Measurement of the Coefficients of Internal Conversion of γ-Rays of Sr^{87*}, In^{113*}, In^{115*} and V^{51*} on the Electrons of the Atoms

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The total coefficients of internal conversion of γ-rays of Sr^{87*}, In^{113*}, In^{115*} and V^{51*} on the electrons of the atoms are determined by the method of direct measurement of the number of electrons and γ-quanta which are emitted by the source.

The corresponding values, which have been found, i.e., 0.26 ± 0.03, 0.39 ± 0.04, 0.9 ± 0.6 and $(3.1 \pm 0.2) \times 10^{-3}$ give basis for the conclusion that the isotopes Sr^{87*}, In^{113*} and In^{115*} have electric 2^5 pole radiation transition and that V^{51*} has electric quadrupole radiation transition.

1. INTRODUCTION

IN the case of the nuclear radiation transition, the magnitude of the internal conversion coefficient of γ-rays depends on the character of the transition and the multiplicity of the radiation[1].

The coefficients of internal conversion corresponding to the electric or magnetic character of radiation in the most cases differ by no more than 20-50 % in the neighboring multiplicities. Therefore, precise conclusions about the multiplicity as well as about the character of the nuclear radiant transition which may be obtained by means of comparing theoretical and experimental values of coefficients of internal conversion of γ-rays, can be made only after precise experimental works. In the experimental determination of those coefficients, it is advisable to use various methods to avoid errors which are inherent in any one method.

In this work, the coefficients α of internal conversion of γ-rays which are emitted by isomeric transitions of Sr^{87*}, In^{113*} and In^{115*}, have been determined by the means of direct measurements of the number of the γ-quanta N_γ and electrons N_e emitted by the isomer, i.e., $\alpha = N_e/N_\gamma$.

Ionization methods were used in measuring N_e and N_γ. In those particular cases which are the subject of this work, the measurement of electron and γ-monochromatic emission can also be made by the application of other methods. In this work, the emissions have been detected by means of gas-discharging counters. After the application of corrections, it was possible to determine the absolute number of electrons and γ-quanta which were emitted by sources with monochromatic spectra of γ-emission. Our investigations were performed with the purpose of verifying the data[2] which are in contradiction with the conclusions about the character of isomeric transitions Sr^{87*}, In^{113*} and In^{115*} obtained in other researches which were related to the classification of nuclear isomers[3].

2. METHODS OF EXPERIMENT

For the investigation of γ-rays in this work, the gas-discharging cylindrical counter was 10 cm long and 2 cm in diameter. The inner glass part of the counter was coated with a thin layer of copper. The efficiency ϵ of this counter, in the region of γ-ray energy with which we are concerned, was measured by means of radioactive isotopes Hg^{203}, Sr^{87*} and A^{198} with the simple γ-ray spectrum[4] which has intense monochromatic lines and energies 279, 390 and 411 kev, respectively. The number of γ-quanta emitted by the above mentioned source had been measured with an ionization chamber (provided with slit). The efficiency of this chamber with relation to the γ-quanta was known[5]. the relation between ϵ and the energy of γ-quanta was determined; it is presented by Fig. 1.

As the gas-discharging counter has a low efficiency relating to the γ-quanta, the sources of the

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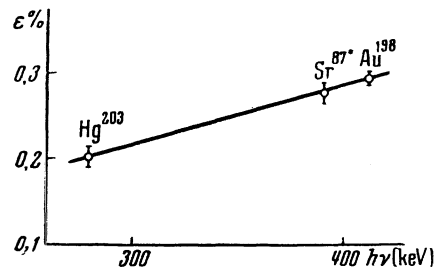

Fig. 1. The dependence of the efficiency of the gas discharging counter of the γ-quanta energy.

order of 0.1 mCu were kept at the distance 3-8 cm from the counter.

The geometrical conditions of these experiments were calibrated beforehand using the sources of higher intensity and various distances, even higher than 3-8 cm. The calculation of a solid angle of the source relative to the counter was easily done for distances of 20-50 cm.

The source was deposited on a mica plate of thickness 13.5 mg/cm^2 which in its turn was attached to a cup-shaped aluminum piece.

When electrons, emitted by the source, have been measured, the aluminum cup (*1*) with the source was placed in the inner part of a glass vacuum tube (*2*) with inside diameter 30-35 mm (Fig. 2).

