Preliminary calculations have been carried out on the basis of Eq. (6) for emulsions. For Ag and Br one should expect to have an intermediate case between I and II, but nearer to II than to I. A more precise definition is difficult since the photoelectric cross sections of Ag and Br as functions of the energy of the incident photon are not very well known. We have carried out calculations in both limiting cases I and II. The results are reported in Fig. 1 together with the experimental data of Morrish[5] and Daniel *et al.*,[6] both experimental and theoretical curves being normalized to 1 for $E \rightarrow \infty$.

According to this theory, as the kinetic energy of the ionizing particle becomes larger than its rest energy, a relativistic increase of both the specific ionization and the emitted Čerenkov radiation should be expected in dense media. In gases, there should be an increase of specific ionization and of excitation. In this case the emission of Čerenkov radiation of moderate intensity should become appreciable only at larger energy.

A detailed account of this work will be published in *Il nuovo cimento*.

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The Energy Loss of a Fast Charged Particle by Čerenkov Radiation*

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It has been shown[1] that for a medium with no absorption and described by a single type of dispersion oscillator, the relativistic rise of the ionization loss should escape as Čerenkov radiation. This result is in disagreement with the observed rise of the ionization pulse of μ mesons in crystals[2] and with the relativistic rise of the grain count in emulsion.[3] In actual cases, the index of refraction n has contributions from the various absorption limits. Moreover, most of the Čerenkov radiation should occur near the line frequencies where the absorption coefficient is large. It will be shown that when these effects are included the resulting energy escape is small (<0.01 Mev/g cm^{-2}) both for macroscopic crystals and for emulsion.

According to Fermi's theory,[4] the energy escaping to a distance larger than b from the particle is[5]

$$W_b = \frac{2e^2 b}{\pi v^2} \,\mathrm{Rl} \int_0^\infty \left(\frac{1}{1+\alpha} - \beta^2 \right) i\omega k^* K_1(k^* b) K_0(kb)\, d\omega, \tag{1}$$

where α is 4π times the polarizability and k is the square root with real part $\geqq 0$ of

$$k^2 = (\omega^2/v^2)(1-\beta^2) - (\omega^2 \alpha / c^2). \tag{2}$$

In order to treat the case of emulsion, we take $b = 0.13\mu$ ($\sim$grain radius). Since $|k|b$ is generally >1, we may use[6]

$$K_0(kb) \cong (\pi/2kb)^{\frac{1}{2}} \exp(-kb), \tag{3}$$

$$K_1(k^* b) \cong (\pi/2k^* b)^{\frac{1}{2}} \exp(-k^* b). \tag{4}$$

Equation (1) becomes

$$W_b = \frac{e^2}{v^2} \,\mathrm{Rl} \int_0^\infty \left(\frac{1}{1+\alpha} - \beta^2 \right) i\omega \left(\frac{k^*}{k} \right)^{\frac{1}{2}} \exp[-(k+k^*)b]\, d\omega. \tag{5}$$

α is given by[7]

$$\alpha = -\frac{4\pi n e^2}{m} \sum_i (f_i/\omega_i^2) \times \frac{\ln[(\omega_i^2 - \omega^2 - 2i\bar{\eta}_i \omega)/\omega_i^2] + [(\omega^2 + 2i\bar{\eta}_i \omega)/\omega_i^2]}{[(\omega^2 + 2i\bar{\eta}_i \omega)/\omega_i^2]^2}, \tag{6}$$

where f_i, ω_i, $2\bar{\eta}_i$ are the oscillator strength, frequency, and damping constant of the ith absorption limit. Equation (6) is obtained from the Kramers-Kallmann-Mark theory of dispersion and gives good agreement with measurements of n in the x-ray region.[7] Fourteen terms in Eq. (6) were considered corresponding to the K, L, M_{I}, $M_{\mathrm{II-III}}\cdots$ limits of Ag and Br. The ω_i were obtained from the table of Sommerfeld;[8] the widths $2\bar{\eta}_i$ were taken as[7] 11.2 ev for the K limit of Ag, 4.7 ev for K of Br, 3.2 ev for the L and M limits, and 1 ev for the N limits of both elements. Equation (5) was integrated numerically for $\beta = 1$, giving 2.2×10^{-3} Mev/g cm^{-2}. This value is considerably smaller than the rise of the ionization loss (0.12 Mev/g cm^{-2}) for two reasons: (1) Because of the absorption bands on the high frequency side of each absorption limit, the index of refraction does not attain as large values as would be predicted for a single narrow line. In fact, n does not rise much above 1, except for $\hbar\omega < 0.47$ ry below the ultraviolet absorption band. Since the condition for Čerenkov radiation is essentially $n > 1$, this leads to a sharp reduction of the Čerenkov loss. (2) The effect of absorption is pronounced because the radiation is emitted in the forward direction so that it travels a distance $>b$ before leaving the grains traversed by the particle.

