DECAY OF NUCLEI WITH LESS THAN 126 NEUTRONS

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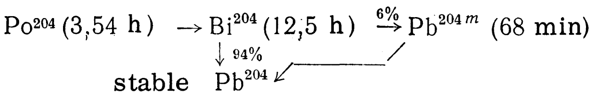
The ratio of the α-decay probability to the overall decay (α decay plus E capture) probability $\alpha/(\alpha + E)$ was measured for Po^{204}. The coefficients a and b in the linear dependence (1) for polonium isotopes with $N < 126$ were determined. The values of $\alpha/(\alpha + E)$ for $Po^{196,198,200}$ were estimated with the aid of this linear relation. The values of the reduced derivative widths δ_L^2, which characterize the probability of α-particle formation were calculated for these isotopes from the value of $T_{1/2}(\alpha)$. The hindrance coefficients for a number of α transitions were found for even-odd Po isotopes.

In previously published studies [1,2] of Po^{204} the ratio $\alpha/(\alpha + E)$ of the probability of α decay with an α-particle energy $E_\alpha = 5.37$ MeV to the overall decay probability (α decay and E capture) was not measured directly. Karraker and Templeton [1] estimated this ratio to be $\sim 1\%$ and Latimer et al. obtained the value $(0.63 \pm 0.16)\%$ by interpolation.

We carried out an experiment in which the ratio of the probabilities $\alpha/(\alpha + E)$ for Po^{204} was measured. To do this we compared the activity of Po^{204}, which undergoes α decay and E capture, with the corresponding activity of Po^{206}, for which the α-decay and E-capture rates are known $[\alpha/(\alpha + E) = (5 \pm 1)\%]$. The amount of Po^{204} nuclei undergoing α decay was measured relative to the α decay of Po^{206} by means of an ionization α spectrometer. The fraction of Po^{204} undergoing E capture was determined from the amount of Bi daughter nuclei separated chemically from Po. The Bi daughter-nucleus activity was measured with a 4π scintillation counter under the assumption that the Po^{204} decay via E capture proceeds through the following radioactive chain [3]:



Here the Po^{204} yield in the Bi fraction was measured relative to the Po^{205} yield, while the Po^{205} yield was measured relative to the Po^{206} yield. It was then possible to determine the amount of nuclei undergoing E capture relative to the total amount of Po^{206}. A more detailed description of the experimental method can be found in [4].

On the basis of several runs, the value of the ratio $\alpha/(\alpha + E)$ for Po^{204} was found to be $(0.645 \pm 0.084)\%$. The error represents the rms error for the series of measurements and does not include the error in the ratio of $\alpha/(\alpha + E)$ for Po^{206}.

Using the experimental data listed in Table I for even-even isotopes of Po^{204} and $Po^{200,202,206,208}$ (see [4-6]), we can plot the logarithm of the partial half-life for ground-state transitions as a function of $(Q_{eff})^{-1/2}$, where Q_{eff} is the total α-decay energy with allowance for the recoil-nucleus energy and the influence of the electron shell of the atom (see [7], p.156). This dependence can be represented in the linear form (see figure)

$$\log T_{1/2}(\alpha) = a/\sqrt{Q_{eff}} + b. \qquad (1)$$

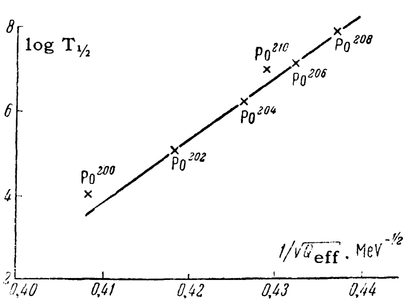
The position of the line was determined by the method of least squares from the data for $Po^{202,204,206,208}$ for which the energy E_α and the value of $\alpha/(\alpha + E)$ have been more reliably determined.

If the partial half-life is measured in seconds and the total α-decay energy is measured in MeV, then the coefficients for the series of even-even isotopes of Po ($N < 126$) are: $a = 150.36$ and $b = -57.746$. It has been shown earlier (see [7], p. 141) that, for even-even isotopes of Po with $N > 126$, these coefficients have the values $a = 129.35$ and $b = -49.9299$. Hence the radioactive series of even-even isotopes of Po can be represented by linear dependences of type (1) with two sets of coefficients a and b. Here the isotopes with $N < 126$ usually have an anomalously low probability for α decay. The isotope Po^{210} does not lie on the line, owing to the effect of the shell with $N = 126$ (see figure).

