lating current in an accelerator the use of a contractor may prove to be valuable.

The magnetic and electrostatic fields of the beam also influence the focusing of electrons in the beam. Damping of oscillations about the equilibrium orbit results from decreasing electrostatic repulsion within the beam, as some of the circulating current is being lost to the walls. This damping is of the same order of magnitude as the orbit contraction in the example above.

[1] D. W. Kerst and R. Serber, Phys. Rev. **60**, 47 (1941); J. A. Rajchman and W. H. Cherry, J. Franklin Inst. **243**, 281 (1947).
[2] Leon Bess and A. O. Hanson, Rev. Sci. Inst. **19**, 108 (1948).
[3] In process of publication by G. D. Adams.

The Neutron Density in the Free Atmosphere up to 67,000 Feet*

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SINCE neutrons in cosmic rays cannot be considered as primary particles because of their short lifetime, a maximum in the intensity distribution of neutrons as a function of the altitude must exist. Considerable work[1-4] has been done in the past to determine the neutron distribution in the atmosphere, and the results obtained thus far show that at low altitudes the slow neutron intensity increases exponentially with the altitude up to about 20 cm of Hg, with an absorption depth, λ, of the order of 150 g/cm^2, where λ is given by the expression $N=N_0\exp(-x/\lambda)$.

The following is a preliminary report on recent results obtained at high altitudes where a maximum in slow neutron intensity has been observed.

The measurements were carried out by sending aloft two identical BF_3 proportional counters to an altitude of 67,000 feet by means of free balloons. These counters were filled with enriched boron of 96 percent B^{10} to a pressure of 20 cm of Hg, and they were operated at a voltage plateau centered at 800 volts.

One counter was shielded with 0.030 inch of cadmium and the other counter was enclosed in a tin shield of the same thickness for the compensation of possible effects caused by stars produced in the cadmium shield. Both shields were sealed airtight and were maintained at atmospheric pressure throughout the flight, thus eliminating any possible effects caused by corona discharge at the high voltage terminals.

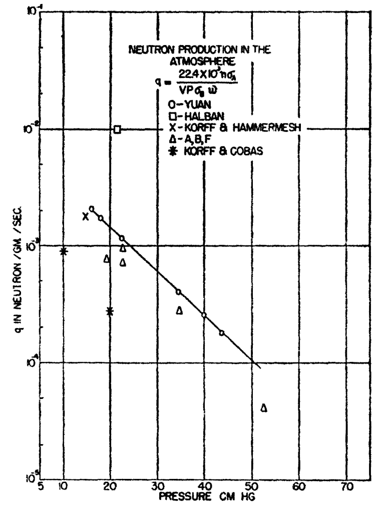

FIG. 2. Rate of neutron production in the atmosphere.

The measured neutron counts were radioed down by means of a frequency-modulated telemetering system.

A calibrated fixed signal of constant amplitude was switched on every 15 minutes for a period of 8 seconds. This served as a check on the constancy of the amplifier gain and the performance of the whole system.

The temperature and the pressure were measured by means of a thermal resistor and an aneroid barometer, respectively.

The measurements were recorded on a galvanometer-type oscillograph, as well as by a scaling circuit arrangement, whose readings were photographed automatically every minute.

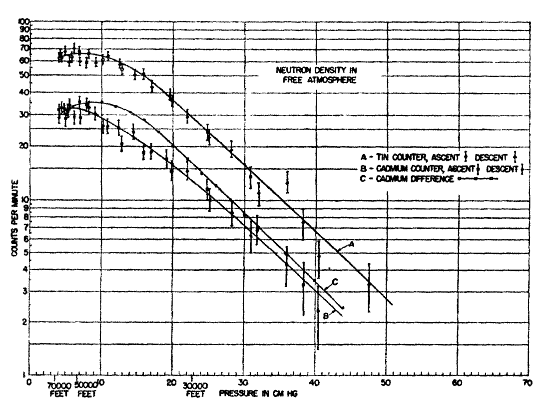

FIG. 1. Neutron density as a function of pressure in the free atmosphere.

The results of this flight are collected in Fig. 1. This shows the counting rate as a function of altitude. The upper curve (A) is for the tin-shielded counter and the lower one (B) for the cadmium-shielded counter. A maximum in the neutron intensity has been obtained for both counters at about 7 cm of Hg. The maximum intensity for slow neutrons, obtained by taking the cadmium difference ($E_n<0.4$ ev), occurs at approximately 9 cm Hg (center curve, C).

Up to 18 cm of Hg the neutron intensity increases exponentially with the altitude, with an absorption depth of 156 g/cm^2, which is in agreement with our previous measurements at lower altitudes.

Our counter sensitivity was calibrated experimentally through the courtesy of the Argonne National Laboratory by using their standardized neutron source. The result of the rather elaborate calibrations is that the efficiency of our 20-cm Hg counter for thermal neutrons is 6.8 percent. By means of this calibration, the absolute values of the rate of production of neutrons in the atmosphere per gram per second are calculated from the expression given by Bethe, Korff, and Placzek.[2] These values, as well as those calculated from recent results of Korff and Cobas,[3] Agnew, Bright, and Froman,[4] are shown in Fig. 2. (The upper limit of q cannot exceed twice the calculated value.)

