MASS OF THE Pu^{240} ISOTOPE

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Precision mass-spectrographic measurements of the mass of the Pu^{240} isotope have been made.

We measured the mass of the Pu^{240} isotope on a mass spectrograph with a resolving power of ~ 60,000.[1] The Pu^{240} ions were produced by the evaporation of plutonium enriched to approximately 10 — 12% Pu^{240}. The doublet used for the measurement was produced by the Pu^{240} ion and a fragment of the organic compound of perylene ($C_{20}H_{12}$, M = 252) containing $C_{18}C^{13}H_{11}$ (M = 240). The mass of the C^{12}, C^{13}, and H^1 isotopes were measured previously with sufficient accuracy.[1,2] The ions were produced in an arc ion-source in which the basic discharge was maintained in helium. The vapors of the plutonium and the organic compound were introduced into the discharge by the evaporation of these substances in crucibles of special design.

The analysis of the doublet $C_{18}C^{13}H_{11} - Pu^{240}$ was carried out in the standard way.[1] To determine the dispersion constant, we used perylene fragments with a mass difference of one mass of hydrogen (M = 239, M = 240, and M = 241). The value of the doublet and the value of the mass of the Pu^{240} isotope corresponding to it were found to be the following:

$C^{12}_{18}C^{13}H_{11} - Pu^{240}$ doublet:	$\Delta M = 35.497 \pm 0.126$ mmu
Pu^{240} mass:	240.130316 ± 130 amu
Pu^{240} mass from reference 3	240.129105 ± 100 amu

For comparison, we have given here the Pu^{240} mass from the work of Huizenga.[3]

The mass-spectrographic mass of Pu^{240} has not been measured until now. The difference in the value obtained in the present experiment from Huizenga's value is 1.211 ± 0.170 mmu, i.e., about seven times the total error of measurement. This difference, however, can be accounted for by the difference in the values for the reference element used by Huizenga, namely, the mass of the Pb^{208} isotope. The value of 208.041640 ± 1000 amu for this mass, which he used as the standard in the calculations, was taken from the measurements of Stanford et al.[4] This value differs by approximately 10^{-3} amu from the data of later measurements made independently in two different experiments, according to which M (Pb^{208}) = 208.042658 ± 35 amu[5] and M (Pb^{208}) = 208.042779 ± 6 amu.[6] The mean difference between these values, which are in satisfactory agreement with each other, and the standard mass of the Pb^{208} isotope used by Huizenga is 1.073 ± 0.050 mmu. If this difference is taken into account, then the mass of the Pu^{240} isotope calculated from the measurements of Huizenga will be M (Pu^{240}) = 240.130178 ± 120 amu, which is in good agreement with the value obtained in the present experiment.

Moreover, the data of Everling, König, Mattauch and Wapstra[9] were available to us. These authors made a statistical analysis of the data on the masses of isotopes in the range $1 \leq A \leq 254$ with the aid of an electronic computer by the method of least squares. According to their data, the value of the mass of the Pu^{240} isotope is equal to M (Pu^{240}) = 240.130292 ± 40, which is in very good agreement with the value obtained in the present experiment.

It is known that the Pu^{240} isotope and the Th^{232} isotope are members of the natural radioactive 4n series. The mass of the Th^{232} isotope has been measured previously.[7] To check the accuracy of the measurements and the consistency of the results, it is of interest to compare the difference in the masses of Pu^{240} and Th^{232} obtained by the mass-spectrographic method and the difference calculated from the energies of the α decays by which the isotope Pu^{240} is converted into Th^{232}, i.e., of the decays

$$_{94}Pu^{240} \rightarrow {}_{92}U^{236} \rightarrow {}_{90}Th^{232}.$$

The total values of the decay energies Q and the value of the α-particle mass have been measured with sufficient reliability.[8,1] The values of the Pu^{240} and Th^{232} masses obtained by the mass-spectrographic method are completely unrelated to each other. They were measured from different doublets at different times. The value of the difference obtained by the mass-spectrographic method is $\Delta M\ (Pu^{240} - Th^{232}) = 8.018448 \pm 270$ amu. The analogous difference obtained with the aid of the Q-values for the α decays is $\Delta M = 8.018324 \pm 150$ amu. The difference between these two values is $\delta = 0.124 \pm 0.310$ mmu, i.e., almost one-third the error of measurement. This agreement in the results obtained by completely different methods indicates that the value found for the mass of the Pu^{240} isotope is sufficiently reliable.

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