interaction cases, respectively, all normalized to 100 to 150 kev. The effect of the detector response has been applied to the theory in this figure. This was done as discussed in our earlier paper[8] except that in the present case, degradation of the photons caused by their passage through the low-Z Lucite absorber was neglected. The uncertainty in the detector response is about 10 percent and forms the principle uncertainty. The standard error from counting statistics is about 3 percent.

The fit of the experimental data to the theory curve for the allowed transition case is much better than 10 percent. We have chosen to show the tensor interaction case for the spectrum from first-forbidden transitions since of the two calculated, it lies nearer the spectrum for allowed transitions. It is, *a fortiori*, evident that the P³² I.B. spectrum does not agree with the first-forbidden scalar.

No measurements were made on the ratio of I.B. photons to beta particles. Other experimenters[4,6,7] have found satisfactory agreement working in the region below 250 kev.

We can improve our earlier figures on the upper limit of the possible number of nuclear gammas per beta particle by a factor of 5. If nuclear gammas were present to the extent of 10^{-4} at 200 kev, 4×10^{-5} at 500 kev, or 2×10^{-6} at 900 kev per beta particle, they would have been observed as humps in the spectrum above the smooth curve actually found.

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Radiative Electron Capture in Fe⁵⁵[†]

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The internal bremsstrahlung emitted in electron capture by Fe⁵⁵ was studied from 14 kev to the upper energy limit at 220 kev. Fair agreement with the formula of Morrison and Schiff is observed at high energies, whereas a strong rise of the intensity occurs at low energies. The discrepancy may be due to failure of the theory to take into account the effects of nuclear charge, capture of p electrons, and forbiddenness of the transition.

THE internal bremsstrahlung emitted in electron capture by Fe⁵⁵ was studied by Maeder and Preiswerk,[1] and by Bell, Jauch, and Cassidy.[2] The high-energy part of the spectrum was shown to agree at least approximately with the formula calculated by Morrison and Schiff[3] for s-electron capture in allowed transitions, assuming a decay energy slightly above 200 kev. The low-energy portion was not investigated in detail owing either to poor resolution of the spectrometer or to presence of impurities.

We therefore undertook careful measurements of the entire spectrum. The Fe⁵⁵ source was over two years old, hence all the Fe⁵⁹ originally present had decayed. Sodium iodide crystals 10 to 12 mm thick were used in combination with DuMont 6292 photomultipliers. The resolution attained corresponds to full widths at half-maximum of 34-36 percent for a 22-kev line and 18-20 percent for an 87.5-kev line. Spectra were recorded under various geometries and with different crystals and photomultipliers, yielding consistent results.

To obtain the spectral distribution of the gamma radiation from the recorded pulse-size spectrum, one must correct for: (1) Percentage of pulses in photoelectric peak; however, up to 200 kev this correction is small at the crystal thicknesses employed. (2) Incomplete efficiency of the crystal at the higher energies. (3) Absorption by materials between source and crystal. (4) Escape of the K radiation of iodine. (5) Gaussian spread of the pulses. Furthermore, at very low energies, one must be certain that none of the pulses observed are due to the K x-rays of Mn at 5.9 kev, at least 10^4 times stronger than the integrated continuum. The curve due to the x-rays, measured by using a thin Fe⁵⁵ source in immediate contact with an NaI crystal, showed that under our experimental conditions the effect of the x-rays was certainly negligible above 14 kev. Hence the bremsstrahlung was investigated only above this energy. Corrections for absorption at low energies in 0.188 g/cm² Lucite and 0.015 g/cm² Al interposed between source and detector were made by means of tabulated absorption coefficients and checked by taking spectra with additional absorbers. Corrections for lack of efficiency at high

