the data are not as good as could be obtained by present techniques. If the author leans rather heavily on the work of his own laboratory in these illustrations it is simply because the original data and figures are available to him.

10.1. THE DISINTEGRATION $Cs^{137} \rightarrow Ba^{137}$ 33 YEARS

The disintegration scheme of Cs^{137} is one of the most interesting in nuclear spectroscopy. It is relatively simple, but the working out of all the details has brought to light some very fundamental concepts for nuclear physics. In addition, since Cs^{137} has a relatively long life and is procurable as a fission produced source, it serves as a standard for many investigations.

Cs^{137} emits one γ-ray whose energy is 661.65 ± 0.15 keV. The β-ray spectrum is shown in Fig. 16 in which $N(p)\,dp$ is plotted against p. The spectrum was taken with a magnetic lens of medium resolution. The gross features of the spectrum show a single β-ray spectrum and an internally converted γ-ray. Since superficial inspection discloses that there is only one β-ray group of comparable intensity to that of the γ-ray, it is natural to suppose that this one group feeds the γ-ray. Beta–gamma coincidence experiments were tried but no β-γ coincidences were found. Since the lack of coincidences might be explained on the assumption that the first excited state

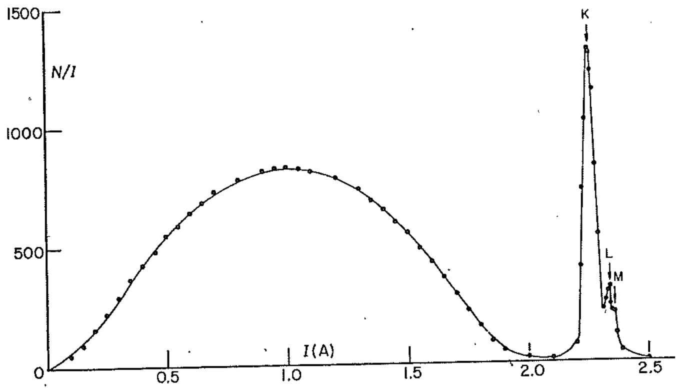


Fig. 16. Beta-ray spectrum of Cs^{137}, low energy part showing internal conversion lines

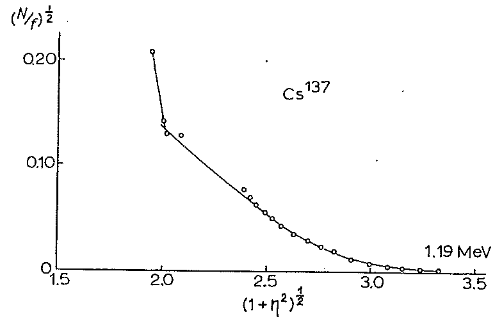
of Ba^{137} has a measurable half-life, a chemical separation of barium from cesium was performed and the half-life of the γ-ray was found to be 156 ± 3 secs.

A curve of the type of that shown in Fig. 16 allows one to estimate the K/L ratio and the internal conversion coefficient in the K-shell, α_K. The presently accepted value is $\alpha_K = 0.093 \pm 0.006$. The value of the area under the K-line to that under the L+M-lines from the above figures gives a rough value of 4.3. Graves *et al.*[33], using an instrument of higher resolution, have obtained the value K/(L+M) = 4.64.

[33] G. A. Graves, L. M. Langer and R. D. Moffat, Phys. Rev. **88** (1952) 344.

If a Fermi plot of the β-ray spectrum is made, two things are apparent at once[34] – (1) there is in addition to the main group a high energy, low intensity group which goes to the ground state and (2) neither group gives a straight line Fermi plot. The situation is illustrated in Figs. 17 and 18. The high energy group has an end-point of 1.17 MeV and an abundance of 8 per cent, while the lower energy group has an end-point of 0.521 MeV and an abundance of 92 per cent. Hence an energy balance

Fig. 17. Beta-ray spectrum of Cs^{137}, high energy part



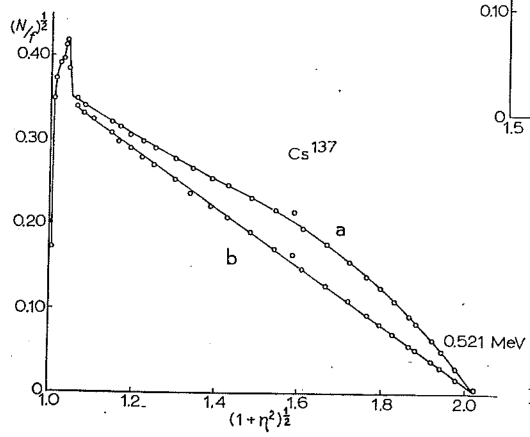


Fig. 18. Fermi plots of Cs^{137}: (a) ordinary plot, (b) corrected for shape factor

is obtained if it is assumed that the high energy group goes to the ground state and the low energy group to the excited (metastable) state and is followed by the emission of the γ-ray. The energy level scheme is given in Fig. 19.

