of levels is $4I+2$. Our method of velocity selection in a strong field involves the use of only one-half the total number of levels. We therefore obtain $2I+1$ components in the deflection pattern. Since we have four components we accordingly find the spin of the sodium nucleus to be $3h/4\pi$.

A complete description of the method and results will be published in this journal.

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March 11, 1933.

Angular Distribution of Low Energy Cosmic Radiation and Interpretation of Angular Distribution Curves

One of us has made an experimental determination of the angular distribution of the cosmic radiation at two different elevations,[1] but an interpretation of the data on the assumption of straight line paths through the atmosphere was not advocated since it was uncertain to what extent the distribution might have been affected by divergences between the paths of primary and secondary rays and by scattering in their passage through the atmosphere. Since it is known that the soft rays suffer the greater deviations[2] we have measured the angular distribution of the radiation which is stopped by 3.8 cm of lead in order to determine the extent to which such scattering affects the angular distribution. At every 15 degree interval between the vertical and horizontal measurements of the coincidence counting rates of three G.M. counters[3] were made alternately with and without a block of lead inserted just above the lower counter.

Each counting rate was the average of fifteen or more independent data, an analysis of which showed that the fluctuations agreed with those to be expected statistically and for which the standard deviation is the quotient of the square root of the total number of counts by the total time. Two such complete runs taken several weeks apart were in good agreement. The differences in counting rates with their probable errors as calculated by combining both sets of data are shown by the experimental points in Fig. 1.

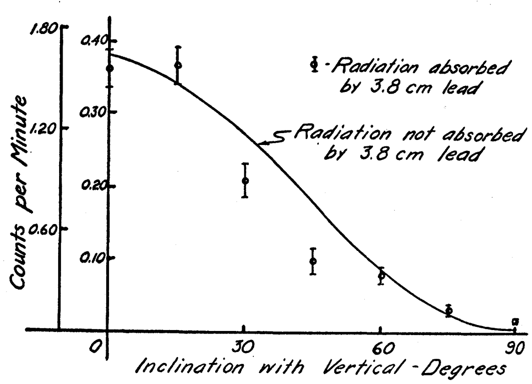

FIG. 1.

For comparison the continuous line represents the distribution of the rays which penetrated the lead plotted to a reduced scale. Although there is an indication that a small fraction of the soft rays, equal to about fifty percent of the horizontal rays, has been scattered through large angles, the majority are fully as concentrated about the vertical as are the penetrating rays, and we may conclude that the distribution of the total radiation is not appreciably broadened by scattering. We may, therefore, interpret the angular distribution of the total radiation on the basis of straight line paths through the atmosphere.

Assuming a simple exponential law the theoretical distribution is:

$$j(\theta)=j_0e^{-\mu h \sec\theta}$$

In Fig. 2 are plotted three sets of experimental data showing the distributions on Mt. Washington, New Hampshire,

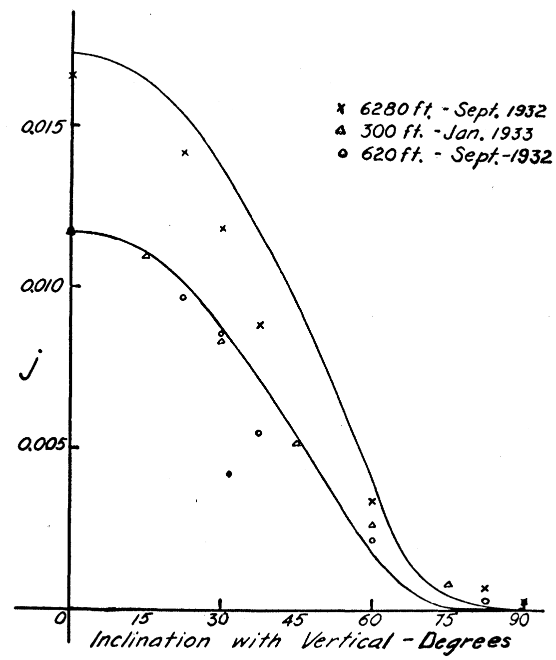

FIG. 2. Distribution of total radiation. Points are experimental; solid curves are computed for $\mu=0.18$ per meter of water for elevations sea level and 6280 ft.

at a base station near Mt. Washington, and on the roof of the Bartol Laboratory. The theoretical distributions for sea level and the top of Mt. Washington for $\mu=0.18$ per meter of water are represented by the continuous curves. The agreement between the observed and calculated dis-

[1] T. H. Johnson, Phys. Rev. **43**, 307 (1933).
[2] C. D. Anderson, Phys. Rev. **43**, 381 (1933).
[3] T. H. Johnson and J. C. Street, J. Frank. Inst. **215**, 239 (1933).

tributions at sea level is remarkably good and the absorption coefficient is in good agreement with the value 0.16 deduced by Millikan and Cameron[4] from the portion of their ionization-depth curve adjoining sea level. For the Mt. Washington elevation there would seem to be a discrepancy between the observed intensities and those calculated from $\mu=0.18$. There is, however, some uncertainty in the relative intensities as measured at the two different elevations arising from a change in the efficiency of the counters with counting rate. Although the change in efficiency was measured[1] the uncertainty of the measurement is sufficient to account for this apparent discrepancy. However, if the absorption coefficient increases with elevation as rapidly as indicated by the data of Millikan and Cameron, unaccountable differences appear between calculated and observed intensities both as regards angular distribution and relative values.

