in this observed spectrum drops off sharply at lower energies, apparently to quite small values. It is impossible to overemphasize the need for further investigations of this spectrum, for these conclusions appear to stand in contradiction of the modern theories of beta-decay.

* The new data reported here, shown as curve (*C*) in Fig. 1, were obtained in 1948 in the research laboratories of The University of North Carolina in Chapel Hill.

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Measurement of Particle Energies with Scintillation Counters

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In a recent paper Kallmann[1] has shown that single crystals of cadmium sulphide, used with a photo-multiplier to detect single α-particles, give output pulses of fairly uniform size from α-particles of a given energy. Such crystals emit red luminescence which matches the spectral response of the photo-multiplier used by Kallmann. We have found that similar uniformity of pulse heights is obtained when small ($1\times1\times1.5$ mm) crystals of natural, transparent scheelite are used as α-particle detectors in conjunction with photo-multipliers having an antimony-caesium cathode. Figure 1 gives the "integrated bias" curve for pulses caused by α-particles of 4.5-Mev energy, and also the pulse height distribution curve derived from it. A considerable spread of pulse heights is shown which is not accounted for by scattering and straggling of the incident particles. Removal of the spherical concave mirror, used in the system for collecting a large amount of the emitted light, does not alter the form of the "bias" curve to any marked extent. Similar "bias" curves were obtained for the scintillations produced in small single crystals of naphthalene activated by anthracene or by stilbene. We find that the average pulse height is approximately proportional to the energy of the incident particles. The rise in counting rate shown at low bias values is the result of multiple counting and is not present for crystals having a much more rapid decay of luminescence than scheelite (3 μsec.).

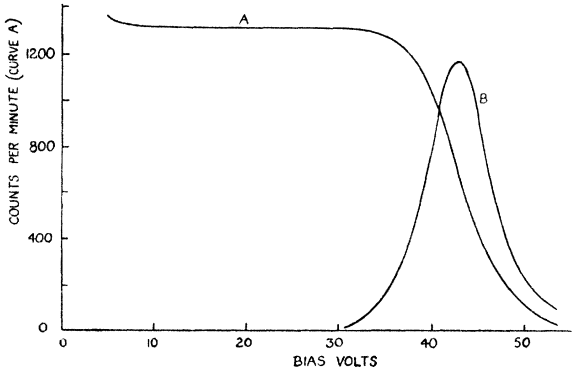

FIG. 1. Bias curves for multiplier output pulses due to scintillations in scheelite crystal bombarded by α-particles of 4.5-Mev energy. *A* is integrated bias curve; *B* is pulse height distribution curve derived from *A*.

Other observations would appear to be of interest here. We have found that stilbene functions as an efficient activator in naphthalene crystals in a similar manner to anthracene, but gives output pulses of about twice the magnitude of those from anthracene-activated crystals. We find also that for both these phosphors, as well as for such inorganic phosphors as zinc oxide, silver-activated zinc sulphide, lead-activated barium sulphate, and synthetic and natural scheelite, there are no marked differences in maximum pulse heights due to α-particles and γ-rays, if these are of equivalent energies. These results are contrary to those reported by Kallmann.[2]

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Beta-Decay Spectrum of Ag^{110}

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The disintegration of Ag^{110} has been studied previously by several authors.[1-3] Of the two modes of disintegration into stable isobars, Pd^{110} and Cd^{110}, the disintegration by electron emission into Cd^{110} is well substantiated.[2] The maximum energy of the beta-spectrum was found to be 0.59 Mev. It was reported that the beta-spectrum is complex with more than half of the disintegration electrons absorbed by 2 mg cm^{-2} of aluminum.[1] The first mode of disintegration, into Pd^{110}, has not been studied as yet either with regard to positron emission or to orbital electron capture. Several gamma-rays, of energies 0.66 Mev −44 percent, 0.90 Mev −47 percent partially converted and 1.40 Mev −9 percent have been found. In the most recent publication a converted gamma-ray of 114 kev has been reported.[3]

In the present work the disintegration of Ag^{110} into the isobars Cd^{110} and Pd^{110} was studied by means of a cloud chamber since disintegration into Pd^{110} by emission of positrons *a priori* could not be excluded.

The silver 110 of high specific activity was obtained from Oak Ridge National Laboratory, AEC. It was purified and mounted in the center of a cloud chamber on zapon film. Pictures of tracks were taken with and without magnetic field applied. The first series of tracks were photographed in air with a field of 372.5 gauss. The distribution of electrons *vs.* energies showed: (a) the existence of converted electrons corresponding to the gamma-rays of Ag^{110}, and (b) electrons of a continuous spectrum.

The Kurie plot produced a straight line in the energy range from 150 kev to 550 kev with upper limit about 0.59 Mev. The presence of converted electron groups limited observation of a continuous spectrum in a cloud chamber.

Several single positrons and pairs were found. The upper ratio of number of positrons, for which pairs could not be established, to the number of the electrons of the continuous spectrum did not exceed 0.2 percent. The experimental data obtained allowed the conclusion that there is no positron disintegration in Ag^{110} with branching ratio β^+/β^- higher than 0.2 percent.

The second series of tracks were photographed in helium with a field of 149 gauss. The subtraction of the 0.59-Mev continuous spectrum and recalculations for a second Kurie plot produced evidence for the existence of a continuous spectrum of electrons with upper energy 90 ± 10 kev. Independently it has been found that the electrons of the 90 ± 10-kev spectrum are in coincidence with gamma-rays.[4] The electron groups in the energy interval 90–150 kev were not sufficiently resolved.

