mesons of this energy. The minimum grain density was assumed to be that observed in cosmic-ray tracks crossing the emulsion in a direction perpendicular to the meson beam, and showing an average multiple scattering of less than 0.1° per 100 microns.

Two methods of scanning were used, and the results are presented separately. The first method consisted in scanning "along the tracks." In this study, individual tracks were followed, and all stars, stoppings, and scatterings by more than 20 degrees noted. The second method of "area" scanning was found to be reliable in detecting stars and inelastic scatterings, and in this way a larger number of these events was catalogued. As a check, all stars and inelastic scatterings, except one, found by "along the track" scanning were also found by "area" scanning.

The results are given in four tables. In Table I is given the frequency of stars *versus* number of prongs as found in "area" scanning. A "star" is defined as any event in which the prongs are only nucleons or groups of nucleons. In the second line are given the relative frequencies of all the stars; in the third line are those of stars emitting at least one lightly ionizing particle greater than 30 Mev. In all but four cases, these particles were identified as energetic protons. These protons were found to have an average energy, as determined from grain density measurements, of 55±8 Mev.[2] Table II gives the frequency of "inelastic" scatterings as found in the "area" scanning. These are here defined as events either (a) associated with an outgoing meson having a grain density greater than three times that of the incoming particle or (b) having one or more nucleonic prongs at the scattering vertex. For these scatterings, a large change in meson energy was evident. The average energy loss of the meson found for this group was about 60 Mev. In the first line of Table II, the number of prongs (usually protons) associated with the scattering is given.

TABLE I. Star-prong distribution ("area" scanning).

No. of prongs	1	2	3	4	5	Totals
No. of stars	17	40	22	11	3	93
No. of stars with a fast proton	6	13	8	3	1	31

TABLE II. Inelastic scatterings ("area" scanning).

No. of recoil prongs	0	1	2	3	4	Totals
No. of scatterings	3	16	2	1	2	24

Results from "along the track" scanning are given in Tables III and IV. Table III summarizes the frequencies of "elastic" scatterings as a function of angles of mesons deflected by more than 20 degrees. These events are not associated with any prongs, although in many cases a heavy cluster of grains is seen at the scattering vertex. The energy change of the elastic scatterings, if any, is less than 30 Mev. In Table IV are summarized all events found in "along the track" scanning. In this table are listed four disappearances-in-flight. These disappearances-in-flight took place in sensitive portions of the emulsion, and the incoming particle was identified as a meson in each case by grain count and multiple scattering measurements.

TABLE III. Elastic scatterings ("along the track scanning").

Scattering angle	20°–45°	45°–90°	90°–135°	135°–180°
No. of scatterings	6	0	0	5

TABLE IV. Summary of results ("along the track scanning").

Stars	Inelastic scatterings	Elastic scatterings	Stoppings
20	6	11	4

In computing the absolute and relative cross sections for the interactions of π^- mesons in emulsion, only the data obtained by scanning along the track were used. In all, 1150±50 cm of track were scanned by this procedure. An analysis of the proportion of μ^- mesons and fast electrons in the flux yielded 30±10 percent. Thus, only 70±10 percent of the accepted tracks were actually due to π^- mesons. Furthermore, the scatterings which occur for projected angles larger than 160° and without sensible change in grain density have almost twice the probability of being counted. A crude correction for this phenomenon was made by ignoring two of the five cases of 135°–180° scatterings. The average length of meson track in the emulsion was 4000 microns. Because events associated with track lengths of less than 500 microns were excluded, a further correction of 0.87 was applied to the flux in computing the mean free path. With these corrections, the mean free path of 75-Mev π^- mesons for the productions of scatterings (excluding the elastic scatterings for angles less than 20°), stars, and stoppings, in emulsion is:

$$[(1150\pm50)(0.70\pm0.10)\times0.87]/(39\pm7)=18\pm4 \text{ cm}.$$

If allowance is made for the finite size of the nucleus, very few, if any, elastic scatterings greater than 20 degrees can be ascribed to coulomb scattering by silver or bromine. With a cut-off angle of 20°, however, a significant fraction of the diffraction scattering expected for mesons of this energy should be included in our results. Most of the observed elastic scatterings in the 20–45 degree interval listed in Table III may be attributed to the diffraction expected on the basis of the observed catastrophic (stars plus inelastic scatterings plus stoppings) interactions.

* This research was jointly supported by the ONR and AEC.
† Now at the University of Rochester, Rochester, New York.
[1] Bernardini, Booth, Lederman, and Tinlot, Phys. Rev. **80**, 924 (1950).
[2] In 11 cases, the energy values were checked by the multiple scattering method and were found to be 70 Mev.

