On the Maximum β-Energy Release in Tritium*

L. Slack, G. E. Owen, and H. Primakoff
Washington University, St. Louis, Missouri
March 10, 1949

SOME time ago (1947) Konopinski emphasized that the then existing data on the half-life and the maximum β-energy release in H^3 implied a "degree of allowedness" for it much greater than that for the supposedly equally allowed He^6 spectrum:[1]

$$|M|^2\,\mathrm{ft.}=900 \text{ for } H^3, \quad |M|^2\,\mathrm{ft.}=5760 \text{ for } He^6.$$

More recently Bowers and Rosen[2] have pointed out that work by Curran *et al.*[3] and by Novick[4] (maximum β-energy release of 16.9±0.3 kev; half-life of 12 years) greatly minimize the above discrepancy, while the yet unpublished maximum β-energy value of Pontecorvo obtained with a proportional counter, 18.5 kev (quoted in Seaborg),[5] practically removes it (see below).

We wish to remark in the present note that the accurate calorimetric determination of the average β-energy release in H^3, 5.69±0.06 kev, just published by Jenks *et al.*[6] enables an equally accurate determination of the maximum β-energy release which, moreover, turns out to be in excellent agreement with Pontecorvo's. Thus, suppose the tritium spectrum is Fermi allowed; one then has:[7]

$$5.69\pm0.06 \text{ kev}=\text{average } \beta\text{-energy release}\equiv\langle(\epsilon-1)\rangle_{\mathrm{Av}}$$

$$=\frac{\displaystyle\int_1^{\epsilon_{\max}}\frac{2\pi Z}{137}\frac{\epsilon}{(\epsilon^2-1)^{\frac{1}{2}}}\left\{1-\exp\left(-\frac{2\pi Z}{137}\frac{\epsilon}{(\epsilon^2-1)^{\frac{1}{2}}}\right)\right\}^{-1}(\epsilon^2-1)^{\frac{1}{2}}\epsilon(\epsilon_{\max}-\epsilon)^2(\epsilon-1)d\epsilon}{\displaystyle\int^{\epsilon_{\max}}\frac{2\pi Z}{137}\frac{\epsilon}{(\epsilon^2-1)^{\frac{1}{2}}}\left\{1-\exp\left(-\frac{2\pi Z}{137}\frac{\epsilon}{(\epsilon^2-1)^{\frac{1}{2}}}\right)\right\}^{-1}(\epsilon^2-1)^{\frac{1}{2}}\epsilon(\epsilon_{\max}-\epsilon)^2d\epsilon} \tag{1}$$

where ϵ=kinetic+rest energy of the emitted β-particle (in units of its rest energy), $\epsilon_{\max}$=maximum kinetic+rest energy of the emitted β-particle, and Z=nuclear charge of the daughter element=2. Numerical integration and interpolation in Eq. (1) gives (see Fig. 1):

$$\epsilon_{\max}-1=(3.64\pm0.04)\times10^{-2}=18.6\pm0.2 \text{ kev},$$

the discrepancy with Pontecorvo's value being well within experimental error. A comparison of the "degrees of allowedness" of H^3 and He^6 (calculated with the above $(\epsilon_{\max})_{H^3}$, with an H^3 half-life of 12.46 years,[6] and with more recent values of the half-life and maximum β-energy release of He^8: 0.89 sec.[5], $(\epsilon_{\max})_{He^6}=3.5\pm0.6$ Mev[8]) yields:

$$|M|^2\,\mathrm{ft.}=3360\pm200 \text{ for } H^3,$$
$$|M|^2\,\mathrm{ft.}=6300\pm3000 \text{ for } He^6.$$

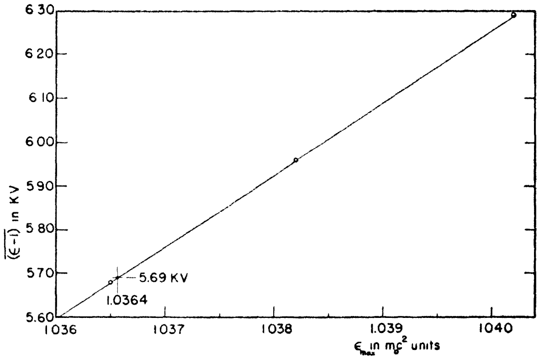

FIG. 1.

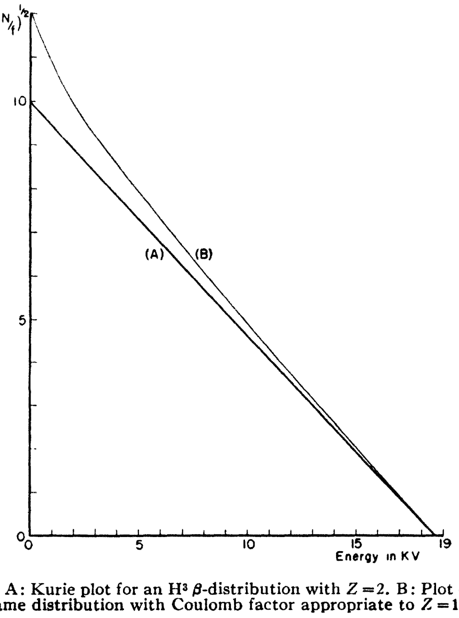

FIG. 2. A: Kurie plot for an H^3 β-distribution with Z=2. B: Plot of the same distribution with Coulomb factor appropriate to Z=1.

Complete consistency is thereby established between the last quoted H^3 and He^6 measurements and between the application of the Gamow-Teller selection rules to these two simplest of the β-active nuclei.

In conclusion it may be pointed out that if we had (incorrectly) used the value $Z=1$, appropriate to the parent nucleus, in the Coulomb factor of the β-energy distribution in the integral, we would have obtained the (incorrect) maximum β-energy release: 17.8±0.2 kev. The error made in using $Z=1$ instead of $Z=2$ is also appreciable in the Kurie plot of the β-spectrum; below we append a Kurie plot of an H^3 β-distribution actually obeying the Fermi allowed shape with $Z=2$ (curve A, Fig. 2); the same distribution is then plotted with use of a Coulomb factor appropriate to $Z=1$ (curve B, Fig. 2).

---

* Assisted by the joint program of the ONR and the AEC.
[1] E. J. Konopinski, Phys. Rev. **72**, 518 (1947).
[2] W. A. Bowers and N. Rosen, Phys. Rev. **75**, 523 (1949).
[3] S. C. Curran, J. Angus, and A. L. Cockcroft, Nature **162**, 302 (1948).
[4] A. Novick, Phys. Rev. **72**, 972 (1947).
[5] G. T. Seaborg, Rev. Mod. Phys. **20**, 585 (1948).
[6] G. H. Jenks, J. A. Ghormley, and F. H. Sweeton, Phys. Rev. **75**, 701 (1949).
[7] The use of the non-relativistic Coulomb factor in the Fermi allowed distribution function in Eq. (1) introduces a negligible error.
[8] H. S. Sommers and R. Sherr, Phys. Rev. **69**, 21 (1946).

Neutron and Proton Binding Energies in the Region of Lead*

Katharine Way**
Oak Ridge National Laboratory, Oak Ridge, Tennessee
March 18, 1949

THE maxima in α-particle decay energies for mass numbers 210-215 recently emphasized by Perlman, Ghiorso, and Seaborg[1] can be looked at in terms of neutron