Fig. 18, curve *a*, shows the Fermi plot for the low energy group made in the usual way. Curve *b* shows the rectified Fermi plot using

$$S_n(W) \cong [W^2 - 1 + (W_0 - W)^2]$$

which is applicable if $\Delta j = \pm 2$ and there is a change of parity. In the original work various forms for $S_n(W)$ were tried and the best fit was given by the one listed above. Later, using a very strong source, Langer and Moffat[34] measured the high energy spectrum and found that a rectified Fermi plot could be obtained using an $S_n(W)$ which is characteristic of $\Delta j = \pm 2$ and no change of parity.

All of the information obtained on the disintegration of Cs^{137} makes it possible to

[34] See C. L. Peacock and A. C. G. Mitchell, Phys. Rev. **75** (1949) 1272; L. M. Langer and H. C. Price, ibid. **76** (1949) 641; L. M. Langer and R. J. D. Moffat, ibid. **82** (1951) 635.

give a complete disintegration scheme for Cs^{137}, assigning spins and parities to all levels concerned. The ground state spin of Ba^{137} has been measured and found to be $\frac{3}{2}$ with a configuration $d_{\frac{3}{2}}$. The half-life of the metastable state, the value of α_K and $K/(L + M)$ for the γ-ray are all consistent with the assumption that the γ-ray transition is M4. Since M4 radiation requires a change of parity and a spin change of 4 units the configurationof the first-excited state is $h_{\frac{11}{2}}$. The shape of the lower energy spec-

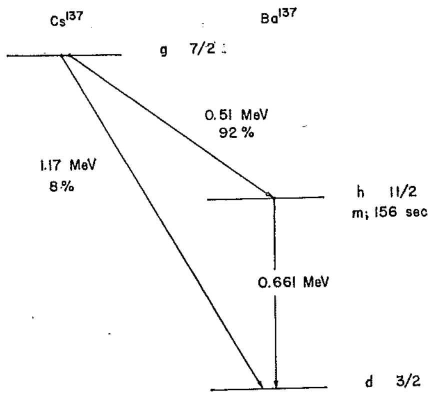


Fig. 19. Disintegration scheme of Cs^{137}

trum requires that the ground state of Cs^{137} have even parity and a spin of $\frac{7}{2}$. The configuration is thus determined as $g_{\frac{7}{2}}$. The shape of the high energy group is consistent with this interpretation. Finally, the spin of Cs^{137} has been measured and is $\frac{7}{2}$.

10.2. The disintegration $Cd^{114} \leftarrow In^{114} \rightarrow Sn^{114}$

As a final example we discuss the disintegration of In^{114}. This isotope shows two half-lives, one of 50 days and one of 72 sec and is, therefore, an isomeric transition. Lawson and Cork[35] showed that the 72-sec state emits a β-ray of 1.984 MeV energy unaccompanied by any γ-rays. The spectrum has an allowed shape. The 50-day state goes to the 72-sec state under the emission of an internally converted γ-ray, whose energy is 0.192 MeV.

Later, through coincidence counting experiments, a high energy γ-ray of low intensity was discovered. The spectrum was reinvestigated by Boehm and Preiswerk[36] and Mei *et al.*[37] who found weak γ-rays at 0.556, 0.722 and 1.27 MeV. Fig. 20 shows the γ-ray spectrum as exhibited by the photoelectrons from a lead radiator. The figure also shows the internally converted γ-ray at 0.190 MeV. The weak γ-ray at 1.27 MeV is not shown in the figure. At 0.576 and 1.30 MeV two additional weak γ-rays have been found.[38]

[35] J. L. Lawson and J. M. Cork, Phys. Rev. **57** (1940) 982.
[36] F. Boehm and P. Preiswerk, Helv. Phys. Acta **22** (1949) 331.
[37] J. Y. Mei, A. C. G. Mitchell and D. J. Zaffarano, Phys. Rev. **76** (1949) 1883.
[38] M. W. Johns, C. D. Cox, R. J. Donnelly and C. C. McMullen, Phys. Rev. **87** (1952) 1134.