Using the dependence of $\log T_{1/2}(\alpha)$ on Q, as determined by us we can calculate the values of $T_{1/2}(\alpha)$ for $Po^{196,198,200}$ and, from the experi-

Table I

Mass No., A	No. of neutrons	E_α, MeV	$T_{1/2}$	$\alpha/(\alpha+E)$, %	$\delta^2_{L=0}$
210	126	5.299	138.4 d	110	0.027
208	124	5.108	2.93 y	~100	0.039
206	122	5.218	9.5 d	5	0.055
204	120	5.370	3.54 h	0.645	0.071
202	118	5.575	44.5 min	2	0.078
200	116	5.86	~10 min	$\sim 5(16^{+4}_{-3})$	0.042 (0.13)
198	114	5.935	~6 min	(23^{+7}_{-5})	— (0.25)
196	112	6.14	~1.9 min	(80±20)	— (0.19)



Dependence of logarithm of partial half-life $T_{1/2}(\alpha)$ (in seconds) on total α-particle energy for Po with N < 126.

mentally known overall half-lives $T_{1/2}$, we can then determine the ratios $\alpha/(\alpha + E)$. The results of the calculations are shown in Table I in parentheses. The discrepancy between the experimental and calculated values of $\alpha/(\alpha + E)$ for Po^{200} can be ascribed to the experimental error which could occur in the case of an isotope with a short half-life and to the presence of α particles from Po^{199} with almost the same energy (E_α = 5.87 MeV) [8].

Information on the partial half-life is of great interest from the viewpoint of α-decay theory, in particular, in connection with the determination of the probability for α-particle formation at the nuclear surface. The "reduced derivative width" δ^2_L, i.e., 2π times the "α width" in the absence of the potential barrier [7] is frequently used as a characteristic of the α-decay probability. The last column of Table I lists the values of δ^2_L obtained with the aid of previously reported data [4,5,7] and the results of the present experiment. The values of δ^2_L calculated with the aid of extrapolated values of $T_{1/2}(\alpha)$ are shown in parentheses. For the calculation we used the rectangular nuclear potential model and assumed that the α-particle angular momentum L was zero. The effective radius R was taken equal to 9.3×10^{-13} cm (see [7]). It is seen from the table that for even-even isotopes of Po with N < 126 the value of δ^2_L displays a tendency to increase with the distance from the shell N = 126. Such a behavior has also been observed [7] for even-even isotopes of Po with N > 126. The value of δ^2_L passes through a minimum in the region of the shell N = 126. Qualitatively, this behavior of δ^2_L is in good agreement with the predictions based on the shell model [9].

For even-odd isotopes of Po with N < 126, we can calculate the forbiddenness coefficients F by means of the formula

$$\log F = \log T_{1/2}(\alpha) - (a/\sqrt{Q_{\text{eff}}} + b), \qquad (2)$$

where the coefficients a and b are the same as those in the previously found logarithmic dependence. The calculated values of F are listed in Table II. The values of E_α, $T_{1/2}$, and $\alpha/(\alpha + E)$ were taken from [4-6].

It is still difficult to draw general conclusions about the distribution of the hindrance coefficients, since experimental data on the level system for daughter nuclei and on the α-particle angular momenta for α transitions of Po are almost entirely lacking. It is seen from Table II that comparatively intense α transitions for even-odd nuclei in the case of Po are, as a rule, weakly forbidden in comparison with α transitions for even-even nuclei. For Po^{205} the anomalously small hindrance coefficient can be explained by the fact that it was actually calculated for a group of lines. This could

Table II

A	E_α, MeV	$T_{1/2}$	$\alpha/(\alpha+E)$,%	F
209	4.877	100 y	~100	1.06
207	5.1	5.7 h	~0.01	2.04
205	5.2	1.5 h	0.074	0.32
203	5.48	47 min	~0.02	32
201	5.67	17.5 min	0.8	3.4
199	5.87	11 min	~7	2.8

also prove to be the case for other nuclei, since Forsling and Alväger established the presence of several groups of α transitions in the case of some neutron-deficient Po isotopes. For Po^{203} the large hindrance coefficient can be related to the fact that this nucleus could have a neutron configuration with only one neutron in the unfilled $f_{5/2}$ subshell. Then the α particle is formed from nucleons of different subshells, and such an α transition is, of course, forbidden. This suggestion is not in contradiction with the experimental value 5/2 for the spin of the Po^{203} nucleus [10].

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