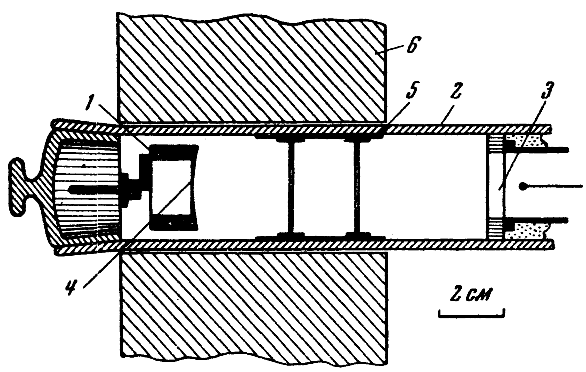

Fig. 2. Device for measuring the intensity of electrons. *1.* Aluminum cup; *2.* Vacuum tube; *3.* Gas-discharging counter; *4.* Source; *5.* Aluminum diaphragm; *6.* Electromagnet.

On the opposite end of the vacuum tube, the gas-discharging counter (*3*) with a mica window 3-4 mg/cm^2 thickness, and diameter 20 mm, was placed between the source (*4*) and counter. The aluminum diaphragm was mounted to shield the scattered electrons. Thus, the region of the tube close to the counter was free from the action of scattered electrons. The distance between a source and counter was 6-9 cm. The size of source was 4-8 mm, so that it could be considered as a point. The vacuum tube was between the magnetic poles, but the counter was placed outside of the magnetic field. During the experiments, the tube was evacuated.

The action of x-rays and γ-emission on the counter was taken into account when experiments with magnetic field of intensity 1600 gauss were performed. In order to determine the absolute intensity of electrons, the corrections were applied for absorption of electrons by the mica window of the counter as well as for back scattering of electrons.

By means of the change of pressure in the tube, the absorption of electrons was measured under the arrangements of these experiments. The measured parts of the absorption curves were approximated by exponentials having absorption coefficients $\mu = 24$ cm^2/g for the electrons emitted by In^{113*}, $\mu = 44$ cm^2/g for electrons emitted by Cr^{51} and $\mu = 46$ cm^2/g for electrons of In^{115*} The absorption of electrons in the counter window and in the preparation was calculated using these experimentally found coefficients of absorption. The correction connected with the absorption of electrons by the mica window was of the order 10-15%. The correction connected with the absorption by the specimen was dependent on the thickness of the specimen.

In the preliminary experiments, the source Cr^{51} was deposited on a mica plate 2.6 mg/cm^2 thick. Later on, an additional layer of mica was attached to the back part of the plate. The registered counts increased by 4-5% with the thickness 13.5 mg/cm^2, and up to 10-12% with thickness 2 mm. Disregarding the reflection of electrons from the thin plate, we obtained the correction with the back-scattering of electrons for measuring the number of electrons emitted by the source. The preliminary tests also proved that it is reasonable to disregard reflection by the aluminum cup. The purity of sources was controlled with the help of disintegration curves of β- and γ-emission. The energy of registered electrons was evaluated by the paths traversed in the aluminum. The values found served as proof that the measurement was concerned only with electrons of internal conversion. The distances traversed by these electrons in our cases were of the order 100 mg/cm^2.

3. THE MEASUREMENTS OF In^{113*}, In^{115*} AND Sr^{87*}

Isomer In^{113*} as a product of a disintegration of the isotope Sn^{113*} was produced in its pure chemical state from the radioactive tin. The source deposited on the mica plate was practically weight-

TABLE I

The characteristic of the isomeric transitions of In^{113*}, In^{115*} and Sr^{87*}

Name of the Isomer	The half-life in hours	The energy of an excitation in kev	The total coefficient of an internal conversion of γ-rays on the electrons of an atom α		The coefficient of an internal conversion of γ-rays on the K-shell of an atom α_K		
			According to the work (2)	According to this work	The experimental value	The Theoretical Value	
						The electric 2^5 pole transition	The magnetic 2^4 pole transition
In^{113*}	1.75	392	0.44 ±0.03	0.39 ±0.04	0.32	0.33	0.46
In^{115*}	4.5	334	0.82 ±0.13	0.9 ±0.06	0.70	0.69	0.92
Sr^{87*}	2.8	390	0.28 ±0.03	0.26 ±0.03	0.22	0.23	0.19

less. The measurements of the number of γ-quanta were first carried out.

Afterwards, the source was placed in the vacuum tube, already described. The measuring of electrons emitted by the source was performed with application of the corrections for the absorption of electrons by the window of a counter (11%) and for the electron's back scattering at the plate (4%). Altogether, four different series of experiments were performed. The pure isomer In^{115*}, which is the result of disintegration of an isomer Cd^{115} with $T = 54$h, was produced by chemical method from the radioactive cadmium. The weight of deposited source on the mica was less than 1 mg. Therefore, the absorption in the specimen was disregarded. During the determination of the number of electrons which are liberated from an atom in the internal conversion of γ-rays , it was taken into account that In^{115*} may by the β-disintegration be transformed into Sn^{115} (the branch of β spectrum,.5.5%)[4].

