Q-value of $-(1.006\pm0.010)$ Mev has been given[3] corresponding to a mass difference of (0.22 ± 0.01) Mev.

The new method of determining the energy-release in electron capture processes may be applied even in some cases where the disintegration goes over an excited level of the daughter nucleus with the emission of a nuclear γ-ray. A more detailed account will be published in *Helvetica Physica Acta*. We thank Professor P. Scherrer for his interest in this work.

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Angular Correlation of the Continuous Radiation Accompanying Beta-Decay*

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THE theory of the continuous gamma-radiation accompanying beta-decay was developed by Knipp and Uhlenbeck[1] and by Bloch.[2] An extension to forbidden transitions was made by Chang and Falkoff,[3] especially for the scalar interaction. This radiation has been found by several investigators,[4] and recently it has been possible to measure the shape of the gamma-ray continuum at low energies (50 kev–300 kev).[5] Theoretical predictions show that for low energies the shapes of the gamma-continua are almost identical for allowed and first-forbidden transitions for any interaction. This point has been verified experimentally (to be published).

We thought it might be of interest to calculate the angular correlation between the beta-particle and its associated gamma-quantum and to see if one could distinguish between allowed and forbidden transitions. We calculated the correlation for allowed and first-forbidden transitions, making use of the tensor interaction and neglecting charge dependence. We obtained the following expressions for the allowed and first-forbidden correlation functions $W(\theta)$. The first-forbidden formula is for the special selection rule ($\Delta J=2$; yes). Allowed correlation function

$$W_A(\theta)=\frac{[W_0-(W+k)]^2}{k}\sin\theta p\frac{(W+k)}{q^2}\left(\frac{(W+k)^2+W^2}{W+k}q-q^2-1\right),$$

first-forbidden correlation function, tensor interaction ($\Delta J=2$; yes)

$$W_F(\theta)=CW_A(\theta)\{[(W_0-(W+k)]^2+(W+k)^2-1-2kq\},$$

where W=final energy of beta-ray, $q=W-p\cos\theta$, $p=(W^2-1)^{\frac{1}{2}}$, k=photon energy in relativistic units, and C=a constant for equalization at 90° (see below).

We have plotted a correlation for the following experimental situation. The beta-transition is taken as first-forbidden tensor for the special case ($\Delta J=2$; yes). The upper energy of the beta-spectrum is $W_0=4mc^2$. We assume that we have a gamma-counter which accepts all gammas above 50 kev. The angular correlations for allowed cases are also plotted and are equalized to the forbidden curves at 90°. The results are plotted for various final energies of the beta-particle.

The curves demonstrate that the ratio of the number of coincidences at the forward peak to that at 90° is greater for the allowed than for the first forbidden. The ratio, of course, depends on the value of the range of final beta-energy one accepts. This ratio becomes quite appreciable if one accepts only high energy gamma-rays in the counter ($h\nu>2mc^2$). This occurs when one beta-particle is created with a high energy in the intermediate state and then emits a high energy photon. An experiment based on this condition is not feasible, however, since for an upper energy of $W_0=4mc^2$, only 10^{-5}-gammas per beta are emitted in the range above 1 Mev.

The calculations also show that it becomes easier to distinguish between allowed and forbidden as the upper energy of the beta-spectrum is increased. From the calculation we can conclude the following results:

