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A POSSIBLE ISOMERIC STATE OF RaE

H. M. Neumann, J. J. Howland, and I. Perlman

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A POSSIBLE ISOMERIC STATE OF RaE

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The neutron irradiation of bismuth at high neutron flux has produced a new bismuth alpha-emitter of very low activity which can best be assigned to Bi^{210m}, an isomeric state of RaE. In a previous report[1] this activity was indicated on an alpha-energy vs. mass number plot as Bi^{208} (with the mass number in question) on the assumption that it was formed by an (n,2n) reaction from the relatively small number of fast neutrons. The alpha-particle energy of this new activity is 5.03 ± 0.05 Mev as determined in an ionization chamber coupled to a pulse height analyzer. This value for the energy is one of the arguments against the assignment to Bi^{208} since, according to the systematics of alpha-radioactivity,[1,2] we would expect the alpha-energy of Bi^{208} to be even less than that of Bi^{209} which itself must be about 4 Mev or less.

The alpha-activity was observed by allowing the irradiated bismuth to stand for six months until all of the five-day RaE had decayed after which it was rigorously purified, first from the great alpha-activity of Po^{210} present and then from all other possible alpha-activities. To reduce any Geiger-counter activity that might be present, special purification from such elements as silver was performed in addition to purification from heavy elements. The bismuth finally reached a constant specific activity of 1.9 ± 0.1 alpha-disintegrations per minute per milligram and 2.0 ± 0.2 electrons or beta-particles.

The principal experimental evidence that this alpha-emitter is an isomer of Bi^{210} is the identification of a thallium daughter with the properties of Tl^{206}. The half-life obtained was 4.2 ± 0.5 min. in agreement with the reported value for Tl^{206}, 4.23 min.[3] There was available insufficient activity to determine the beta-particle energy precisely but through a factor of ten in absorption, the absorption curve looks like that reported by

Krishnan and Nahum[4] for Tl^{206}. Within the experimental uncertainty of about ten percent, then, all of the radioactivity of the Bi^{210m} may be explained by the alpha-particles for Bi^{210m} in equilibrium with its 4-min. beta-emitting daughter Tl^{206}. (At the time this work was done the principal evidence that the 4-min. period is Tl^{206} rather than Tl^{204} is that of Broda and Feather[5] who identified this activity from the rare alpha-branching of RaE. Dr. D. H. Templeton and one of the authors (I. P.) irradiated some enriched thallium stable isotopes** with moderated cyclotron neutrons and obtained evidence that the 4-min. period was indeed Tl^{206}. More conclusive confirmation of this assignment was obtained by Dr. B. H. Ketelle** who irradiated some separated thallium isotopes with pile neutrons.)

The disconcerting aspect of the assignment of this activity to Bi^{210m} lies in the consideration of the lifetimes toward different modes of decay. If it is a metastable state of Bi^{210}, it should also decay to the ground state and directly to Po^{210} by β^--emission. Indeed, if we accept the data to be discussed below, this nucleus should also be unstable with respect to RaD. It is possible to calculate these decay energies from the alpha-energies of the two states of Bi^{210} and known beta-energies, and to set some lower limits on the half-lives for the different processes.

Let us first consider the isomeric transition energy; that is, the difference between Bi^{210m} and RaE, the ground state. This can be obtained by comparing the alpha-energies of the two states, making the assumption that both alpha-transitions go to the ground state of Tl^{206}. The alpha-decay energy for Bi^{210m} as determined in the present study is 5.12 ± 0.05 Mev. That for RaE can be calculated by closing a cycle involving the beta-decay energies for RaE and Tl^{206} and the alpha-decay energy of Po^{210}. Broda and Feather,[5] who discovered the alpha-branching of RaE, made this calculation arriving at the decay energy 4.86 Mev for the alpha-decay of RaE; but in re-evaluating the data of Krishnan and Nahum[4] and of Fajans and Voigt[3] for the beta-energy of Tl^{206}, we have selected 1.63 ± 0.10 Mev which revises the alpha-energy of RaE to 4.94 ± 0.10 Mev.

The energy between the isomeric states of Bi^{210} would then be 0.18 ± 0.11 Mev. The unobserved beta-decay energy is accordingly 1.35 Mev and the electron-capture energy to RaD, 0.1 Mev.

The alpha half-life for Bi^{210m} is not known other than that it must be greater than 25 years, based on observation of the alpha-activity over a period of 15 months. From the failure to find Po^{210} growing into the sample which would result from both the isomeric transition and beta-decay, it is possible to say that these decay modes are at least 2000 times slower than the alpha-decay and therefore have minimum half-lives of 5×10^4 years.

It is obvious that the most stringent requirement in explaining the long half-lives will be demanded by the isomeric transition. Using the expression and conventions given by Segrè and Helmholz[6] relating decay constant to the order of the transition and the transition energy, it would appear impossible to explain the $> 5 \times 10^4$ yr. half-life if the transition energy is as great as 0.18 Mev even if one assumes a fifth order transition. However, if the transition energy is 0.07 Mev, the calculated half-life can become sufficiently long.

With the uncertainties still existing in this study, it is not considered profitable to attempt to assign spin numbers to the different nuclear states in these transitions nor to interpret such states in terms of the newer considerations of shell structure. It is perhaps worth pointing out that other cases of nuclear isomerism are being found in the heavy element region, and the analogy between this case and other odd-odd pairs such as Am^{242}-Am^{242m} and UZ^{234}-UX_2^{234} is not too far fetched.

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