The average value of the total coefficient of internal conversion of γ-rays in In^{115*}, obtained from four experimental series, is given by the Table I. When Sr^{87*} was investigated the chemically pure source of this isomer was not available. Strontium nitrite, containing the isomer in which we have been interested was deposited in the form of fine powder on the mica plate in order to avoid a dispersion in a vacuum tube. The specimen with a thickness 8-16 mg/cm^2 was covered by the organic film with a thickness ~ 0.1 mg/cm^2. The correction for the absorption of electrons by the source was of the order 10-20%. The absorption of the monochromatic electrons with an energy close to those electrons which are emitted by Sr^{87*}, was pretty well studied earlier with the weightless specimen of In^{113*} Five experimental series were carried out and the average values of results are given in the Table I. The fact that the thickness of the source had no effect is an indication that the calculation of the electron's absorption by the source was correct.

In Table I, the principle characteristics of isomeric transitions In^{113*}, In^{115*} and Sr^{87*} are presented. In the first columns of the Table, the half-lives and the energies of the corresponding transitions are shown. In the subsequent columns, the coefficients of internal conversion of γ-rays on the electrons of an atom α, which have been determined by Antonova and Estulin previously[2], as well as α obtained by the present work, are presented.

The experimental errors estimated from the various experiments are given as the arithmetic mean.

In the work with In^{115*}, the discrepancies of separate experiments were negligible. In this particular case, half of the maximum error of the apparatus was taken as experimental error.

In the limits of the experimental error, the results of this work are in agreement with results in reference 2. It should be noted that in this work the method of absolute measurements of the number of electrons and γ-quanta was different from that used in reference 2. Thus the possibility of a systematic error of measurement in the total coefficients of internal conversion on the γ-rays is apparently diminished. On the basis of the values of α determined in this work the experimental values of the coefficients of internal conversion of γ-rays on the electrons of K-shell α_K have been found (column 6, Table I).

The ratio of the coefficients of internal conversion on K and $L + M + \ldots$ shells of an atom $\alpha_K/\alpha_{L+M+\ldots}$ is taken from the experimental works of other authors and is the same as in reference 2. The theoretical values of α_K obtained by the method of an extrapolation* in reference 6 are shown in the last columns of the Table.

The values of α_K found by experiment are in an agreement with the theoretical values of α_K for the 2^5-fold electrical transition. Thus, if the theoretical values α_K in reference 6 are correct, the isomeric transitions In^{113*}, In^{115*} and Sr^{87*} should be considered as types of 2^5 electrical transitions. These conclusions are in agreement with results of reference 2 and do not contradict the predictions of the theory of the nuclear shells.

MULTIPLICITY OF γ-RADIATION OF V^{51*}

The radioactive isotope Cr^{51} which has a half-life of 26.5 days, decays by capture of the orbital electron and subsequently forms V^{51} partially in the excited state[4]. In reference 7 is shown the possibility of two excited states of V^{51}. However, later it was proved that when Cr^{51} decays, only one excited state of V^{51} takes part, with the energy of excitation 320 kev. In the same reference 7 the coefficient of the internal conversion of γ-radiation, which is connected with the transition $V^{51*} \rightarrow V^{51}$ is taken as $\alpha \sim 0.02$. Later on, in reference 8, the value of α is given as $\alpha = 1.5 \times 10^{-3}$.

Thus, the radioactive isotope Cr^{51} emits the intensive characteristic x-radiation and has not any other electron radiation except of those electrons which are torn out from the atom by means of the internal conversion of γ-rays of V^{51*} with the energy of excitation 320 kev.

As the continuous β-spectrum is absent, the measurement of the internal conversion coefficient of γ-rays V^{51*} by the magnetic spectrometer with the method of comparison of the areas is inapplicable. In this particular case, although α is very small, it turns out to be possible to measure its value by means of the absolute measurements of the intensity of electrons and γ-quanta by the method shown in Sec. 2 of this work.

Using the same method as in the case with measurements of In^{113*}, In^{115} and Sr^{87*}, we deposited a source containing radioactive isotope Cr^{51} on the mica plate, and after measurement of γ-rays it was placed in the vacuum tube (Fig. 2). The thickness of the source was 5.5 mg/cm^2. The correction connected with the absorption of the electrons by a source was 10%.

