been unable to find anything so intelligible as geometry. It would be interesting to know whether the exponential or the correct formula of absorption was applied.

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[1] "The Question of the Homogeneity of the γ-Rays. Part II. Absorption in Truncated Hemispheres." F. and W. M. Soddy, *Phil. Mag.*, vi, 19, 733; 1910.
[2] J. W. L. Glaisher, *Phil. Trans.*, **160**, 367; 1870.
[3] "Über Reflexion und Absorption von β-Strahlen." H. Willy Schmidt, *Ann. Phys.*, **23**, 689; 1907.
[4] "Spectrum of Cosmic Rays." E. Regener, NATURE, **127**, 233, Feb. 14, 1931.

If homogeneous radiation of unit intensity and of a kind that is absorbed exponentially is incident on the surface of water at a constant angle θ to the vertical, the intensity at a depth T is given by a formula of the type

$$I_{\theta T} = e^{-\lambda T/\cos\theta}$$

If, however, the radiation, instead of being in one direction only, is arriving from all directions in half-

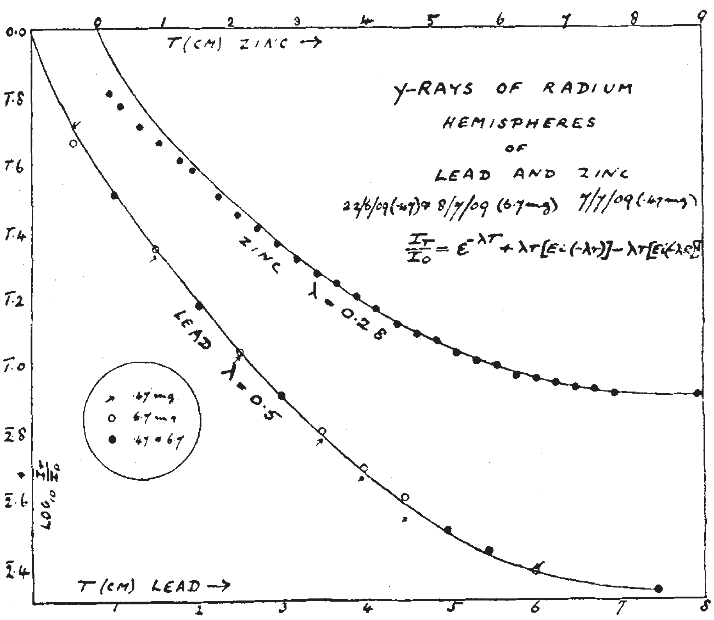

FIG. 2.

space indifferently, then the fraction of the total radiation that is inclined at angles between θ and $\theta+d\theta$ to the vertical is

$$\frac{2\pi R^2 \sin\theta\, d\theta}{2\pi R^2} = \sin\theta\, d\theta$$

The contribution to the total intensity at a depth T made by this part of the total incident radiation is

$$dI_T = e^{-\lambda T/\cos\theta}.\sin\theta\, d\theta$$

Therefore the total intensity at a depth T is

$$I_T = \int_0^{\pi/2} e^{-\lambda T/\cos\theta}\,.\sin\theta\, d\theta$$

By putting $y=\lambda T/\cos\theta$ and then integrating by parts, this expression can be transformed into

$$I_T = e^{-\lambda T} + \lambda T\int_{\infty}^{\lambda T} \frac{e^{-y}}{y}\, dy$$

Then, on putting $u=-y$ we get

$$I_T = e^{-\lambda T} + \lambda T\int_{-\infty}^{-\lambda T} \frac{e^{u}}{u}\,.\, du$$

which may be written, using the ordinary notation for the exponential integral,

$$I_T = e^{-\lambda T} + \lambda T\,\{Ei\,(-\lambda T)\}.$$

The numerical values of the exponential integral corresponding to various values of λT can be found by referring to a suitable book of mathematical tables.

HARRIS BOOTH.

Atomic Transmutation and the Temperatures of Stars

THE letter of Gamow and Landau[1] suggests that an upper limit to the internal temperature of a star can be obtained by considering the disintegration of lithium. Investigations of this kind will probably be of great importance in the future development of astrophysics, but the actual proposal of Gamow and Landau rests on an assumption which is scarcely likely to be true. They postulate that any lithium found at the surface must have been carried there by diffusion from the central region, where it is presumed to have been created. Diffusion in a star is an exceedingly slow process, the time of relaxation being of the order 10^{13} years[2]. It would make small progress during the maximum age of the giant stars. But there is a process of mixing which is likely to operate much faster, namely, the circulating currents in meridian planes indirectly caused by the rotation of the star. The order of magnitude is indicated in an example treated by the writer in which the speed of the vertical current was found to be 60 metres a year[3]. The example was chosen with the view of giving an upper limit to the amount of this circulation; but, allowing for slower currents in an average star, the lithium will be brought to the surface far more quickly in this way than by diffusion.

It is difficult to see how any consistent theory of distribution could be given if diffusion alone were operating. If there is time for lithium produced at the centre to reach the surface, there is time for the heavy elements to have disappeared from the surface by downward diffusion; or if it is supposed that they, like lithium, were created at the centre, there is no mechanism by which they could ever reach the surface. In the steady distribution towards which diffusion is slowly tending, there should not be a single atom of lead in the outer half of the volume of the star.

The existence of these circulating currents will raise the upper limits given by Gamow and Landau. Since the disintegration is sensitive to changes of temperature, the increase may not be very large; but it may well be sufficient to remove any difficulty in accepting the temperatures of the order $10^7 - 2\times 10^7$ found by astronomical methods, whilst negativing any suggestion of considerably higher temperatures.

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Oct. 9.

[1] NATURE, **132**, 567, Oct. 7, 1933.
[2] "Internal Constitution of the Stars," § § 195–196.
[3] *Monthly Notices R.A.S.*, **90**, 54; 1929.