even-even core to a high spin state, probably 8+. This may be obtained by breaking a $g_{9/2}$ pair of protons and putting one of the protons into a $g_{7/2}$ state. The odd neutron probably remains in a $g_{7/2}$ state throughout the three-step isomeric transition while the core goes from $8+\rightarrow 4+\rightarrow 2+\rightarrow 0+$. Thus, the spin of Mo^{93m} may be as high as $(8+)+g_{7/2}=23/2+$, and this is supported by the absence of cross-over transitions.[4]

The total excitation energy of Mo^{93m}, 2.43 Mev,[3] is of the order expected on the assumption that it is due to the breaking of a $g_{9/2}$ proton pair (1–2 Mev) and the flipping of a spin $g_{9/2}\rightarrow g_{7/2}$ (spin orbit coupling energy $\sim$1.5 Mev). The low cross section of the $Nb^{93}(p,n)Mo^{93m}$ reaction[5] and the lack of success of attempts to produce Mo^{93m} by (d,p), (n,γ), and (γ,n) reactions (see reference 1) may be connected with the unusual character of this state. General consideration on even-even nuclei[6] indicate that "core isomerism" should be a rare phenomenon.[7]

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Energy Loss and Čerenkov Radiation of a Relativistic Ionizing Particle

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In the energy region where the bremsstrahlung is still not effective, the energy lost by a relativistic ionizing particle in traversing a material medium contributes essentially to the following three phenomena: (a) ionization of the atoms of the medium; (b) excitation of the atoms of the medium; (c) emission of the Čerenkov radiation.

At impact parameters larger than $\rho_0\approx 10^{-8}$ cm, the calculation of the energy lost in processes like (a) or (b) leads to the formula:

$$\left.\frac{dW_\sigma}{dx}\right|_{>\rho_0}=\frac{ne^2c}{\pi v^2}\int_0^\infty\frac{\sigma(\omega)}{|\epsilon(\omega)|^2}\left\{\log\frac{4v^2}{\gamma^2\omega^2|1-\epsilon(\omega)\beta^2|\rho_0^2}-\beta^2\,\mathrm{Re}[\epsilon(\omega)]\right\}d\omega, \quad (1)$$

where $\sigma(\omega)$ is the atomic cross section, related to the process considered, for a photon of frequency ω, n is the number of atoms per cm^3, and $\epsilon(\omega)$ is the frequency-dependent dielectric constant of the medium. All other symbols have the conventional significance. $\mathrm{Log}\gamma=0.577\cdots$.

The energy lost by direct excitation (that is, neglecting[1] reabsorption of the Čerenkov radiation) can be calculated by substituting in the preceding relation

$$\sigma(\omega)=-\mathrm{Re}[i\omega\epsilon(\omega)/cn]. \quad (2)$$

For the energy lost in processes (c) we have found the formula

$$\frac{dW}{dx}=\frac{e^2}{v^2}\int_{\check{\mathrm{C}}\mathrm{erenkov}}\left[\beta^2-\frac{\mathrm{Re}[\epsilon(\omega)]}{|\epsilon(\omega)|^2}\right]\omega d\omega, \quad (3)$$

where the integration is to be performed over all frequencies for which

$$\mathrm{Re}[\epsilon(\omega)]>\beta^{-2}\quad \text{(Čerenkov frequencies).} \quad (4)$$

It should be pointed out that, when the emitted radiation is to be observed at the distance ρ, the supplementary condition $\beta^2(\omega/v)\,\mathrm{Im}[\epsilon(\omega)]\rho\ll 1$ should be added.

When the damping constants are not too large, one gets, by adding Eq. (3) to Eq. (1) [and using (2)], the well-known Fermi[2] formula giving the total amount of energy emitted by the ionizing particle to a distance larger than ρ_0. The repartition of this energy between Eq. (3) and Eq. (1) [with (2)] depends critically on the value of the quantity

$$\Theta_i=mg_i\omega_i/4\pi Ne^2f_i, \quad (5)$$

where ω_i, f_i, and g_i are, respectively, the frequency, the oscillator strength, and the damping constants relating to the ith spectral line, and N = number of electrons per cm^3. When $\Theta_i\ll 1$ (dense media with narrow lines), the relativistic increase of the energy loss beyond the minimum relative to the ith line is caused by the emission of Čerenkov radiation, while the energy lost in excitation of the corresponding line does not show any increase (as in the case discussed by Schönberg,[3] who puts $g_i=0$). When $\Theta_i\ll 1$ (dense media with wide lines, or rarified gases) Eq. (1) [with (2)] gives

$$\left.\frac{dW_{exc}}{dx}\right|_{>\rho_0}=\frac{2\pi Ne^4}{mv^2}\sum_{i=1}^{r}f_i\left\{\log\frac{4v^2}{\gamma^2\omega_i^2\rho_0^2[(1-\beta+\beta^2D_i)^2+\beta^2\Theta_i^{-2}]^{\frac{1}{2}}}-\beta^2\right\}, \quad (6)$$

where

$$D_i\approx\frac{4\pi Ne^2}{m\omega_i^2}\sum_{j=1}^{i-1}f_j.$$

Hence, it is seen that the Bethe-Bloch formula is valid for energies E satisfying the condition

$$E^2\lesssim\beta^{-2}(D_i^2+\Theta_i^{-2})^{-\frac{1}{2}}, \quad (7)$$

which determines the upper limit of the energy, below which there is no Čerenkov radiation from the corresponding band.

The expected behavior of the ionization may be discussed classically, considering the transition to the continuum as pertaining to wide bands ($\Theta_i\ll 1$) and therefore described by Eq. (6). According to the two following conditions:

$$\text{Case I: } D_i>\Theta_i^{-1},$$
$$\text{Case II: } D_i<\Theta_i^{-1},$$

the saturation of the ionization occurs gradually (I), as expected from the Halpern and Hall[4] formula, or more sharply (II). (See Fig. 1.)

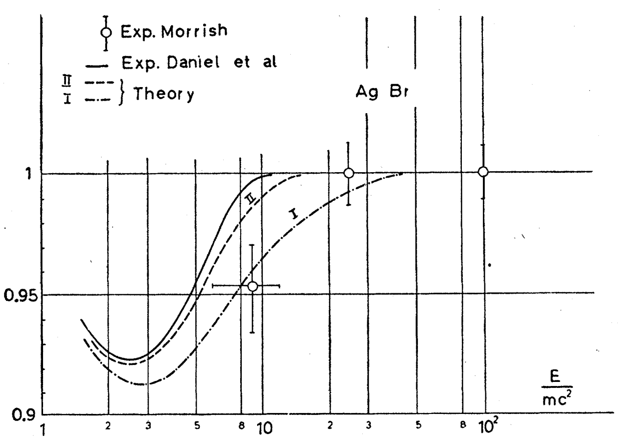

FIG. 1. Total rate of ionization in silver bromide (transfers less than 5 kev). The dashed curve II is computed with Eq. (6) and $D_i<\Theta_i^{-1}$. The dot-dash curve I is computed with Eq. (6) and $D_i>\Theta_i^{-1}$.

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]

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

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]

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

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 $0\rightarrow0$ 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 $I_i=I_f\neq0$, 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