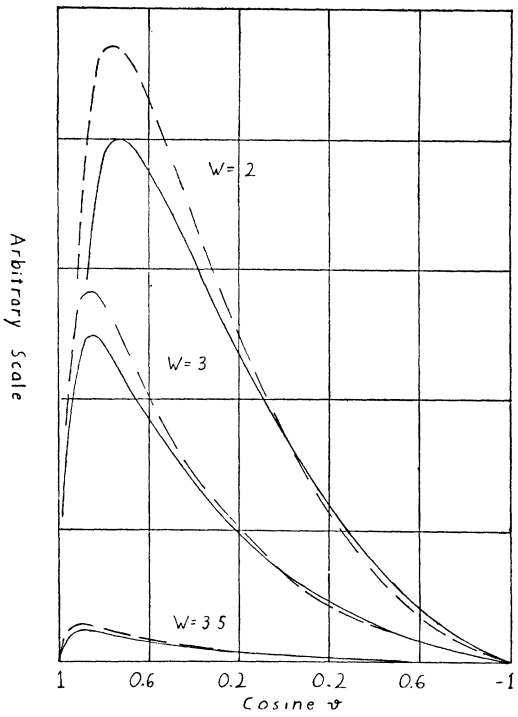

FIG. 1. The angular correlation $W(\theta)$ as a function of $\cos\theta$ for final beta-energies of 2, 3, and 3.5 mc^2. Dotted curves are for allowed transitions, solid curves for first-forbidden transitions—tensor interaction ($\Delta J=2$, yes). The curves for equalized at 90° for each final beta-energy.

1° The correlation for allowed transitions is independent of the form of the interaction;
2° The nuclear matrix elements for first-forbidden transitions are identical with the ones obtained in the ordinary beta-decay. Hence the shape of the beta-ray spectrum uniquely determines the angular correlation.

Although the internal bremsstrahlung does not provide any new information on the form of beta-decay interaction, it does provide a secondary means of studying beta-decay.

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Additional Data on the Radioactive Isotopes of Tin and Tellurium*

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THE existence of many stable isotopes in tin together with the small cross section for neutron capture displayed by most of them, has made difficult the correct assignment of the observed radioactivities. Spectrometric studies of specimens enriched in masses 112 (72.5 percent), 116 (89.6 percent), 122 (45.8 percent), and 124 (83.1 percent) and irradiated in the pile for two months, yield results differing from those previously reported[1,2] for certain of the isotopes.

Tin-113. This isotope is produced by neutron capture in Sn-112 with the largest cross section of any of the isotopes, and gives in the spectrometer several electron lines. Three low energy lines are interpretable as of Auger origin accompanying indium x-rays. Three strong lines are the K, L, and M electron groups for the known transition in indium-113 (112 min) whose energy is here

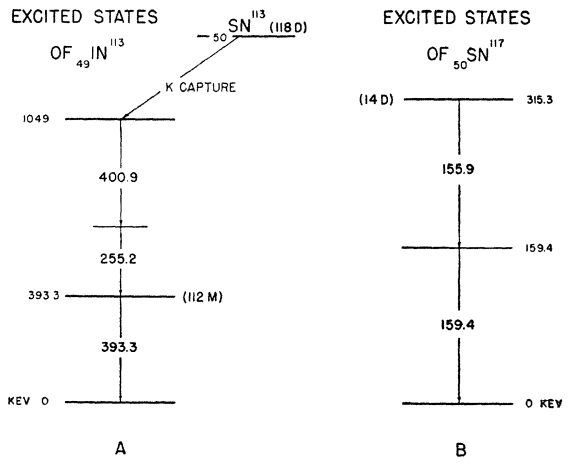

FIG. 1. Decay schemes for Sn^{113} and Sn^{117}.

found to be 393.3 kev. Two weaker electron lines with energies of 227.2 and 373.0 kev are present and appear by their half-life to be associated with the same activity and hence represent gamma-transitions in indium with energies of 255.2 and 400.9 kev. No evidence could be found either spectrometrically or by absorption for a gamma-ray of energy around 90 kev, as reported, nor could any positrons be observed coming from the specimen. The half-life of the enriched specimen as observed for 8 months appears to be 118±2 days, a value higher than those previously reported, which ranged from 70 to 112 days. A possible decay scheme is presented in Fig. 1(A).

Tin-117. An excited state of tin-117, whose half-life has been variously reported as from 13.0 to 14.5 days, was produced by neutron capture in tin-116. This specimen yielded 4 electron conversion lines at energies of 126.7, 129.3, 151.5, and 155.0 kev in addition to lines due to indium-113 and one other of Auger origin. This indicates the existence of two gamma-rays of energy 155.9 and 159.4 kev. The former is highly converted with a K/L ratio of about 7. Only the weak K line is observed for the latter. No evidence is found for the existence of a 174-kev gamma-ray as reported.[2] The half-life is noted to be 14.0±0.5 days. A nuclear level scheme is proposed in Fig. 1(B).

