K^{40} beta-radiation is most likely not allowed but actually exhibits a concave curve which has been distorted to nearly a straight line due to the source thickness. In order to investigate its true distribution without distortion, a highly enriched K^{40} source (~50 percent) is desirable.

In all these investigations, the thick sources were prepared by precipitating the KCl inactive salts from alcohol on a plastic film of 2 mg/cm². The source area is circular in form with a radius of 1 cm. The resolution under this operating condition is calibrated by using internal conversion lines and is around 8–9 percent defined as the full width at the half-value of the maximum intensity. The thin sources were investigated with a resolution of 4 percent of the same spectrometer.

We wish to express our appreciation to Dr. W. W. Havens, Jr., Dr. L. J. Rainwater and Professor J. R. Dunning for their help and advice throughout this investigation.

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The Beta-Spectrum of Be^{10}*

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RECENT determination[1] of the spin of the ground state of B^{10} of three units has aroused great interest concerning the energy distribution of the beta-ray spectrum from Be^{10}. According to Marshak's theoretical investigation,[2] the beta-spectrum of Be^{10} should be fitted by an unique D_2 spectrum (using Marshak's notation) which is very different from an allowed spectrum. On the other hand, Hughes[3] and his co-workers investigated the beta-spectrum of Be^{10} by absorption methods and found its distribution in disagreement with the D_2 shape but in agreement with the allowed spectrum within experimental error. If the allowed distribution interpreted from the absorption method is real, then the present theories of beta-decay will have to undergo serious revision.

Because of the extremely long life and small activation cross section, the specific activity of Be^{10} by the ordinary method of preparation is rather poor. When a thick beta-source is used in investigating its spectrum, the true distribution is inevitably distorted due to the effects of slowing down, absorption and back scattering of the electrons in the source itself. Nevertheless, the distortion of the Kurie plot due to source thickness follows a definite trend. This trend can be reasonably explained and interpreted as presented in the preceding letter[4] in the case of Y^{91}, P^{32} and RaE.

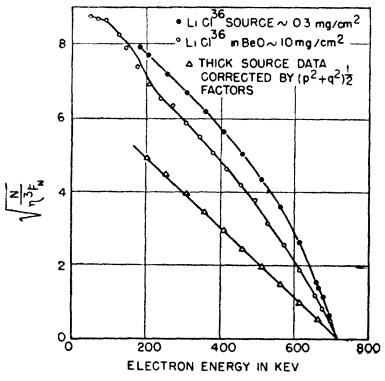

FIG. 1. Kurie plots of beta-spectra of Cl^{36} in thin and thick sources.

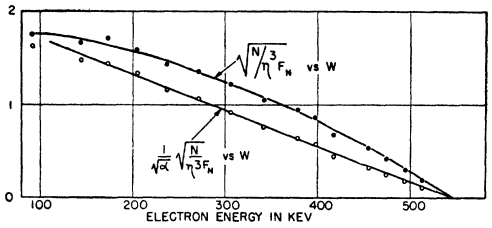

FIG. 2. The upper concave curve represents the conventional Fermi plot of Be^{10} beta-spectrum from a thick source of BeO of 12 mg/cm². The lower linear curve represents the forbidden Fermi plot after being corrected by the α-factor $[\alpha^{\frac{1}{2}} \sim (p^2+q^2)^{\frac{1}{2}}]$.

The beta-spectrum of Be^{10} has an upper energy limit of around 550 kev, a comparative study of the spectra of Cl^{36} (713 kev), Be^{10} (550 kev) and Cu^{64} (e^- 571 kev; e^+ 657 kev) in thick BeO sources should shed some lights on the true distribution of the beta-spectrum from Be^{10}.

The active $Be^{10}O$ source used in this investigation was kindly loaned to us through the courtesy of Professor Stephens of the University of Pennsylvania. No more chemistry was done on the BeO after it was received. The specific activity of Be^{10} used in this investigation in only 3×10^{-4} μc/mg of BeO. A rather thick source of around 10 mg/cm² of an area of 3 cm² has to be used. For comparison, both the Cl^{36} and Cu^{64} are thoroughly mixed with inactive BeO to form beta-sources of around 10 mg/cm² of an area of 3 cm². The resolution under this operating condition is 8–9 percent.

