gamma-ray is strongly internally converted, and the conversion electron and following x-ray or Auger electrons are detected, simultaneously, with the beta-ray, and produce a pulse 80 kev larger than the beta-ray. If 80 kev is subtracted from the apparent energy of the spectrum points, and a new Kurie plot is made, curve B results with an end point at 255 ± 10 kev. For confirmation, the gamma-spectrometer was set to 675 kev and the beta-coincidence spectrum run. The remaining number of counts was small, but the Fermi-Kurie plot of the results is shown in curve C. The endpoint is 255 ± 15 kev. This seems to confirm the lower beta-ray energy and establishes the position of the 720-kev transition in the decay scheme.

* Work performed for the Atomic Energy Project at Oak Ridge National Laboratory.

[1] Zeldes, Brosi, and Ketelle, Phys. Rev. 81, 642 (1951).
[2] K. Way *et al.*, Nuclear Data, Nat. Bur. Standards (U. S.), Circ. 499 (1950).
[3] Kern, Mitchell, and Zaffarano, Phys. Rev. 76, 94 (1949).
[4] B. H. Ketelle, Phys. Rev. 80, 758 (1950).

On the Magnetic Moments of Mg^{25}, Re^{185}, Re^{187}, and Be^9

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Using the nuclear induction spectrometer,[1] the magnetic moments of Mg^{25}, Re^{185}, and Re^{187} have been determined. The values of the magnetic moments listed in Table I were computed directly from the measured frequency ratios, and the values of the magnetic moments of N^{14} and Na^{23} were used for the comparison without corrections of any kind.

Table I. Magnetic moments.

Nucleus	Magnetic moment in nuclear magnetons
Mg^{25}	-0.85466 ± 0.00015
Re^{185}	$3.1433\ \pm0.0006$
Re^{187}	$3.1755\ \pm0.0006$
$\mu(Re^{187})/\mu(Re^{185})=1.01026\pm0.00008$	

From the optical hfs method the nucleus Mg^{25} was known to have a spin value 5/2 and its magnetic moment was determined to be[2] -0.96 ± 0.07 nm. Using a magnetic field of 11,000 gauss and a sample of 4.6-molar solution of $MgCl_2$ in water, the resonance of Mg^{25} was located near a frequency of 3.9 Mc. Comparing the resonance frequency of Mg^{25} with that of N^{14} from a sample of concentrated HNO_3, we found

$$\nu(Mg^{25})/\nu(N^{14})=0.84714\pm0.00008. \tag{1}$$

The sign was verified to be negative. Taking the value 5/2 for the spin of Mg^{25}, the frequency ratio (1) leads to

$$\mu(Mg^{25})=-0.85446\pm0.00015 \text{ nm} \tag{2}$$

for the magnetic moment of Mg^{25} which is in good agreement with the spectroscopically determined value. In computing the value (2), we have made use of the value 0.40355 ± 0.00005 nm for the magnetic moment of N^{14}, which is different from the value 0.40369 ± 0.00006 nm reported by Proctor and Yu.[3] This is due to the fact that the newly determined value[4]

$$\mu(P)=2.79245\pm0.00020 \text{ nm} \tag{3}$$

for the proton moment was used instead of the value 2.79348 ±0.00034 nm obtained by Taub and Kusch.[5]

The two isotopes Re^{185} and Re^{187} of rhenium were investigated by Schüler and Korsching.[6] From the hfs of the line λ4889 in the ReI spectrum, they obtained the ratio

$$\mu(Re^{187})/\mu(Re^{185})=1.02069\pm0.00043 \tag{4}$$

for the magnetic moments of Re^{185} and Re^{187}. In the present investigation, we have used a sample of an aqueous solution of the compound $NaReO_4$. As in the case of MnO_4^-, the ReO_4^- ion was presumed to be only feebly paramagnetic. The perturbation caused by a strong magnetic field at the position of the rhenium nucleus due to strong paramagnetism could thus be avoided. On the other hand, no resonance could be found with a water solution of the paramagnetic compound K_2ReCl_6. The two resonances of Re^{185} and Re^{187} were located near a frequency of 6.4 Mc in an external field of 6700 gauss. Their resonance frequencies were compared with that of Na^{23} from a 0.25-molar aqueous solution of NaCl with 1 molar of $MnSO_4$. We obtained