The cadmium ratio, i.e., the ratio between the unshielded and cadmium-shielded counters, is of the order of 2.2 over the depth from 22.8 cm of Hg to 4 cm of Hg. This is in agreement with Agnew, Bright, and Froman's[4] results.

The author wishes to express his gratitude to Professor R. Ladenburg for many helpful discussions, to Mr. D. B. Davis, who is responsible for the designing and building of the balloon equipment and to members of the Ordnance Research Laboratory who helped to make the flight a successful one.

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[1] E. Fünfer, Naturwiss. **25**, 235 (1937); E. Fünfer, Zeits. f. Physik **111**, 351 (1938); S. A. Korff and B. Hamermesh, Phys. Rev. **69**, 155 (1946).
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[3] S. A. Korff and A. Cobas, Phys. Rev. **73**, 1010 (1940).
[4] H. M. Agnew, W. C. Bright, and Darol Froman, Phys. Rev. **72**, 203 (1947).

Neutron Absorption in Samarium

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In a recent paper[1] it was shown that the large neutron absorption in samarium is due to the isotope at mass 149. Since the alteration produced by the neutrons was not very large, the experiment was repeated with a 4-mg sample exposed in a thin layer of approximately 1 mg per sq. cm to a much stronger neutron flux. The isotope at mass 149 was so reduced that it could not be detected. One of ten mass spectra made with one milligram of the sample is shown in Fig. 1, together with a mass spectrum of normal samarium. The intensity of the isotope at mass 150 was greatly increased so that it appears approximately equal to the one at 154. A faint gadolinium impurity showed on the long exposures, with the two absorbing isotopes at 155 and 157 missing.

Photometric measurements of the plates showed that the densities at the masses 147, 148, 152, and 154 fell on a normal photographic density curve indicating no changes as a result of neutron absorption in any of these isotopes. The new abundance at mass 150 was found from four spectra to have increased to 21.2±0.4 percent. The normal abundance at 150 is 7.47, and at 149, 13.84 percent, the sum being 21.3 percent. This shows that within the experimental error the isotopes that disappear at mass 149 reappear at mass 150. The absorbing cross sections of the other isotopes were estimated to be less than one percent of that of the isotope at mass 149.

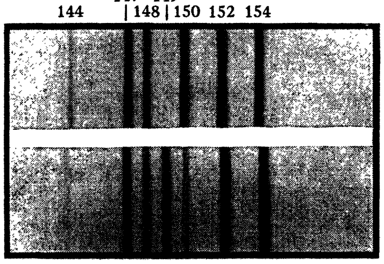

FIG. 1. Samarium isotopes altered by neutron absorption.

[1] R. E. Lapp, J. R. Van Horn, and A. J. Dempster, Phys. Rev. **71**, 745 (1947).

The Origin of Elements and the Separation of Galaxies

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The successful explanation of the main features of the abundance curve of chemical elements by the hypothesis of the "unfinished building-up process,"[1,2] permits us to get certain information concerning the densities and temperatures which must have existed in the universe during the early stages of its expansion. We want to discuss here some interesting cosmogonical conclusions which can be based on these informations.

Since the building-up process must have started with the formation of deuterons from the primordial neutrons and the protons into which some of these neutrons have decayed, we conclude that the temperature at that time must have been of the order $T_0 \cong 10^9$ °K (which corresponds to the dissociation energy of deuterium nuclei), so that the density of radiation $\sigma T^4/c^2$ was of the order of magnitude of water density. If, as we shall show later, this radiation density exceeded the density of matter, the relativistic expression for the expansion of the universe must be written in the form:

$$\frac{d}{dt}\lg l = \left(\frac{8\pi G}{3}\frac{\sigma T^4}{c^2}\right)^{\frac{1}{2}} \quad (1)$$

where l is an arbitrary distance in the expanding space, and the term containing the curvature is neglected because of the high density value. Since for the adiabatic expansion T is inversely proportional to l, we can rewrite (1) in the form:

$$-\frac{d}{dt}\lg T = \frac{T^2}{c}\left(\frac{8\pi G\sigma}{3}\right)^{\frac{1}{2}} \quad (2)$$

or, integrating:

$$T^2 = \left(\frac{3}{32\pi G\sigma}\right)^{\frac{1}{2}} \cdot \frac{c}{t}. \quad (3)$$

For the radiation density we have:

$$\rho_{\text{rad.}} = \frac{3}{32\pi G}\cdot\frac{1}{t^2}. \quad (4)$$

These formulas show that the time t_0, when the temperature dropped low enough to permit the formation of deuterium, was several minutes. Let us assume that at that time the density of matter (protons plus neutrons) was $\rho_{\text{mat.}}{}^{\circ}$. Since, in contrast to radiation, the matter is conserved in the process of expansion, $\rho_{\text{mat.}}$ was decreasing as $l^{-3} \sim T^3 \sim t^{-\frac{3}{2}}$. The value of $\rho_{\text{mat.}}{}^{\circ}$ can be estimated from