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March 13, 1933.

[4] Millikan and Cameron, Phys. Rev. **37**, 235 (1931).

A Neutron of High Velocity, and Energy Relations for Nuclear Disintegration by Non-Capture

1. High velocity neutron

One of the photographs which we have obtained of the disintegration of N^{14}, by capture of a neutron from beryllium, into B^{11} and He^4 is remarkable with respect to the length of the track of the boron nucleus. The energy of the neutron which caused the disintegration is found by calculation to have been 16×10^6 electron-volts, which is about twice the value 7.8×10^6 usually[1] given for "fast" neutrons. The velocity of this neutron is found as 5.6×10^9 cm per sec. From the mass[2] 9.0155 of the beryllium atom, it is found that 6.9×10^6 electron-volts is the amount of energy given by the change of mass in the reaction with the incident α-particle, provided C^{12} is formed, or considerably less if the product is three α-particles. The α-particles used in the disintegration of the beryllium were those from Th C', which for the ordinary higher velocity have an energy of 8.8×10^6 electron-volts. Thus, if no γ-rays are emitted in the process of emission of the neutron, the total energy available is 15.7×10^6 electron-volts, or, making allowance for the kinetic energy imparted to the C^{12} nucleus, the maximum energy of the neutron should be 14.7×10^6 electron-volts. The fact that the energy found experimentally is greater by 1.3×10^6 electron-volts might be due to the action on the beryllium of a particle of higher velocity than that assumed, but is much more probably due to the fact that present knowledge of the range-velocity relations of B^{11} is not sufficiently exact to give a better agreement. The high energy found seems to indicate that the amount of energy which is transformed into γ-rays when the neutron is emitted is zero or very small.

2. Disintegration by non-capture

If the neutron is not captured, then the reaction may be:

$$N^{14}\rightarrow B^{10}+He^4,\quad \Delta m=0.0077 \text{ mass units} \tag{1}$$

$$N^{14}\rightarrow C^{13}+H^1,\quad \Delta m=0.0038 \tag{2}$$

$$N^{14}\rightarrow C^{12}+H^2,\quad \Delta m=0.0091 \tag{3}$$

However, (2) and (3) are excluded, at least in many of these events, by the fact that the track of the light atom has too great a line density of ions to be due to hydrogen.

The mass increase in (1) is 0.0077 as given by Aston's data. This corresponds to a gain of energy of 7.1×10^6 electron-volts. Thus the neutron must lose $(7.1\pm4.4)\times10^6$ electron-volts. The error of 4.4×10^6 electron-volts included here is the arithmetical sum of all of Aston's estimated errors, which are not likely to be all in one direction, so that the probable error is less than this.

The energy which must be supplied lies between 6 and

[1] I. Curie and F. Joliot, Nature **130**, 57 (1932).
[2] Bainbridge, Phys. Rev. **43**, 367 (1933).

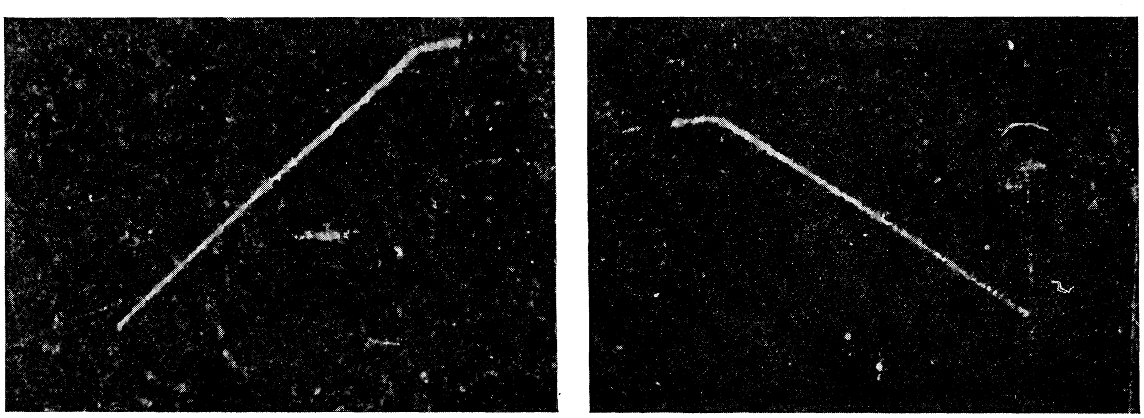

FIG. 1.