about the [111] and [100] axes would be important. Perhaps it is also obvious that alignment of crystals preferentially orientated is never perfect so that the angles shown by Fig. 5 vary somewhat in the actual samples.

It is seen that the total cross section *vs.* energy curve for the pressed Al powder, Fig. 3, with neutrons incident in the direction of compression, is closely similar to Fig. 2, and therefore the orientations for these two cases must be approximately the same.

The cross-section curve for the cast Al sample, Fig. 4, exhibits relatively weak Bragg scattering, although fairly large crystals could be seen in the specimen by visual inspection. Apparently the crystals are so orientated as to avoid any considerable Bragg reflection.

In addition to the cold-drawn half-hard Al, the pressed Al powder and the cast Al, two other types of Al, 2-SO (soft) aluminum, and a 99.95 percent pure Al casting which had been worked with several passes to reduce grain size, were measured. The soft Al specimen (cut from a drawn rod) yielded total cross section *vs.* neutron energy curves very similar to Figs. 1 and 2 for neutron beams parallel and perpendicular to the soft Al rod. Hence, crystal orientations in the soft Al are about the same as for the cold-drawn half-hard Al. The results for the pure casting established that the small impurities present in the specimens were of little significance in determining the shape of the Figs. 1–4 curves.

4. CONCLUSION

The results show that crystal orientation effects can be investigated conveniently with monoenergetic neutrons as well as with x-rays. It is to be noted that the neutron diffraction experiments yield intensities rather directly since total cross sections are obtained at once, and from these the coherent scattering cross sections can be separated ordinarily without difficulty. The required size of samples, much larger at present for neutron than for x-ray diffraction, has some definite advantages for investigations such as the present one since it is not necessary to work with a small volume of the material being measured.

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The Latitude Dependence of Neutron Densities in the Atmosphere as a Function of Altitude

J. A. SIMPSON, JR.
Institute for Nuclear Studies, University of Chicago, Chicago, Illinois

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IN order to study nuclear evaporation processes and the origin of neutrons in the atmosphere, a series of experiments was performed in B-29 aircraft which included the measurement of neutron densities for several altitudes at 0°, 19°N, 40°N, and 53°N magnetic latitude. The total vertical intensity of charged particles traversing 5 g/cm^2 and the vertical intensity of mesons traversing 20 cm of lead were also measured at the same time. The neutron detectors were BF_3 proportional counters surrounded by paraffin cylinders[1] which were covered with cadmium. Two of these detectors containing enriched boron were connected in parallel to a fast amplifier and scaling circuit; a second pair of these detectors containing normal boron was connected with an identical electronic system. These detectors had flat operating characteristic curves of at least 100 volts. They were mounted in the rear pressurized cabin of the plane approximately two feet from any equipment. The detectors respond to neutrons above the cut-off energy for cadmium but are essentially fast neutron detectors. Although they do not have an energy response curve identical with the "long" counters[1]

[1] A. O. Hanson and J. L. McKibben, Phys. Rev. **72**, 673 (1947).

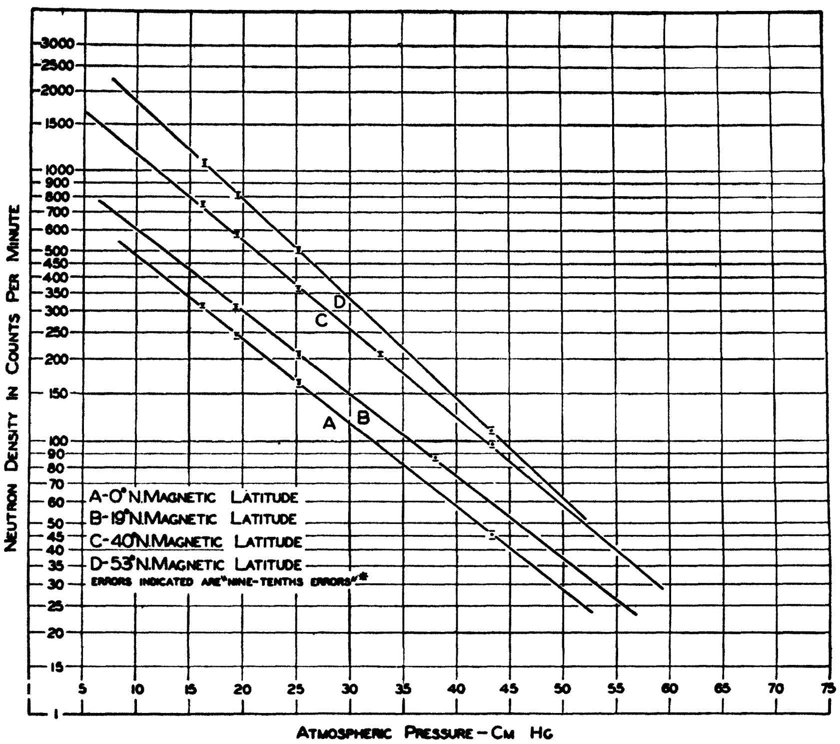

FIG. 1. The relative fast neutron density in the atmosphere.
* The errors shown are such that there is a 0.9 probability that the measured value is within the range of the indicated error.

