In order to classify all the interactions in this way, we have investigated the condition for the "closing" in the renormalization theory as applied to the most general type of interaction. Let the number of field quantities U^α of the field (α), and the maximum number of the derivation operators which operate on the $U^\alpha(\alpha=1, 2, \cdots)$ in the interaction hamiltonian $H_l(l=1, 2, \cdots)$ be $k_l{}^\alpha$ and a_l, respectively, and let the asymptotic form of the fourier amplitude $\Delta^\alpha(p)$ of the propagation function of the field (α) be $p^{b^\alpha-2}$ for large p. Then, the condition for the closing is given by

$$K_l \equiv -\Sigma_\alpha \tfrac{1}{2}(b^\alpha+2)k_l{}^\alpha+4-a_l \geqslant 0 \quad (l=1, 2, \cdots). \tag{1}$$

The results so far obtained for various cases by actual calculations[4] are found to be compatible with the conclusions from condition (1).

Now, in connection with the requirement (1) concerning the limit of applicability of the renormalization theory, it is of interest to recall Heisenberg's[5] classification of interaction types into first and second kinds. According to his considerations, when the coupling constant is of the dimension l^n with $n>0$, the present quantum field theory cannot give correct results for phenomena relating to a wavelength shorter than l (in this case the series expanded in powers of the coupling constant does not converge).[6] Such phenomena are regarded as being closely connected with the so-called "universal length r_0,"[7] and so with the structure of elementary particles.

Now, it can be verified that n is equal to $-K_l$, whose value is the criterion for the applicability of the renormalization procedure. This important fact gives the physical basis for condition (1) and also clarifies the reason that the renormalization theory has succeeded in the electrodynamics of the electron.

In view of condition (1), we may classify the interaction types as follows: (a) the case in which the renormalization procedure gives a consistent closed theory, i.e., interaction of the first kind of Heisenberg with $n=-K=0$, (b) the case in which the renormalization procedure gives a consistent closed theory, i.e., interaction with $n=-K<0$, (c) the case in which the renormalization fails, i.e., interaction of the second kind of Heisenberg with $n=-K>0$.

For the closing of the theory type (a) occasionally requires the further introduction of type (b). As an example of such cases, we may mention the interaction between a nucleon and a scalar meson via scalar coupling, where a $\lambda\phi^3$-term is required. Type (c) corresponds to the case in which the perturbation expansion does not converge.

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[*] Read at the Nagoya meeting of REKS (the Kansai Branch of the Elementary Particle Theory Group), held on February 6, 1951.

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The α-γ Angular Correlation in the Decay of Radiothorium[*]

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THE most reasonable energy level diagram for those levels in RdTh and ThX that are displayed in the α-decay of RdTh is given in Fig. 1. This arrangement of levels is based on a number of measurements of the various radiations involved in the α-decay. The α fine structure was measured by Rosenblum and co-workers.[1] They found only the two α-lines shown, except that the line α_1 showed a broadening that would be consistent with the existence of the close doublet at the ground state of ThX. This doublet is suggested by the observations of two gamma-rays (of energies 83.3 and 86.8 kev) by Surugue and Tsien[2] and by Riou.[3] The conversion coefficients for the γ's can be computed from their data and they both correspond to electric quadrupole transitions. It is likely that the spins J_1 and J_4 are equal to zero because the nuclei involved are even-even. All these data together imply that all the levels have the same parity.

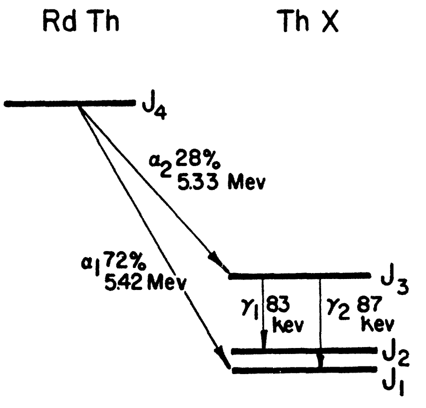

FIG. 1. Energy levels in the decay of RdTh.