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[1] D. Maeder and P. Preiswerk, Phys. Rev. 84, 595 (1951).
[2] Bell, Jauch, and Cassidy, Science 115, 12 (1952).
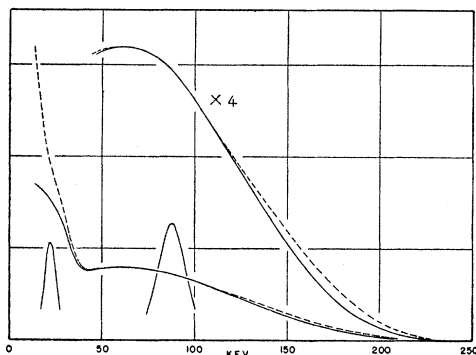[3] P. Morrison and L. I. Schiff, Phys. Rev. 58, 24 (1940).

FIG. 1. Experimental spectrum of Fe^{55}. Solid line represents observed pulse-size spectrum; dotted lines indicate spectrum corrected for absorption at low energies and incomplete crystal efficiency at high energies. Peaks obtained from 22-kev and 87.5-kev lines under same conditions show resolution.
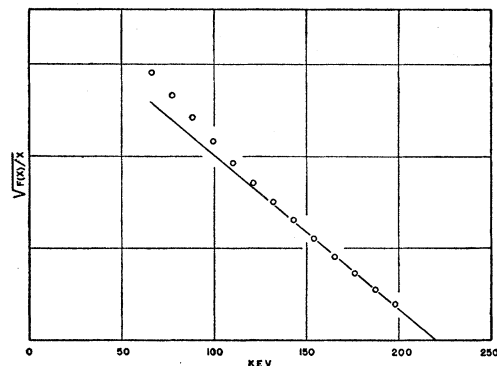

FIG. 2. Plot of $F(x)/x^{\frac{1}{2}}$. Circles represent corrected experimental points; straight line corresponds to formula of Morrison and Schiff with $k_0 = 220$ kev.

energies were made on the same basis. Corrections for effects (1) and (4) were not attempted. Correction for the Gaussian pulse distribution was applied near the upper energy limit, where it is important for evaluating the decay energy. For the remainder of the energy region above 50 kev, this correction is unimportant; at lower energies it was not attempted owing to lack of a satisfactory theoretical formula and the inaccuracy of the experimental data due to absorption effects. Pulses were detected up to 235 kev; however, taking into account the Gaussian spread of the pulse size, it appears that the maximum energy k_0 is near 220 kev. The latter value is used in comparison with the theory.

The experimental results are represented in Fig. 1. The solid line gives the measured spectrum, the dotted line indicates the corrections for absorption and efficiency. It is immediately apparent that there is a large low-energy component not predicted by the formula of Morrison and Schiff, $f(x) = x(1-x)^2$, where $x = k/k_0$. At the higher energies (above 60 kev) the experimental spectrum corresponds fairly closely, but not exactly, to this formula. To facilitate comparison, in Fig. 2 we plot the square root of the corrected experimental intensity divided by $x^{\frac{1}{2}}$. If the spectrum

followed the Morrison-Schiff formula, the points would lie on a straight line. Discrepancies are apparent below 130 kev, but the points above this energy fit well a straight line with $k_0 = 220$ kev.

As possible effects contributing to the disagreement between the observed spectrum and the Morrison-Schiff formula, the following may be listed.[4] (1) The spectrum was calculated for allowed transitions; the spectra emitted in forbidden transitions are expected to depend on the form of beta interaction. The transition in Fe^{55} is probably first forbidden, since log $(ft) = 6.1$. (2) The contribution of radiative capture of p electrons may be important. Cutkosky[4] evaluated the effect for allowed transitions, neglecting the effect of nuclear charge, and obtained spectra rising at low energies, similar to the one observed. (3) Important corrections at low energies might result from the use of correct Coulomb wave functions even in the case of s electrons; all existing calculations were based on a plane-wave approximation.

In conclusion, it seems impossible at present to compare the experimental results, especially at low energies, with a satisfactory theoretical formula.