted from barrier penetration calculations.

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E_α(MeV)	Source	$t_{1/2}$(exp.)	$\frac{t_{1/2}(\text{exp.})}{t_{1/2}(\text{calc.})^{a)}}$	$\frac{t_{1/2}(\text{exp.})}{t_{1/2}(\text{calc.})^{a)}}$(R.E.)
5.53	Lr-No	28±10d	1x10^{-7}	7x10^{5} (Lu)
5.14	Bk[b]	4±1y	1x10^{-6}	6x10^{9} (Eu)
	Pu[b]	4±1y	5x10^{-5}	2x10^{11}(Nd)
5.19	Cm	(300-1)[c]y	2x10^{-3}	1x10^{12}(Sm)
4.04	Am	(300-1)[c]y	2x10^{-13}	4x10^{7} (Pm)
3.0	Am	(300-1)[c]y	4x10^{-24}	1x10^{1} (Pm)

[a] Reference 6.

[b] Since the intensity at the beginning grew with time this group may be due to decay of a daughter of Bk produced for instance by several E.C. decays.

[c] The limits on the lifetimes were obtained according to the possible number of produced atoms.