It has been shown recently that excess of low energy electrons in Kurie plots very often are due to imperfect mounting.[5]

Conversely, with proper mounting the abundance of low energy electrons may be due to additional spectra as is the case with Ag^{110}.

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The Hyperfine Structure of the Ground Term of Hydrogen

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REFERENCES to a paper[1] by the authors on the hyperfine structure of hydrogen indicate that the results are understood to have a higher accuracy than they do. The present note is intended as an addendum to the paper with the object of stating the limitations more clearly. The Hamiltonian contains a term called Y in the paper referred to, which contains products of Dirac's α-matrices. This term is responsible for the hyperfine structure. The employment of its expectation value in order to obtain an additive correction to the energy is the apparent limit of its applicability. The wave function by means of which the expectation value is calculated is obtained from Eq. (2) in reference 1 which is not accurate to relative order v^2/c^2 where v is the electron velocity. The expectation value of Y cannot be expected to be accurate to relative order v^2/c^2 except by accident. Therefore no claims for the correctness of the relativistic terms in the correction to hyperfine structure involving m/M can be made. The reason for reporting on the results of the calculations which gave such effects was that the relativistic effects which have been calculated can be expected to have a bearing on the actual corrections. No certain method of obtaining these appears to be available.

It should also be mentioned that in the first of the two Eqs. (3.1) an approximation has been made. This is immaterial for the hyperfine structure terms of relative order m/M and it does not affect the relativistic corrections to these terms in a qualitative way.

The hyperfine structure appears in the calculation as a relativistic effect. The relativistic corrections to it remain uncertain because the Hamiltonian does not determine the wave function with the required accuracy.

* Assisted by ONR.
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On the Decay of K^{40}

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AN interesting feature of the K^{40} decay is the evidence for electron capture[1–5] and no evidence for positron emission.[6] The purpose of this note is to point out several consequences of this fact.

The consequences are: (1) a determination of an upper limit to the $A^{40}-K^{40}$ mass difference, (2) the possibility of observing positrons from K^{40} if estimates[1–3] of the K capture are correct, and (3) a determination of the ratio of the nuclear matrix elements for the A- and Ca-transitions.

The ratio of positron emission to electron capture is independent of the nuclear matrix elements to a large extent** and should, therefore, give a reliable estimate of the mass difference. If the expressions for forbidden β-transitions[7,8] are used, the ratio of positron emission to electron capture under the third forbidden axial vector or tensor interactions and $Z=19$ is

$$\lambda^{\beta^+}/\lambda^c=\frac{0.450\eta^{6\frac{1}{2}}}{(\eta+2)^8}[0.0676+1.25\eta+8.48\eta^2+12.5\eta^3+1.74\eta^4+0.079\eta^5],$$

where $\eta=\Delta M-2$ and ΔM is the atomic mass difference in units of the mass of the electron. The mass difference obtained by use of this expression and from the expressions arising from various fourth forbidden interactions are practically identical.

Table I gives the $A^{40}-K^{40}$ atomic mass difference as a function of the ratio of positron emission to electron capture. If the experimental values[1–3] $\lambda^{\beta^-}/\lambda^c=\frac{1}{2}$ and $\lambda^{\beta^+}/\lambda^{\beta^-}<0.01$ are used,[6] then $\lambda^{\beta^+}/\lambda^c<0.005$ and the $A^{40}-K^{40}$ mass difference is less than 1.6 Mev.

TABLE I. $A^{40}-K^{40}$ atomic mass differences.

$\Delta M(mc^2)$	0–2	3.00	3.25	3.50	3.75	4.00	4.25
$\lambda^{\beta^+}/\lambda^c$	0	0.00165	0.00675	0.0203	0.0494	0.104	0.195

The experiments on the K^{40} β^--energy endpoint require that the 1.55 Mev γ-ray be placed on the A^{40} side of the decay scheme. If experiments of references 1 to 3 are correct there are approximately fifteen K captures to one γ-ray so that most of the K captures go to the ground state. This would lead to the conclusion that there is one positron to every two hundred and fifty electrons. The probability for positrons from the internal pair creation of the γ-ray or β-ray is much smaller.

If one uses the value of the $\lambda^{\beta^-}/\lambda^c$ ratio, the corresponding upper limit to the $K^{40}-A^{40}$ mass difference, and β^--energy endpoint, one can estimate the ratio of the $(K^{40}-A^{40})$ to $(K^{40}-Ca^{40})$ nuclear matrix element. These are

$$\left(\frac{|Q_{K-A}|^2}{|Q_{K-Ca}|^2}\right)=50,\quad \left(\frac{|Q_{K-A}|^2}{|Q_{K-Ca}|^2}\right)=\tfrac{1}{2},$$

$$\lambda^{\beta^-}/\lambda^c=\tfrac{1}{2},\quad \lambda^{\beta^-}/\lambda^c=10,$$

$$E_{\beta^-}=1.4\text{ Mev},\quad E_{\beta^-}=1.4\text{ Mev}.$$

If the higher value of $\lambda^{\beta^-}/\lambda^c$ is approximately correct, it would indicate that the A^{40} and Ca^{40} nuclear states are very similar and probably have the same parity. However, the lower value of $\lambda^{\beta^-}/\lambda^c$ has more experimental support.

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** This ratio is completely independent of the nuclear matrix element for the third forbidden tensor and axial vector interaction and the fourth forbidden scalar, axial vector and pseudoscalar interactions. For the other fourth forbidden interactions and the various linear combinations, the $\lambda^{\beta^+}/\lambda^c$ ratio involves the ratio of certain matrix elements between the same initial and final states. These can be estimated fairly well.
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