$$\nu(Re^{187})/\nu(Na^{23})=0.85987\pm0.00009, \tag{5a}$$

$$\nu(Re^{185})/\nu(Na^{23})=0.85114\pm0.00009, \tag{5b}$$

$$\nu(Re^{187})/\nu(Re^{185})=1.01026\pm0.00008. \tag{5c}$$

The sign of the magnetic moment was verified to be positive for both isotopes. Since both Re^{185} and Re^{187} are known[7] to have a spin 5/2, the ratio (5c) is equal to the ratio of their magnetic moments, which agrees very well with the hfs value (4). Taking the spin value 5/2 and the value 2.2158 ± 0.0003 nm for the magnetic moment of Na^{23}, we obtained the values of the two magnetic moments of rhenium listed in Table I. The value of the magnetic moment of Na^{23} was computed from the proton moment (3) and the frequency ratio $\nu(Na^{23})/\nu(P)$ given by Bitter.[8] Both rhenium isotopes possess a large quadrupole moment. The interaction of this quadrupole moment with the molecular electric fields gave a line width of about 10 gauss for both rhenium signals. The magnitude of these signals was very much enhanced by using an rf field of about 3 gauss.

In the course of these measurements, we have also investigated the sign of the magnetic moment of Be^9 with the use of an aqueous solution of $Be(NO_3)_2$. An earlier and, as it seems to us, unambiguous determination by Rabi and his co-workers[9] gave the sign to be negative; nevertheless, it is listed in the table compiled by Mack[10] with a question mark. Our result fully confirms the correctness of the above-mentioned earlier assignment.

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[1] W. G. Proctor, Phys. Rev. 79, 35 (1950).
[2] Crawford, Kelly, Schawlow, and Gray, Phys. Rev. 76, 1527 (1949).
[3] W. G. Proctor and F. C. Yu, Phys. Rev. 81, 20 (1951).
[4] F. Bloch and C. D. Jeffries, Phys. Rev. 80, 305 (1950).
[5] H. Taub and P. Kusch, Phys. Rev. 75, 1481 (1949).
[6] H. Schüler and H. Korsching, Z. Physik 105, 168 (1937).
[7] Zeeman, Gisolf, and de Bruin, Nature 128, 637 (1931).
[8] F. Bitter, Phys. Rev. 75, 1326 (1949).
[9] Kusch, Millman, and Rabi, Phys. Rev. 55, 666 (1939).
[10] J. E. Mack, Revs. Modern Phys. 22, 64 (1950).

On the Nuclear Interaction of π^- Mesons in Nuclear Emulsions*

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The preliminary analysis of the nuclear interactions produced by π^- mesons in nuclear emulsions has been extended to the kinetic energy range of 70–90 Mev. Results are here presented on the nuclear stars, scatterings, and stoppings in flight observed in this energy range.

The experimental arrangement was similar to that already used for mesons of kinetic energy of 30–50 Mev.[1] The G-5 plates were exposed directly to the external meson beam ($KE=95\pm5$ Mev) of the Nevis cyclotron. Because of ionization losses suffered in traversing the glass and emulsion, the corresponding energies of mesons studied ranged between 70 and 90 Mev. Only those tracks entering the emulsion from the proper direction and longer than 500 microns were accepted in the analysis. The average grain density of the allowed tracks as compared to the minimum was found to be 1.18 ± 0.07, in agreement with that expected for 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.

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† 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

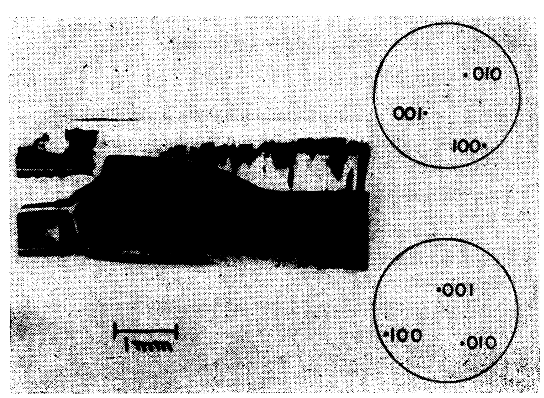

FIG. 1. Bicrystal of nickel and the orientations of the individual crystals.