In the visible region, where the absorption is negligible (α = real), Eq. (5) reduces to the Frank and Tamm expression, in agreement with the result of Fermi[4] for a single dispersion oscillator.

In view of the result for emulsion, the Čerenkov loss for a macroscopic crystal is negligible compared to the ionization pulse, since the factor $\exp[-(k+k^*)b]$ decreases rapidly as b is increased. A more detailed account will be published soon.

I would like to thank Dr. Ernest D. Courant for stimulating discussions.

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The Fermi Term in $\beta-\nu$ Correlation*

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A survey is made to find the β-transitions most suitable for a $\beta-\nu$ (recoil) correlation experiment to determine the Fermi part of the β-decay interaction. The most favorable parent isotope appears to be A^{35}.

The linear combination in β-decay appears[1] to be half Fermi (F) and half Gamow-Teller (G). Absence of $1/W$ terms in allowed spectra[2] shows that F must be pure S or pure V, and G must be pure T or pure A. Measurements[3] of $\beta-\nu$ correlation on He^6 show that $G = T$. One now seeks a suitable case for determining the F component by $\beta-\nu$ correlation.

The G component is excluded only in a $0 \rightarrow 0$ transition; and the only known examples (C^{10} and O^{14}) have energetic gammas following the β-decay, which disturb the recoil and make the experiment almost prohibitively difficult. In allowed transitions where $\Delta I = 0$ but $I_i = I_f \neq 0$, both F and G components will be present. For mirror image transitions the matrix element of F is unity and of G is $\boldsymbol{\sigma}^2$. The $\beta-\nu$ correlation function for this case is $1+\alpha(v/c)\cos\theta$, where

$$\alpha=(\tfrac{1}{3}\boldsymbol{\sigma}^2\pm1)/(\boldsymbol{\sigma}^2+1). \quad (1)$$

The sign in Eq. (1) is + for V and − for S. From an experimental point of view it is desirable to have a minimum value for $\boldsymbol{\sigma}^2$, in order to maximize the difference between α_+ and α_-.

Table I accordingly lists $\boldsymbol{\sigma}^2$ for radioactive gases that undergo mirror image β-decays. The values of $\boldsymbol{\sigma}^2$(calc) are computed for the configurations listed, and $\boldsymbol{\sigma}^2$(obs) are taken from the ft values fitted to the empirical[1] constant $1+\boldsymbol{\sigma}^2=5.2\times10^3$ sec/ft. For $Ne^{19}-F^{19}$ we adopt the independent suggestions of E. Feenberg and M. Umezawa that the configuration is $(d_{5/2}{}^2d_{5/2})_{1/2}$, which gives the best agreement between $\boldsymbol{\sigma}^2$(calc) and $\boldsymbol{\sigma}^2$(obs).

TABLE I. Mirror image β-decays.

Gas	Configuration	$\boldsymbol{\sigma}^2$(calc)	$ft.$	$\boldsymbol{\sigma}^2$(obs)
N^{13}	$p_{1/2}$	0.33	4.7×10^3 sec	0.11
O^{15}	$p_{1/2}{}^{-1}$	0.33	3.8	0.37
F^{17}	$d_{5/2}$	1.4	2.3	1.3
Ne^{19}	$(d_{5/2}{}^2d_{5/2})_{1/2}$	1.6	2.0	1.6
Cl^{33}	$d_{3/2}$	0.60	3.4	0.53
A^{35}	$(d_{3/2}{}^2d_{3/2})_{3/2}$	0.32	3.4	0.53

The average recoil energies of the nuclei, neglecting $\beta-\nu$ correlation, are on the order of 60 ev for N^{13}, 100 ev for O^{15}, F^{17}, Ne^{19}, and 200 ev for Cl^{33}, A^{35}. Simple gaseous molecules containing N, O, or C have exceptionally high binding energies on the order of 10 ev, which might seriously interfere with the recoil ions in at least the case of N^{13}. The situation is much more favorable for Cl^{33}, with a molecular binding energy of order 10^{-2} times the recoil energy. The discrepancy between $\boldsymbol{\sigma}^2$(calc) and $\boldsymbol{\sigma}^2$(obs) for A^{35} is commensurate with the rather large probable error in the ft value. If both chemical binding and the values of $\boldsymbol{\sigma}^2$ are considered, the isotopes of Table I are roughly in order of increasing suitability for a $\beta-\nu$ correlation measurement of the Fermi term.