Ferromagnetic Domains in Bicrystals of Nickel

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THE method of growing bicrystals of predetermined orientation developed by Chalmers[1] has been adapted for metals of high melting points.[2] In the course of these investigations, bicrystals of Mond nickel (99.92 percent Ni) were produced. Figure 1 shows the top surface of such a specimen. The orientations of the individual crystals are indicated.

The preparation of bicrystals of nickel was undertaken in order to observe the influence of grain boundaries on ferromagnetic domain patterns. Up to now, no distinct domain pattern has been

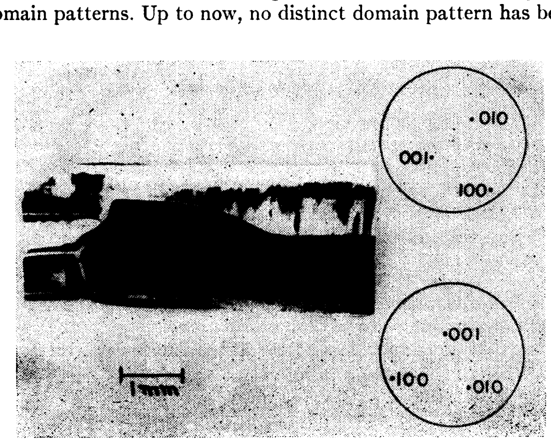

FIG. 1. Bicrystal of nickel and the orientations of the individual crystals.

observed for nickel. The low anisotropy energy has been regarded as the reason for the failure to observe the domains. Bozorth and Walker[3] reported recently a pattern on a crystal of a cobalt-nickel alloy (40 percent Ni; 60 percent Co). This alloy was chosen because it has a higher anisotropy energy than nickel but the same direction of easiest magnetization.

Previous considerations of the effects of grain boundaries on ferromagnetic properties[4] led to the prediction that a domain structure should be observable in nickel bicrystals of suitable orientations. This has been confirmed by using ferromagnetic powder technique.[5] The experiments showed simple domain structures on the electropolished crystal surface. A typical pattern, obtained in the absence of an external field, is shown in Fig. 2,

FIG. 2. Powder pattern on the surface of the bicrystal. AB is the grain boundary.

in which AB is the grain boundary. Patterns formed in external magnetic fields were also studied. All observed patterns are consistent with domain structures to be expected in nickel. They contain basic domains and "tree pattern" with the walls of the basic domains as "trunks." In the immediate neighborhood of the grain boundary, however, the boundary itself forms the "trunk." Effects of the grain boundary can be observed on all patterns.

The study of ferromagnetic domain structures in their relationship to grain boundaries may provide additional information about the properties and structure of crystal boundaries.

[1] B. Chalmers, Proc. Roy. Soc. (London) **A175**, 100 (1940).
[2] K. V. Gow and B. Chalmers, to be published.
[3] R. M. Bozorth and T. G. Walker, Phys. Rev. **79**, 888 (1950).
[4] U. M. Martius, Can. J. Phys. 1 (1951).
[5] Williams, Bozorth, and Shockley, Phys. Rev. **75**, 155 (1949).

Does Diffusive Separation Exist in the Atmosphere below 55 Kilometers?*

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IN a recent letter,[1] McQueen infers that above 40 km diffusive separation increases the proportion of $N^{14}N^{14}$ molecules as compared to the $N^{14}N^{15}$ molecules. This inference rests on mass spectrographic analyses of six air samples obtained by rockets under an U. S. Army Signal Corps contract with the University of Michigan. For purposes of discussion (and also inasmuch as there are errors in the dates and altitudes of several of the samples), McQueen's table of results is reproduced here with the correct dates and with certain results obtained at the University of Durham and at the University of Michigan, which will be discussed in a later paragraph.

Suppose that in a particular layer of the atmosphere there is no mixing at all. Then, for any constituent of molecular weight M, the height distribution in terms of the number of molecules, n, per unit volume is given by

$$n=n_0e^{-h/H}, \tag{1}$$

where n_0 = number of molecules per unit volume at the base of the layer, h = height above the base of the layer, and, if it is assumed that the temperature T is essentially constant throughout the layer, $H=RT/Mg$ where R is the molar gas constant. Now consider the relative concentration, $\rho=n'/n$, of two gases of molecular weights M and M'. From Eq. (1)

$$\rho=\rho_0e^{-(h/H'-h/H)}=\rho_0e^{-h/H_1}, \tag{2}$$

where $H_1=RT/(M'-M)g$ and ρ_0 is the ratio at the base of the layer. The percent change, P, in ρ relative to ρ_0 is, from Eq. (2),

$$P=-100(1-e^{-h/H_1}). \tag{3}$$

McQueen's results imply that there is no diffusive separation up to about 47 km but that there is about a 3 percent separation at about 55 km, implying a cessation or reduction of mixing over the 8.4 km between mean levels of the two groups of samples. (The time interval between the two groups is only a few months, and in this region diffusion is too slow for any appreciable change in P between the two levels to occur during this interval.) If it is assumed that no mixing occurs over the 8.4-km range and if T is taken as 280°K,[2,3] then for the $N^{14}N^{14}/N^{14}N^{15}$ ratio, for which $M'-M=-1$, Eq. (3) gives $P=3.5$ percent so that McQueen's results are not inconsistent in this respect. On the other hand, for the $He/(N_2+A)$ ratio ($M'=4$, $M=28$), Eq. (3) gives $P=134$ percent under the same conditions; and for Ne/A, $P=107$ percent.