Figure 1 shows the Kurie plots of Cl^{36} from thin and thick sources. The spectrum of Cl^{36} from thin source has been shown[5] to follow the unique D_2 spectrum closely, but the curvature of the Kurie plot from a thick source shows much less concave toward the energy axis as compared with that from a thin source. In fact, the Kurie plot is well matched by an α-spectrum[6] $[\alpha \sim (p^2+q^2)^{\frac{1}{2}}]$. Although the exact fitting of the α-correction factors is rather a chance coincidence, it does strongly demonstrate the general trend that a thick source invariably distorts a D_2 spectrum to a less concave curve such as an α-spectrum.

Figure 2 shows the Kurie plot of the beta-spectrum of Be^{10} from a BeO source of around 12 mg/cm². The upper energy limit of the spectrum is 550±10 kev. The Kurie plot is definitely concave toward the energy axis and is well fitted by an α-spectrum. By comparing the data on Be^{10} with the Kurie plot of Cl^{36} from a thick source, one is inclined to conclude that the true distribution of the Be^{10} beta-spectrum is more concave than an α-spectrum and may well be a D_2 spectrum as predicted theoretically.

We also investigated the Cu^{64} electron and positron spectra from a thick BeO source. In this case, the straight allowed shapes are both distorted to convex curves due to the finite source thickness. Therefore, it seems to us that the spectrum of Be^{10} can not be interpreted as an allowed spectrum.

Although this type of comparative studies does not give the detailed distribution of a spectrum, it does help to guide the interpretation of a spectrum obtained from a thick source. At least, it serves to limit the shape of the spectrum to only a few possible known shapes. It is needless to say that a highly enriched Be^{10} source would be most desirable for further investigation in this case.

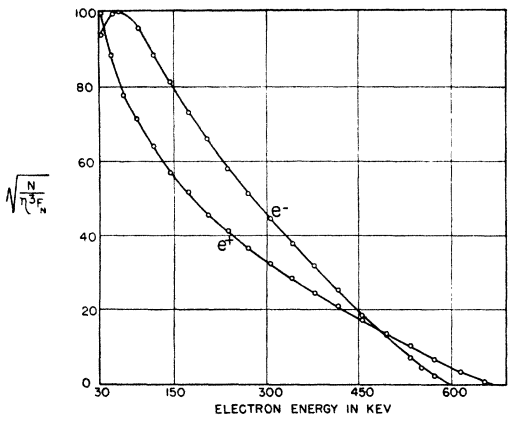

FIG. 3. Kurie plots of Cu^{64} electron and positron spectra from BeO of 11 mg/cm².

We wish to thank Professor W. E. Stephens for his kindness in sharing his radioactive $Be^{10}O$ with us. The constant interest and encouragement of Dr. L. J. Rainwater, Dr. W. W. Havens, Jr. and Professor J. R. Dunning are greatly appreciated.

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Photoelectric Disintegration of the Deuteron

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THE cross section for the photoelectric disintegration of the deuteron has been calculated by many authors, with various assumptions as to the size, shape, and exchange character of the neutron-proton potential.[1] Recent measurements on neutron-proton scattering at high energies are consistent with a Yukawa potential of range $\mu^{-1}=1.18\times10^{-13}$ cm, about half exchange force, and half ordinary force.[2] The combination of half exchange and half ordinary force gives no force on states of odd orbital quantum number, thus greatly simplifying the calculation of the photoelectric cross section.

In this note we shall further simplify the calculation by assuming central forces, and by using an approximate wave function for the Yukawa potential.[3] The calculation is then very similar to the derivation of the Bethe-Peierls formula[4] for zero range of nuclear forces. We shall follow Bethe's notation.[4]

The cross section for the dipole term of the photoelectric effect is

$$\sigma=8\pi^3\nu|M_{OE}|^2/c, \tag{1}$$

where the electric dipole moment between ground state 0 and excited state E is

$$M_{OE}=\tfrac{1}{2}e\int U_O z U_E d\tau. \tag{2}$$

For the ground state of the deuteron we use the wave function[3]

$$U_O=[\alpha\beta(\alpha+\beta)/2\pi(\alpha-\beta)^2]^{\frac{1}{2}}[\exp(-\alpha r)-\exp(-\beta r)]/r. \tag{3}$$