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Molybdenum 90

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In observing the high energy spallation products of niobium,[1] evidence for the existence of a new isotope of molybdenum was obtained. In order to identify this activity, niobium metal foils were bombarded with 55–60-Mev protons in the Harvard 95-inch synchrocyclotron for periods of an hour, and the molybdenum activities were isolated by ether extraction from 6N hydrochloric acid. Gross decay curves taken with an end-window Geiger counter on aliquots of such fractions showed a 5.5–6.0-hour and a 14.5–15.0-hour activity; neither half-life corresponds to known molybdenum periods. The decay curve of a sample separated quickly after the end of the bombardment exhibited an additional 15–20-minute activity ascribable to Mo^{91} (15.5 minutes[2]).

Since Nb^{90} is reported to have a half-life of 15 hours,[3,4] it was considered likely that the observed activities were due to a new nucleide, Mo^{90}, decaying with a 5.5–6.0-hour period into the longer lived Nb^{90}. To check this, niobium carrier was added and separated at twelve hour intervals from purified molybdenum fractions and then counted. One such series of separations was done by precipitating the niobium away from the molybdenum with ammonia, and two more series were done by repeated ether extractions of the molybdenum away from the niobium in 6N hydrochloric acid. The separated samples were then ignited to the oxide, weighed, and counted. In all three series a plot of the yield of the niobium daughter activity *vs* time showed a slope of 5.7±0.2 hours. One series is shown in Fig. 1. All of the separated samples showed a decay period of 14.7±0.2 hours; some were followed through eight half-lives and showed no sign of turning over.

Comparison of the activity of Mo^{90} and its daughter on an end-window (3.5 mg/cm^2) Geiger counter indicated a counting efficiency for the molybdenum activity of 75–80 percent of that of the Nb^{90}. Since the latter is known to have a considerable amount of particulate radiation,[5] then Mo^{90} must also. In fact, aluminum absorption measurements indicate a considerable amount of ~100-kev conversion electrons, some ~240-kev conversion electrons, and either K x-rays or positrons of about 1.4-Mev maximum energy, or both, as is most likely the case. Unfortunately, no beryllium absorbers were available to differentiate these last two types of radiation, but positrons must be present to an appreciable extent, as there would be too many K x-rays involved for all of the radiation to be electromagnetic.

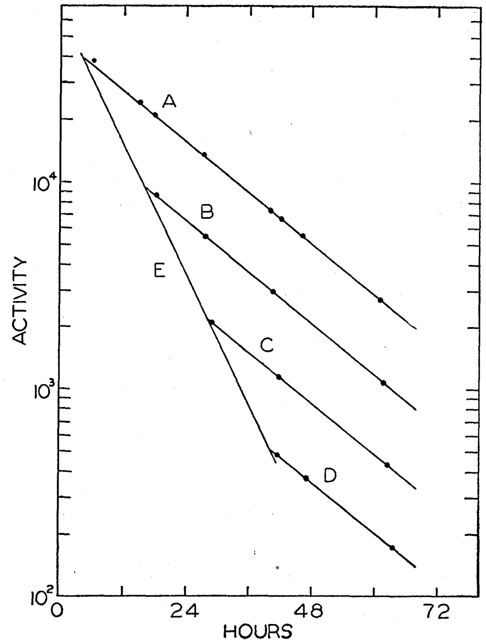

FIG. 1. Yield of Nb^{90} as a function of time of separation from Mo^{90}, curve E. Curves A to D show the decay of the individual Nb^{90} samples.

The value of the positron energy, 1.4 Mev, is an estimate from the extrapolated range in aluminum, and is certainly not a very reliable figure. However, similar aluminum absorption measurements on a sample of Nb^{90} gave a curve with a comparable section due to K x-rays and positrons, and the extrapolated range of the positrons corresponds to an energy of 1.2 Mev. This agrees with the value of 1.2 Mev reported by Kundu and Pool,[4] but not so well with the value of ~1.7 Mev given by Boyd.[3]

Lead absorption measurements on a sample of Mo^{90} exhibited a 1.1-Mev gamma-ray, and 240–260 kev and 100–125 kev gamma-rays; aluminum absorption data indicate that both of these last two are partially electron converted, the lower energy ray to the greater extent. Positron annihilation radiation was not resolvable in the lead absorption curve, but a small amount would not show up among the other electromagnetic radiation observed.