Since a gas-discharging counter with the thin window was effective for the characteristic x-radiation of V^{51}, the precise measurement of the counts of a counter with and without a magnetic field was possible. Altogether, five series of measurements were carried out. A value of the total coefficient of internal conversion $\alpha = (3.1 \pm 0.2) \times 10^{-3}$ was obtained.

We now come to the coefficient of conversion of γ-rays on the K-shell of an atom α_K. Its theoretical value is known[6]. For this purpose, it is reasonable to make use of the ratio of the internal conversion coefficients on the K and L shells of an atom α_K/α_L.

In the case under discussion, when there is either dipole or quadrupole emission and the parameter $Z^2/E = 1.65$ (Z = atomic number, E = the energy of the radiative transition in kev) which determines the ratio α_K/α_L [3] is small, the value of α_K/α_L is of an order 11 for a magnetic type of emission and of the order 12 for emission of an electrical type[10]

TABLE II

The coefficient of internal conversion of γ-rays V^{51*} on the K-shell of an atom α_K

Experimental value	Theoretical value	
	Dipole Magnetic Transition	Quadrupole Electric Transition
$(2.9 \pm 0.2) \times 10^{-3}$	0.95×10^{-3}	3.8×10^{-3}

These values of the ratio α_K/α_L are taken from the theoretical works and very likely can be applied in the present case. The experimental value of α_K (Table II) is obtained from α by taking into consideration the value of a ratio α_K/α_L. In Table II, there are also shown the theoretical

* This problem was considered in more detail in reference 2.

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values of α_K for the dipole magnetic and quadrupole electric transitions, which have been found with the use of extrapolation in reference 6 for $Z = 23$.

The comparison of the experimental and theoretical values of α_K leads to the conclusion that electric quadrupole character of transition should be ascribed to $V^{51*} \rightarrow V^{51}$. It is possible that magnetic dipole emission is available in a very small quantity. In accordance with the theory of nuclear shells with a strong spin-orbital bond, the state $f_{7/2}$ corresponds to the principal state of V^{51}. In the case when the nuclear shells are successively filled up, the first excited level will have state $f_{5/2}$, hole-level will have the state $S_{1/2}$ or $d_{3/2}$.

The conclusion about the quadrupole character of an emission may find its confirmation in the fact that the nucleus of V^{51}, after getting into an excited state, fills up its nuclear levels successively, which is in agreement with an inference of reference 11. The transition $V^{51*} \rightarrow V^{51}$ belongs to the type $f_{5/2} \rightarrow f_{7/2}$.

The correlation of the decay probabilities of Cr^{51} into ground or excited state of V^{51} [8,9] is in agreement with the state $f_{7/2}$ of a nucleus of Cr^{51}, which was predicted by the theory of nuclear shells.

Translated by M. Hadsinskyj
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Some Observations on Possible Formulations of the Theory of Extended Particles

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Some of the features of possible formulations of a theory of non-localized fields are considered. In particular, it is shown that if the operators of the non-localized fields are considered to be non-diagonal matrices in coordinate space, then non-interacting non-localized fields cannot be equivalent to an aggregate of fields of local type. Finally some considerations are presented concerning the comparison of results of a theory of extended particles with experiment.

1. The search for a possibility of eliminating the fundamental difficulties of field theory, associated with the presence of divergent expressions in the apparatus of the present theory, constitutes one of the central parts of contemporary physical literature, devoted to the study of the properties and interaction of elementary particles. The importance of the problem is due to the close connection of these difficulties with the most profound problems of the structure of matter: the mass and structure of elementary particles, the coupling of these particles, nuclear forces, etc.

One may feel[1] that the elimination of many of the difficulties of present physical theory, among which are the difficulties with divergences connected with the incorrect application, for the description of phenomena taking place in small space-time regions, of concepts and principles which are in accord with experiment only over large regions of space-time*. From this point of view, some ideas which have been recently thoroughly discussed are of great interest; these are the hypothesis of non-local fields[2-4], in which the errors in determination of field, ΔA, and coordinate, Δx, are connected by the relation $\Delta A\ \Delta x \sim \lambda_0 A$, and the closely connected hypothesis of non-local interaction[5], i.e., the hypothesis that the interaction is "smeared" over a small space-time domain. Mathematically these ideas are formulated by the introduction into

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* On the other hand, it is hard to deny that a definite part of our difficulties is due to incorrect application in various cases of one or another mathematical method. In particular, it may be that taking account of higher approximations of perturbation theory will bring the essential corrective measure.

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