For the excited state, we use the free wave function

$$U_E=\frac{3^{\frac{1}{2}}}{2\pi\hbar}\cos\theta\left(\frac{M}{k}\right)^{\frac{1}{2}}\frac{1}{kr^2}(\sin kr-kr\cos kr). \tag{4}$$

In Eq. (1), $\alpha=(M\epsilon)^{\frac{1}{2}}/\hbar$, where ϵ = binding energy of the deuteron. We shall use $\beta/\alpha=5.476$[3] corresponding to $\mu^{-1}=1.18\times10^{-13}$ cm, or effective range[5] $b=2.5\times10^{-13}$ cm; k is the wave number of the emitted proton.

The only changes from the Bethe-Peierls derivation are in the wave function for the ground state. Our Eq. (3) as compared to Bethe's Eq. (44c)[4] $U_O=(\alpha/2\pi)^{\frac{1}{2}}\exp(-\alpha r)/r$ has the extra term $\exp(-\beta r)$ and a different normalization factor. Our 4 equations give us

$$\sigma=\left[\frac{\beta(\alpha+\beta)}{(\alpha-\beta)^2}\right]\left[1-\left(\frac{\alpha^2+k^2}{\beta^2+k^2}\right)^2\right]^2\left[\frac{8\pi}{3}\frac{e^2}{\hbar c}\frac{\hbar^2}{M}\frac{\epsilon^{\frac{1}{2}}E^{\frac{3}{2}}}{(E+\epsilon)^3}\right]$$
$$=20.4\left[1-\left(\frac{\gamma}{29+\gamma}\right)^2\right]^2(\gamma-1)^{\frac{3}{2}}\gamma^{-3}\text{ millibarns}. \tag{5}$$

Here γ = photon energy/binding energy of the deuteron.

The term $\beta(\alpha+\beta)/(\alpha-\beta)^2$ in Eq. (5) represents our use of a different normalizing factor[6] for the bound wave function from that used by Bethe. The term $[1-(\alpha^2+k^2)^2/(\beta^2+k^2)^2]^2=[1-\gamma^2/(29+\gamma)^2]^2$ represents the effect of the $\exp(-\beta r)$ term in the wave function for the ground state. This interference term, due to the finite range of nuclear forces, greatly reduces the cross section at high energies. For $\gamma\gg29$, the cross section varies as $\gamma^{-7/2}$, instead of as $\gamma^{-\frac{3}{2}}$ in the Bethe-Peierls formula. The interference effect is very small for $\gamma\ll29$, or photon energy much less than 65 Mev. The term $(8\pi/3)(e^2/\hbar c)(\hbar^2/M)[\epsilon^{\frac{1}{2}}E^{\frac{3}{2}}/(E+\epsilon)^3]$ in Eq. (5) is the Bethe-Peierls formula for zero range of nuclear forces.

In Fig. 1, we show the photoelectric cross section as a function of photon energy, both as given by Eq. (5), and as given by the Bethe-Peierls formula. This dipole term for the photoelectric cross section should be a fair approximation to the total photo-disintegration cross section between photon energies of about 6 Mev and about 100 Mev. At energies near the threshold for photo-disintegration the photomagnetic cross section is of importance.

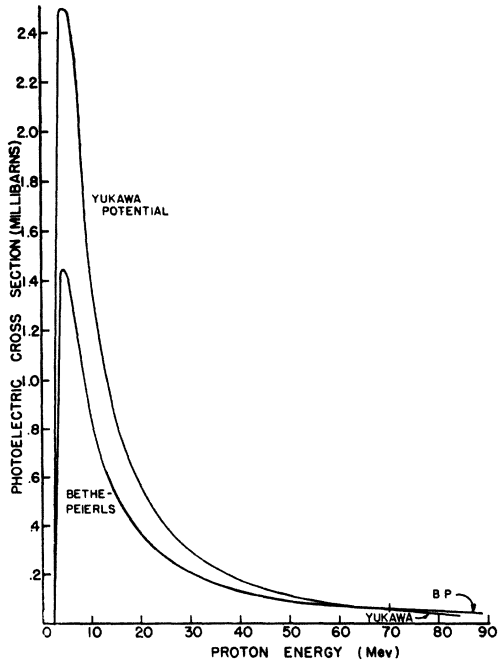

FIG. 1.