RELATIVE MEASUREMENTS OF THE LONGITUDINAL POLARIZATION OF ELECTRONS IN BETA DECAY

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We have made relative measurements of the longitudinal polarization of electrons in the β decay of P^{32}, In^{114}, Pr^{142}, Ho^{166}, and Re^{188} for an energy $E_\beta \approx 1250$ keV. The experiment measured the circular polarization of the bremsstrahlung produced by the electrons in a lead target. The circular polarization value of the bremsstrahlung produced in this way from In^{114}, Pr^{142}, Ho^{166}, and Re^{188} was compared with that from P^{32}. The electron energy was selected by means of a magnetic lens spectrometer. We obtained the following values for the longitudinal polarization P_i, referred to $P_{P^{32}}$: $P_{In^{114}}/P_{P^{32}} = 0.960 \pm 0.015$, $P_{Pr^{142}}/P_{P^{32}} = 0.934 \pm 0.015$, $P_{Ho^{166}}/P_{P^{32}} = 0.942 \pm 0.015$, $P_{Re^{188}}/P_{P^{32}} = 1.005 \pm 0.016$.

In recent years several papers have reported the observation of deviations of the longitudinal polarization of electrons in β decay from the value $-v/c$ required by theory.[1-3] The explanation of these deviations by the existence of definite relations between the matrix elements of the β transition is applicable only to certain first-forbidden β transitions, in RaE, Au^{198}, and Cd^{115m}. [3-5] For interpretation of the other cases it has been proposed that there is an effect due to internal nuclear structure, i.e., a significant contribution from corrections due to higher order forbiddenness. For verification of this hypothesis it is of interest to investigate the dependence of the deviations on electron energy.

All of the measured deviations are associated with the electron energy region 100—400 keV. For energies $E_\beta \sim 1$ MeV and above, the data on longitudinal polarization of the electrons are not particularly accurate (errors ~ 5—10%). We have measured the longitudinal polarization of the β-decay electrons from a number of isotopes at an energy $E_\beta \approx 1250$ keV, with an error of 1.5%. The polarization was measured by observing the degree of circular polarization of the bremsstrahlung produced in a lead target by an electron beam of a definite energy, selected by a magnetic lens spectrometer.

The measurements are relative; i.e., the circular polarization of the bremsstrahlung from the β-electrons of a given isotope was compared with that from P^{32}.

A schematic drawing of the apparatus is shown in the figure. The bremsstrahlung circular polarization was measured from the forward scattering in magnetized iron. An Armco iron shield and compensating coils were used to remove the effect of the stray magnetic field of the polarimeter on the photomultiplier and on the spectrometer.

The sources were deposited on a ~ 5 mg/cm^2 Al backing and had a surface density of 2—3 mg/cm^2 for P^{32} and ≤ 10 mg/cm^2 for the remaining isotopes. The activity of the sources was 1—5 Curies. A check of the effect of source and target thickness on the size of the measured effect did not disclose a noticeable depolarization of the β-electrons and bremsstrahlung for the thicknesses used. The effect of the size of the source and accuracy of its placement was also checked.

During the measurements the source was replaced once every twenty-four hours, and measurements with the P^{32} source used for comparison were made systematically every two to three days. The effect in phosphorus remained constant during the entire period of the measurements.

The whole measurement cycle was automated. The results of the measurements are presented below (the values of the longitudinal polarization of electrons from In^{114}, Pr^{142}, Ho^{166}, and Re^{188} are referred to the value for P^{32}):

P^{32}	In^{114}	Pr^{142}	Re^{188}	Ho^{166}
1.000	0.960 ± 0.015	0.934 ± 0.015	1.005 ± 0.016	0.942 ± 0.015

The errors indicated in the results include statis-

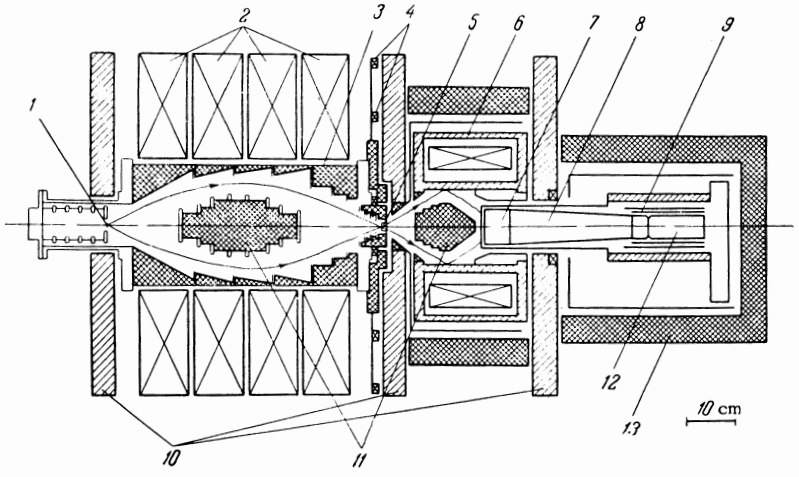

FIG. 1. Schematic drawing of the apparatus: 1 – source, 2 – magnetic spectrometer coil, 3 – vacuum chamber, 4 – compensating windings, 5 – lead target, 6 – γ polarimeter, 7 – 70 × 50 mm NaI(Tl) crystal, 8 – light pipe, 9 – Permalloy shields, 10 – Armco shields, 11 – lead shields blocking the direct beam, 12 – FÉU-13 photomultiplier, 13 – lead shielding to reduce room background.

tical errors and possible systematic errors.

Since Spivak et al[1] and Brosi et al[6] have shown that the longitudinal polarization of electrons from P^{32} at energies of 340 and 615 keV is equal to $-v/c$ with an accuracy of 1–1.5%, we can assume that it is also equal to $-v/c$ for $E_\beta \approx 1250$ keV. Therefore our results give with a known confidence level the value of polarization for the isotopes listed, referred to $-v/c$. The results obtained allow us to draw the following conclusions.

The longitudinal polarization of β-decay electrons from In^{114} (an allowed transition), Pr^{142} (a unique first-forbidden transition), and Ho^{166} (a mixture of unique first-forbidden and $0^- \rightarrow 0^+$ transitions) deviates from the value $-v/c$ if we assume the longitudinal polarization for P^{32} electrons to be strictly equal to $-v/c$.

The deviation in the case of Pr^{142} is the first experimentally observed deviation of the longitudinal polarization of electrons in a unique first-forbidden β transition.

Comparison of the measured deviations with the data of Spivak et al[1] shows that, for the isotopes studied in both works (In^{114} and Ho^{166}), the deviations from $-v/c$ decrease with increasing energy roughly as $1/W$, where W is the total energy of the electrons. An energy dependence of this type is consistent with the hypothesis of an internal nuclear structure effect.

The electron longitudinal polarization of the nonunique first-forbidden transition in Re^{188} (still assuming a polarization of $-v/c$ for P^{32}) is equal to $-v/c$ with a possible error of 1.5%.

The observed deviations in the polarization do not correlate with existing data on the shape of the β spectra of the corresponding transitions. However, it should be noted that the data on the shape of the β spectra are not particularly accurate or else (in the case of In^{114}) do not agree with each other.

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