because the neutrons are incident isotropically, this is not important since these counters are only used to make *relative* measurements. It has been shown that the neutron energy spectrum up to at least 100 ev does not change over the range of atmospheric pressures encountered in this experiment, and that the altitude dependence of the neutron density as measured by these cadmium-paraffin covered detectors is the same as for a bare counter in free space.[2]

In Fig. 1, only measurements were included in which the plane was flown along a course of constant magnetic latitude and pressure altitude. No data were taken under opaque clouds, and it was shown that the measurements were independent of the amount of airplane gasoline and disposition of equipment and personnel in the plane. The constant ratio of counting rates from the enriched boron and normal boron detectors at all altitudes proved that only ionizing events caused by neutron capture were being detected. Data were collected on at least two different days at each latitude, and the flights extended over a period of nine weeks. Points at 16.3 cm Hg and 19.5 cm Hg on the 53°N curve were taken before and after the points on the 0° and 19°N curves.

Each point in Fig. 1 represents from 4000 to 8000 counts, and the error shown is such that there is a 0.9 probability that the measured value is within the range of the indicated error. The atmospheric pressure has been corrected for temperature and instrumental errors. It is seen that the altitude dependence of the neutron density D is adequately represented by $D = D_0 \exp(-bp)$ for the magnetic latitudes between 0° and 53° north. In Table I the values for b are tabulated for p expressed in centimeters Hg. The total exponential absorption in air of the neutron producing radiations is expressed in g/cm^2 and assumes only vertically incident particles.

There are several independent ways to show that this latitude effect is the same as the latitude effect in free space. For example, the recent free-space measurements of Yuan and Ladenburg[3] at

[2] H. M. Agnew, W. C. Bright, and Darol Froman, Phys. Rev. **72**, 203 (1947); their paper contains references to earlier atmospheric neutron measurements.

[3] L. C. L. Yuan and R. Ladenburg, Bull. Am. Phys. Soc. **23**, 21 (1948).

TABLE I.

Magnetic latitude	b	Exponential absorption g/cm^2
0°	0.071 ± 0.003	191 ± 8
19°	0.070 ± 0.003	194 ± 8
40°	0.075 ± 0.003	181 ± 7
53°	0.085 ± 0.004	160 ± 7

TABLE II. Latitude factor between 0°–3° and 51°–53°N.

Atmospheric pressure cm Hg	Vertical "soft" component	Vertical meson	Total[4] ionization ions/cm^3/sec./atmos.	Fast neutron density
45	1.1_4	1.2_3	1.4_5	2.3_2
35	1.1_9	1.2_7	1.6_1	2.6_7
25	1.2_3	1.3_2	1.9_0	3.0_8
15	1.7_7	1.3_6	2.2_2	3.5_3

53°N mag. lat. and the earlier free-space measurements of Agnew, Bright, and Froman[2] at approximately 43°N magnetic latitude may be compared with Fig. 1 for 53°N and 40°N magnetic latitude after correcting for the differences in latitude. Their measurements are in agreement, within their experimental errors, with the latitude effect shown in Fig. 1 for 40° and 53°.

Measurements of neutron production in lead at 0°, 40°N, and 53°N and in aluminum at 40°N and 53°N mag. latitude were made at a few of the same altitudes at which the neutron densities were measured. These measurements show that the changes of neutron density with latitude correspond to those in free space.

Measurements of neutron density at 25.2 cm Hg between 0° and 56°N at intervals of 2°–5° clearly show characteristic plateau regions near 0° and above 50°N; therefore, a comparison of the results in Fig. 1 may be made with charged particle data in these two latitude regions. Table II gives a preliminary summary of the factor of increase between 0°–3° and 51°–53°N mag. latitude in the vertical intensities of the so-called "soft" component, the meson component as described above, the total ionization,[4] and the neutron densities. These charged particles do not appear to account for the large neutron density latitude effect. However, the slopes of the total ionization curves[4] for 3° and 51° in the pressure range 15–40 cm Hg are in excellent agreement with the 0° and 53° curves in Fig. 1.

It may be concluded that most, if not all, the neutrons in the atmosphere which have been measured are of secondary origin and arise from processes in which the primary particles are charged particles.

It may be shown from the above data, from $p=15$ to $p=45$ cm Hg, that the ratio of neutron production to ionization production is approximately constant between 0° to 20°N and 20°N to 40°N, but that the ratio has increased by a factor of 3 between 40° and 53°N. An interpretation of the data may be made by assuming that the primary particles, say protons, produce high energy neutrons, protons, and mesons at the top of the atmosphere and that the largest contribution to the neutrons which are measured in the atmosphere arises from the production of high energy nuclear bursts and "stars" by these high energy secondary neutrons and protons along with primary particles. Then, from the change of the neutron-ionization production ratio with latitude it might be concluded tentatively that the magnitudes of the cross sections for nucleon production relative to meson production decreases rapidly with increasing energy of the primary particles. The details and discussion of the experiment along with new data will be published.

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[4] I. S. Bowen, R. A. Millikan, and H. V. Neher, Phys. Rev. **53**, 855 (1938).

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