Other portions of the samples analyzed by McQueen have also been analyzed by the charcoal absorption method at the University of Durham by Paneth and co-workers[4] for He, Ne, A, and N_2, and by the present writers for He, Ne, and (N_2+A.) In these samples and in six others, the relative concentrations of the gases did not vary more than several percent from the corresponding values at the surface of the earth. At this time, analyses by the charcoal method have been made for only three of the six samples reported by McQueen (results on the three other samples will be reported later); results from these three samples are given in Table I in terms of percentage deviation of the relative helium (to nitrogen plus argon) concentration in the sample from the corresponding concentration at the surface of the earth, and in terms of the percentage deviation of the neon to argon ratio from the corresponding surface value.

The small concentration of helium in the earth's atmosphere implies escape of helium from upper atmospheric levels. This

TABLE I.[a] Comparison of McQueen's results (reference 1) with those of Paneth and co-workers (reference 4) and with those obtained at the University of Michigan. The percent deviation is from the corresponding ratios at the earth's surface—i.e., the quantity P in Eq. (3). The mean deviations are given.

	Height	Date	Separation (%) $N^{14}N^{14}/N^{14}N^{15}$ McQueen (reference 1)	Separation (%) Paneth and co-workers (reference 4) He/(N_2+A)	Ne/A	Separation (%) He/(N_2+A) (Univ. of Mich.)
(19B)	54.7–58.3	7–21–49	3.9±0.4			
(15C)	53.6–57.7	6– 2–49	2.7±0.2	0.3±0.3	−1.3±0.8	−3[b]
(5B)	49.0–59.8	7–26–48	2.7±0.5			0[c]
(25B)	50.4–53.3	12– 6–49	0.4±0.3			
(20B)	45.0–47.8	9–20–49	0.8±0.3			
(28B)	41.4–44.9	12– 6–49	less than 0.3			−0.3±0.3[d]

[a] The samples are labeled by a number and a letter. The number refers to the original sample and the letter to the subdivision. The particular letters given in this table refer to the subdivisions sent to McQueen.
[b] Only one valid run was made on this subdivision of sample 15 so that a mean deviation cannot be deduced. This run was made early in the analysis program, and it is estimated that the mean deviation is not greater than 3 percent.
[c] This is the average of two runs which were made early in the analysis program, and it is estimated that the mean deviation is not greater than 3 percent.
[d] This is the average of four runs.

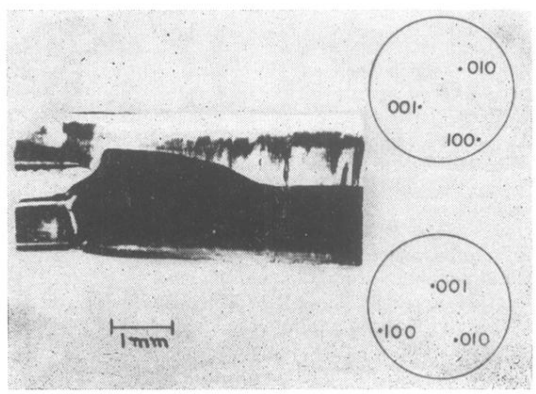

FIG. 1. Bicrystal of nickel and the orientations of the individual crystals.

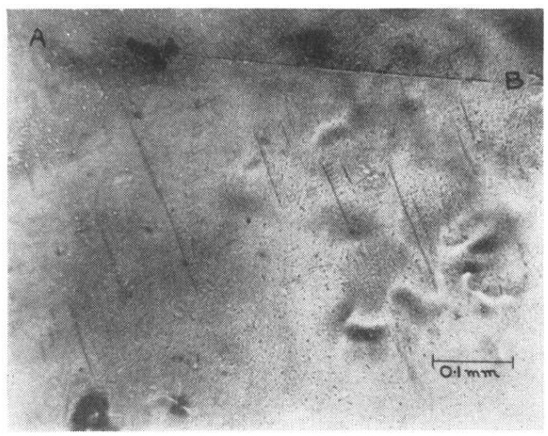

FIG. 2. Powder pattern on the surface of the bicrystal.
AB is the grain boundary.