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...ransformation with the Absorption of the Orbital Electron

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Table II.

Z	a_K^2	Δw	σ(Fermi)	σ(K-U)
14	0.1	2	2.9	0.15
14	0.1	5	250.	36.
27	0.2	2	0.2	0.022
27	0.2	5	21.	3.1
82	0.6	2	0.8×10^{-3}	2.5×10^{-3}
82	0.6	5	0.1	0.016

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By Hideki YUKAWA and Shoichi SAKATA.

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...n of Neutrons with Deuterons

Shoichi SAKATA.

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...OF THE PENETRATING ...COSMIC RAY

With the Authors' Compliments

...e Efficiency of the γ-Ray Counter

By

HIDEKI YUKAWA
SHOICHI SAKATA

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...of Disintegration of Nucleus by Neutron

...oshihiko MIYAGAWA.

湯川秀樹は大阪帝国大学に主論文と参考論文９編からなる博士学位論文を提出した。
昭和 13 年（1938 年）4 月 5 日、大阪帝国大学第 584 号の学位が湯川に授与された。

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SHOICHI SAKATA

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Theory of Disintegration of Nucleus by Neutron Impact.

By Hideki YUKAWA and Yukihiko MIYAGAWA.

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Ay Hideki YUKAWA.

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On the Nuclear Transformation with the Absorption of the Orbital Electron

According to the present theory of β disintegration, the nucleus of atomic number Z transforms into its isobar $Z-1$ with the emission of a positron and a neutrino, if the difference ΔW of proper energies of these isobars is larger than $mc^2+\mu c^2$, where m and μ are the masses of the electron and the neutrino, respectively. On the contrary, the isobar

TABLE I.

Z	αZ	τ(Fermi)	τ(K-U)
1	1/137	2740 $(\Delta w+1)^{-2}$ years	1860 $(\Delta w+1)^{-4}$ years
2	2/137	170 $(\Delta w+1)^{-2}$ years	120 $(\Delta w+1)^{-4}$ years
14	0.1	200 $(\Delta w+1)^{-2}$ days	130 $(\Delta w+1)^{-4}$ days
27	0.2	25 $(\Delta w+1)^{-2}$ days	16 $(\Delta w+1)^{-4}$ days
69	0.5	12 $(\Delta w+0.87)^{-2}$ hours	8 $(\Delta w+0.87)^{-4}$ hours

$Z-1$ transforms into Z with the emission of an electron and an antineutrino, if ΔW is smaller than $-mc^2-\mu c^2$. The isobar Z can transform into $Z-1$ also by absorbing one of the orbital electrons and emitting a neutrino at the same time, if ΔW is larger than $-E+\mu c^2$, where E is the total energy of the orbital electron.

Thus, two isobars with consecutive atomic numbers are both stable, only if ΔW lies between $-mc^2-\mu c^2$ and $-mc^2+\mu c^2$. This condition can be fulfilled very rarely, if the neutrino mass is small compared with the electron mass. Since the existence of several such pairs of stable nuclei was confirmed by experiment recently,[1] it will be worthwhile to give a brief account of the results of our previous calculations on this subject.[2] It will be interesting, moreover, to determine the ratio of the probabilities of the positron emission and the electron absorption above considered, when ΔW is larger than $mc^2+\mu c^2$.

First, the mean lifetime τ of the nucleus Z due to the absorption of either of two K electrons with $E=mc^2(1-\alpha^2Z^2)^{\frac{1}{2}}$ was calculated for the allowed transition, where α was the fine structure constant. If the neutrino mass is assumed to be zero, τ is approximately proportional to

$$(\alpha Z)^{2\gamma+1}/(\Delta w+\gamma)^2 \quad \text{or} \quad (\alpha Z)^{2\gamma+1}/(\Delta w+\gamma)^4,$$

according as the coupling scheme of Fermi or Konopinski-Uhlenbeck is adopted, where

$$\Delta w=\Delta W/mc^2, \qquad \gamma=(1-\alpha^2Z^2)^{\frac{1}{2}}.$$

The numerical values for several cases are shown in Table I.[3]

The apparent discrepancy between these results and the existence of stable pairs of heavy nuclei can be removed, only if we assume (i) the difference of nuclear spins to be large in every case, or (ii) the neutrino mass to be comparable with the electron mass, or (iii) the wave functions of the electron in the neighborhood of the nucleus to be much smaller than those calculated by Dirac's theory.

TABLE II.

Z	αZ	Δw	σ(Fermi)	σ(K-U)
14	0.1	2	2.9	0.15
14	0.1	5	250.	36.
27	0.2	2	0.2	0.022
27	0.2	5	21.	3.1
82	0.6	2	0.8×10^{-3}	2.5×10^{-5}
82	0.6	5	0.1	0.016

The extreme case $Z=1$ in Table I, which corresponds to the transformation of the hydrogen atom into the neutron, will not occur actually according to the recent data of mass defects, whereas the case $Z=2$ has some practical importance indicating the spontaneous transformation of He^3 into H^3 by absorbing one of the K electrons.

Next, the ratio σ of the probabilities of the positron emission and the K electron absorption was calculated on similar assumptions as above, when ΔW is larger than $mc^2+\mu c^2$, the numerical results for $\mu=0$ being summarized in Table II.

Thus, for ordinary radio elements emitting positrons, for which Z is small and Δw is about 5 or more, the ratio σ is so large that the order of the mean lifetime calculated by assuming the positron emission alone is not changed by the additional contribution of the absorption of the orbital electron. On the contrary, for large values of Z, the latter process will occur far more frequently than the former as long as Δw is not too large compared with 1. It will be possible to test these conclusions by experiment.

Department of Physics,
Osaka Imperial University,
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February 18, 1937.

HIDEKI YUKAWA
SHOICHI SAKATA

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On the Theory of Collision of Neutrons with Deuterons

By Hideki YUKAWA and Shoichi SAKATA.

ON A POSSIBLE INTERPRETATION OF THE PENETRATING COMPONENT OF THE COSMIC RAY

By

HIDEKI YUKAWA

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