Tin-123. Neutron capture in enriched tin-122 yields a beta-active emitter whose half-life has been reported[3] as from 130 to 136 days. The maximum beta-energy has been given as 1.42 Mev with a converted gamma-ray of 394 kev. It now appears highly probable that this gamma-ray when observed in any isotopic enrichment is due to traces of tin-113, and is the highly converted indium gamma-radiation. No gamma-radiation appears to be associated with tin-123. The half-life observed in this investigation, following the decay of the enriched specimen for 18 months and allowing for the presence of some 2.5-year antimony-125 radiation, appears to be slightly less than that previously reported, namely 125±3 days. No further information of a conflicting nature applying to the other known radioactivities in tin has so far been found.

Tellurium. Using isotopes of tellurium enriched in masses 120 (22.3 percent), 122 (86.2 percent), 126 (95.4 percent), and 128 (90 percent), some information has been obtained of a revisory nature to that previously reported.[4] It is believed that the energies of the internally converted gamma-rays as now determined photographically are accurate to ±0.2 percent. The radioactive decay of the various specimens has been followed for over 300 days leading to half-lives somewhat different than are in the literature.

All of the gamma-rays found in this investigation to be associated with the enriched isotopes represent isomeric transitions in Te with the probable exception that a 575-kev gamma occurs in Sb-121 following K capture from Te-121. The evidence for this

TABLE I. Summary of half-lives and gamma-energies in tellurium.

Mass	121	123	125	127	129
Half-life	140-day	121-day	58-day[a]	115-day	33.5-day
Gamma energy (kev)	81.8 213 6 575(Z=51)	88.7 159.2	109.6 35.3	88.7	106.0

[a] See reference 5.

575-kev gamma is a single electron line at 544.7 kev in the enriched Te-121 specimen. No evidence could be found for a gamma-ray of energy 615 kev following K capture in Te-121 as reported, indicating the above interpretation of the 544.7-kev electron line. The revised values of the gamma-energies and the half-lines as here determined are shown collectively in Table I.[5]

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Electrodynamic Displacement of Atomic Energy Levels

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THE modifications in the fine structure and hyperfine structure of hydrogenic atoms, produced by electrodynamic effects, have thus far been computed essentially only to the order $\alpha=1/$"137". In view of the high accuracy of recent measurements we have extended the theory to include effects of order $Z\alpha^2$. In contrast with corrections of order α^2, these terms arise from a more precise treatment of the nuclear coulomb field in the relativistic domain, rather than from higher order electrodynamic phenomena.

For the hyperfine structure of S levels, we find the following fractional correction of order $Z\alpha^2$,

$$-(5/2-\log 2)Z\alpha^2. \tag{1}$$

In conjunction with the known α^2 contribution to the electron moment,[1] we have, as the total electrodynamic correction factor

$$1+\alpha/2\pi-(2.97/\pi^2)\alpha^2-(5/2-\log 2)Z\alpha^2 = 1.001145-0.963\cdot 10^{-4}Z = 1.001049,\ Z=1. \tag{2}$$

In a recent survey of atomic constants, Dumond and Cohen[2] have provided tables of constants based upon an adjustable correction factor, which was arbitrarily written

$$1.001147/(1+\Gamma). \tag{3}$$

Thus the reciprocal of the fine structure constant is stated as

$$1/\alpha=(137.0429\pm 0.0009)(1-0.486\Gamma). \tag{4}$$

The electrodynamic correction embodied in (2) would, in itself, imply

$$\Gamma=0.98\cdot 10^{-4}, \tag{5}$$

whence

$$1/\alpha=137.0364. \tag{6}$$

However, this ignores the contribution to Γ associated with the spatially distributed nature of the proton magnetic moment.

An indication of the magnitude of this effect can be obtained from the ratio of the hyperfine structures in hydrogen and deuterium. If the residual discrepancy in this quantity[3] is ascribed to