The measurement of angular correlations between successive nuclear decay radiations is a means of checking a given set of assumptions concerning the spins and parities of the levels involved. In the case of the natural radioactivities, e.g., RdTh, many data have been accumulated. It was felt that an $\alpha-\gamma$ angular correlation in this case, would have the property of confirming or denying the validity of the accumulated picture (Fig. 1) in all of its details. The results of a previous attempt[4] to measure this correlation were not sufficiently reliable for this purpose.

In the present experiment scintillation counters were used for both the α- and γ-detectors. A large number of runs, each lasting several hours and including angles in all four quadrants, were made

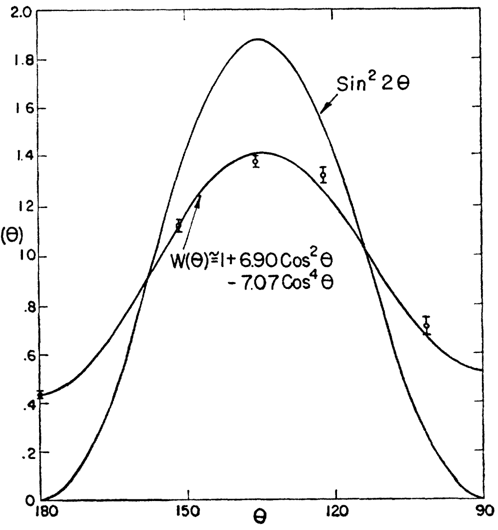

FIG. 2. The observed correlation with both γ-rays. $W(\theta)$ is the least squares fit to the data. $\mathrm{Sin}^2 2\theta$ is the theoretical correlation corresponding to the spin sequence $0 \xrightarrow{\alpha} 2 \xrightarrow{\gamma} 0$. The two curves are normalized to the same total coincidence rate.

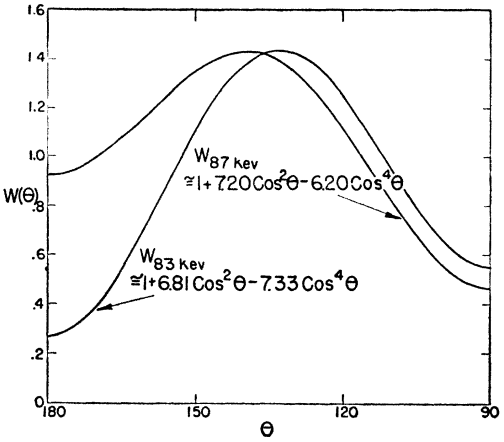

FIG. 3. The separate correlations of the 83- and 87-kev photons. The data for the five angles, from which W_{83} was constructed, were known only to about 10 percent. The errors on the individual points for W_{87} are closer to 50 percent, since they were obtained by a subtraction procedure.

on thin sources of RdTh freshly separated from the equilibrium mixture of RdTh and its decay products. Various checks showed that possible spurious effects of long-lived radioactive impurities and of the build-up of removed activities were negligible. The experimental chamber was lined with lead to reduce effects of photon scattering. As a further precaution, differential discrimination was used on both the α- and γ-pulses.

It was possible to confirm a number of features of the decay scheme in Fig. 1. Absorption measurements of the coincidences showed that the γ's have energies between the K edges of gold and lead (81 and 88.5 kev) and that their intensity relative to α's is roughly as expected. The fact that the coincidences are observable with a 0.3 μsec resolving time implies that the γ-multipolarity is probably no higher than electric quadrupole.[5] The large $\cos^4\theta$ term in the observed correlation indicates that the radiations are at least quadrupole. These results are thus in agreement with the implications of the conversion coefficients on the nature of the γ-radiation. It was also possible to confirm that the γ-rays do not occur in cascade.

