Erratum: Cosmic-Ray Particles at Great Depth

(Phys. Rev. **55**, 870 (1939))

On page 872, second column, line 22, of the above article "0.15 percent" should be changed to "0.15 per mill." The correct statement is:

"This agrees well with the observation that the intensity at 980 m depth and with 120 cm Pb between the tubes was found to be only 0.15 per mill (0.015 percent) of the total intensity at sea level."

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Multiple Scattering of Electrons

In a previous paper[1] a method was given for the treatment of the multiple scattering problem. The results appeared in the form of a series in Legendre polynomials with the coefficients determined by the theory.

We have now completed numerical computations for a large number of examples. Fortunately, the results can be represented by approximate formulas which are very convenient for comparison with experimental data.

Consider electrons of energy $w \cdot mc^2$ scattered by a material of nuclear charge Z and atomic mass M in a foil of σ grams/cm². The value of $w \sin \theta$, θ being the angle of deflection, averaged over the scattering distribution per unit solid angle is approximately given by

$$w\langle \sin \theta \rangle_{\mathrm{Av}} = 0.683(Z^2\sigma/M)^{\frac{1}{2}} \times [4.66 - \tfrac{1}{3} \log Z + \tfrac{1}{2}(Z^2\sigma/M)]^{\frac{1}{2}}. \quad (1)$$

The direct computations were made for Z ranging from 6 to 90, $(Z^2\sigma/M)$ between 1.25 and 10, and for $w = 5$ to 30 for the thinner scatterers and 15 to 55 for the thicker ones. The approximate formula comes within a few percent of the computations, its results being slightly too large for the thicker foils for low energies.

The numerical computations are based on the Thomas-Fermi atom and the Born approximation. The latter approximation causes some uncertainty in the results for heavy elements. Another unknown error arises from the higher relativistic terms in the Mott formula; the terms up to the order $(Z/137)$ increase the computed average angle of multiple scattering for large Z by about five percent and the effect of higher terms is difficult to estimate.

For the scattering intensity per unit solid angle, $f(\theta)$, we find, at $\theta = 0°$,

$$C = 4\pi f(\theta)/w^2 = 2.85/(Z^2\sigma/M) \times [4.66 - \tfrac{1}{3} \log Z + \tfrac{1}{2} \log (Z^2\sigma/M)]. \quad (2)$$

This approximation agrees very well with the direct computations except that for small $(Z^2\sigma/M)$ and energies below $10mc^2$ it yields a value which is a few percent too high. The uncertainties here are due to the same causes as those mentioned above.

The scattering intensity per unit solid angle can be represented roughly as a Gaussian curve in $w\theta$,

$$4\pi f(\theta)/w^2 = C \exp [-\tfrac{1}{4}C(w\theta)^2], \quad (3)$$

where C is given by Eq. (2).

We hope to publish in the near future details of the computations and tables for interpolation.

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[1] S. Goudsmit and J. L. Saunderson, Phys. Rev. **57**, 24 (1940).

Some Fission Products of Uranium

We have bombarded uranium with neutrons from the Berkeley cyclotron and investigated some new fission products. The following is a brief description of our results.

Langsdorf[1] has reported a noble gas with a period of 5.5 days. This has been identified as xenon growing out of the 22-hour iodine discovered by Abelson.[2] The complete chain is

$$\underset{10\text{ min.}}{\mathrm{Sb}} \rightarrow \underset{60\text{ min.}}{\mathrm{Te}} \rightarrow \underset{22\text{ hr.}}{\mathrm{I}} \rightarrow \underset{5\text{ days}}{\mathrm{Xe}} \rightarrow$$

We have in addition, also found the new chain:

$$\underset{\sim 15\text{ min.}}{\mathrm{Te}} \rightarrow \underset{6.6\text{ hr.}}{\mathrm{I}} \rightarrow \underset{9.4\text{ hr.}}{\mathrm{Xe}} \rightarrow$$

In both cases no active deposit of the xenon with a life between a few seconds and several months could be found.

The same chains have been observed in the case of thorium bombardment. In order to have some information about the rate of formation of these products under different conditions, the following experiment was performed.

After having bombarded our material for one hour, we have extracted iodine two hours after the end of the bombardment, and, ten hours later, we have extracted xenon out of the iodine. This xenon decayed with a curve showing only the 9.4-hour and the 5-day period. The ratio of the intensities of the components is 9.4 in the case of uranium for both fast and slow neutrons whereas for thorium it is 17. However the identity of the ratio of formation of the xenons for fast and slow neutrons has to be considered as accidental because in the case of other products the identity is not maintained.

There are also one or more short-life xenons growing out of iodine which we have not yet investigated.

Hahn has reported a 67-hour molybdenum which he thought to be the one which was studied by Seaborg and Segrè;[3, 4] this identification has been made certain by the extraction of the very characteristic 6.6-hour activity of element 43 out of the molybdenum produced by fission.

A careful chemical separation of germanium, arsenic and selenium out of irradiated uranium has failed to show any active product with a life longer than about half a day.

In conclusion we thank Professor E. O. Lawrence for his interest in this work and the Research Corporation for financial assistance.

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February 29, 1940.

[1] A. Langsdorf, Jr., Phys. Rev. **56**, 205 (1939).
[2] P. Abelson, Phys. Rev. **56**, 1 (1939).
[3] G. T. Seaborg and E. Segrè, Phys. Rev. **56**, 808 (1939).
[4] O. Hahn and F. Strassmann, Naturwiss. **27**, 451 (1939).