The observed correlation between the α's and both γ's was very pronounced and is shown in Fig. 2. It was also possible to obtain a relatively rough idea of the separate correlations for the two γ-rays by the use of thallium absorbers (the K-edge of Tl falls between the two γ's). These results are given in Fig. 3. The observed correlations are fairly close to those expected for the spin assignment $J_2=0$, $J_3=2$, but the differences are significantly outside the experimental error.

A number of attempts were made to account for these differences. Partial reorientation of the excited ThX nucleus, before γ-ray emission, could account for the differences between the observed correlation and the one with the spin sequence $0\xrightarrow{\alpha}2\xrightarrow{\gamma}0$. However, these interactions which we have been able to consider do not appear to be sufficiently strong to induce reorientation in the required time. Other level schemes (some admittedly inconsistent with accepted data) including a large number of reasonable (and unreasonable) spin assignments were considered in computations of new correlation functions in order to find a better fit than the one above. Mixtures of different angular momenta for both the α- and γ-emissions were also considered. It has not, however, been possible to find a really convincing fit. In fact, most of the computed correlations are not nearly as sharp as the observed one. It is felt that the sequence $0\xrightarrow{\alpha}2\xrightarrow{\gamma}0$ must play a prominent role in the RdTh decay.

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The *K*-Capture/Positron Branching Ratio in Cu^{64}

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THE K-capture/positron branching ratio in Cu^{64} has been measured in a 180° magnetic spectrometer by comparing the relative intensities of the K Auger electrons and the positrons. The branching ratio for this isotope has been reported by several investigators,[1–4] but previous to this letter only Cook and Langer have obtained a ratio by comparing relative Auger electron and positron intensities. Improved techniques in the detection of low energy electrons and in source preparation[5] have made it possible to obtain more reliable data.

The copper activity was obtained in the cyclotron by bombarding a copper probe with 8-Mev deuterons. Then approximately 0.1 mg of active copper, removed from the tip of the probe, was placed in a platinum boat which was the filament of a vacuum evaporator. The spectrometer source was prepared by thermal evaporation of the metallic radioactive copper from this filament in a vacuum. This source, estimated to be 5 micrograms/cm² thick, was deposited on a double layer of zapon 15 micrograms/cm² thick and was grounded by means of a previously evaporated and extremely thin copper film. By overlapping points throughout the experiment, a single half-life of 12.9 hours was observed, indicating the absence of any noticeable impurities.

The measurements were made in a 15-cm radius of curvature, shaped magnetic field spectrometer.[6] A zapon side window counter was used as a detector. The zapon film was supported by a Lectromesh grid, and the 2-cm total pressure in the counter was maintained constant by means of a cartesian monostat system.[7]

Figure 1 shows the K Auger electron lines at 6.56 kev and 7.48 kev which correspond to K-$2L$ and K-L-M energy differences in nickel.[8] Part of the line width is attributed to the unresolved energy difference between L_{II} and L_{III} electrons. The normal resolution from monogenergetic electrons from a thin source 0.3 cm wide is 1 percent in this spectrometer. The absence of any appreciable low energy tail indicates that there was negligible source absorption at this energy.

The positron intensity was obtained by taking measurements in the region below 250 kev with the zapon side window counter. This data was then analyzed into a Fermi plot with the appropriate corrections for screening.[9] The resulting straight line was extended to the known end-point energy of 657 kev. The complete momentum distribution for the positrons was obtained from this Fermi plot. From this a ratio of 1.18±0.10 is found for the intensity of the K Auger electrons to the intensity of the positrons.

To obtain the K capture/positron ratio for Cu^{64}, this K Auger electron/positron ratio must be divided by one minus the fluorescent yield in nickel. If the value of 0.38 is used for this fluorescent yield,[8] the K-capture/positron branching ratio of Cu^{64} is 1.90 ±0.20. Recently, West and Rothwell[10] measured the fluorescent yield in krypton and obtained a value 20 percent higher than previously reported. Using their value and extrapolating to $Z=28$, a fluorescent yield of 0.45 is obtained for nickel. This gives a