of ion cores. E_F is the Fermi energy of the $4s$ electrons. Thus

$$H_i = 3A^2SN_A/16\mu_B E_F N_s. \qquad (5)$$

Now if H_i should be $\approx$ 100 to 500 oersteds, it would help eliminate the apparent frequency dependence of the g-values in metals and it would also help lower the values of g and thus bring them into better agreement with the theoretical relation $g-2\approx 2-g'$. We need $A\approx 10^{-2}$ ev to give $H_i=300$ oersteds, according to Eq. (5); on this estimate $M_s\approx 1$ gauss and is not itself a major source of magnetization. The suggested value of A is of the order of magnitude we expect after correction for screening.[4]

The relaxation time may be estimated by making appropriate modifications in the calculation by Abrahams[7] of the magnetic dipolar interaction between spin waves and conduction electrons in metals. We would expect our interaction to increase his relaxation frequency by a factor $\approx (A/4\pi M\mu_B)^2 \approx 10^4$ for iron, and this is confirmed approximately by doing the calculation. The resultant relaxation time for iron is of the order of 10^{-8} sec at room temperature, and this is indeed the observed order of magnitude.

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[1] R. Hoskins and G. Wiener, Phys. Rev. **96**, 1153 (1954).

[2] For a survey of the situation see C. Kittel, J. phys. radium **12**, 291 (1951).

[3] C. Zener, Phys. Rev. **81**, 440 (1951); many consequences of the exchange interaction between s and d electrons have been discussed by S. Vonsovsky, J. Phys. U.S.S.R. **10**, 468 (1946), and subsequent publications.

[4] We have made estimates suggesting that screening by $3d$ electrons in Fe, Co, and Ni may reduce the sd interaction to only 1 to 5 percent of the free atom value. This assumes the $3d$ electrons are effective in screening, which may be only partially true.

[5] The spin-orbit mechanism considered by R. J. Elliott, Phys. Rev. **96**, 266 (1954), should be highly effective when s and d bands overlap, as in the transition elements.

[6] I. Solomon, Phys. Rev. **99**, 559 (1955).

[7] E. Abrahams, Phys. Rev. **98**, 387 (1955); see his Eq. (19).

Hyperfragment Production

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THE detailed solution of the problem of Λ^0 fragment formation in heavy nuclei probably requires a knowledge both of the properties of Λ^0 particles and of the mechanism of production of the fragments. We still lack this knowledge; however, it seems possible to justify some of the features of the phenomenon with the simple model that we shall describe.

When an energetic particle (nucleon, meson) hits a heavy nucleus (Ag or Br in emulsion), Λ^0 particles are produced with cross section σ_Λ. There is good evidence[1] that a sizable fraction f of the Λ^0's do not leave the nucleus immediately, but are slowed down by collisions with the nucleons in the nucleus to the Fermi energy of the nucleons. So, of the N neutrons in the nucleus, the fraction

$$p_\Lambda = \sigma_\Lambda f/\sigma_g N$$

is replaced by Λ^0 particles. The cross section for interaction with the nucleus is assumed equal to the geometrical cross section, σ_g.

TABLE I. Z spectrum of hyperfragments.

Z	3	4	5	6	7	8	9	10
$100n(Z)$	10	54	12	10	3	5	3	3
$\dfrac{(A-Z)n(Z)\times 27}{\Sigma(A-Z)n(Z)}$	2	11	4	3	1	2	2	2
Λ^0 fragment production[a] in emulsion	6	6	5	7	0	3	0	0

[a] Average of hyperfragments produced by pions, protons, and cosmic rays.[6]

We now assume that p_Λ is also the probability that a Λ^0 is substituted for one of the neutrons in a fragment coming out of the star. The justification for this assumption rests on the fact that the slowing down of the Λ^0 particle in the nucleus takes place together with the subdivision of the energy of the primary particle among the nucleons in the nucleus, so that the probability of Λ^0 capture by a fragment does not depend strongly on the energy of the fragment.

This point of view is valid only for fragments with charge $Z\geq 3$, which show a binding energy for Λ^0 approximately equal to that of neutrons; it is not valid for $Z=1$ and 2, which show instead binding energies substantially smaller.[2] If $n(Z)$ is the average number, per star, of fragments of large Z, hence containing $A-Z$ neutrons, the probability of formation of an excited fragment of charge Z is then

$$P(Z) = (A-Z)p_\Lambda n(Z) = \frac{\sigma_\Lambda f}{\sigma_g}\,\frac{(A-Z)n(Z)}{N}.$$

Jastrow[3] has calculated $\sigma_\Lambda f$, utilizing the elementary cross sections and the Monte Carlo method. For π-mesons of 1.5 and 2 Bev and protons of 3 Bev on Ag, he found $\sigma_\Lambda f \sim 15$ mb. For protons, this is obtained if one assumes a cross section per nucleon for Λ^0 production comparable to that of the pions, i.e., $\sim$1 mb.[4]

The fragment production of these stars, following Perkins,[5] is given by the second row of Table I.

With these values, and $\sigma_g = 1300$ mb, one obtains

$$\sum_{Z=3}^{10} P(Z) = \frac{\sigma_\Lambda f}{\sigma_g N}\sum_{3}^{10} (A-Z)n(Z) \sim 10^{-3}.$$

This compares favorably with the values, for all fragments with $Z\geq 3$, found by Fry[6] for both protons of 3

Bev and π-mesons of 1.5 and 3 Bev, i.e., $\sim 10^{-3}$, and is not inconsistent with the value found for cosmic rays,[7] i.e., $2\text{–}3\times10^{-4}$. This agreement lends support to our assumption of uniform distribution of the Λ^0's within the nucleus, connected with the evaporation model for the hyperfragments.

Rows 3 and 4 of Table I give the values of $(A-Z)\times n(Z)$,[8] normalized to 27, and the values of the frequencies of Λ^0 fragments in emulsion as observed by Fry[6] for 27 cases with $Z\geq 3$. Within the poor statistics, the two distributions are not in disagreement.

I am indebted to Professor G. Cocconi for helpful discussions.

Note added in proof.—A recent systematic study by Fry[9] of hyperfragment stars produced by cosmic rays, 6-Bev protons, and 3-Bev π^- mesons shows the same (or slightly smaller) production probabilities, and a similar Z spectrum.

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[3] R. Jastrow, Phys. Rev. **97**, 181 (1955); M. M. Block and R. Jastrow, Nuovo cimento **4**, 865 (1955).

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[9] W. F. Fry (private communication).

Inelastic Scattering of 42-Mev α's by Mg†

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EXPERIMENTAL work on the inelastic scattering of nucleons which leave the residual nucleus in an excited state[1] revealed a complexity in the angular distribution of the scattered particles which cannot be explained by the theory of the compound nucleus.[2] These results show, in general, angular distributions which are peaked in the forward direction. McManus and Sharp[3] and Austern, Butler, and McManus[4] proposed a direct interaction theory which describes the scattering by an interaction between an incident neutron and a nuclear proton taking place at the nuclear surface. The predicted distributions are a sum of different spherical Bessel functions according to the spin change between initial and final state.

Most experimental results are given for the excitation of the first excited state of even-even nuclei where the single-particle excitation is not likely to hold. More recently, Hayakawa and Yoshida[5] described the scattering process for even-even nuclei by the excitation of Bohr-Mottelson surface vibrations. A simple Born approximation calculation using this model shows that the angular distribution of scattered nucleons should be proportional to $j_2^2(QR)$ for a 0 to 2^+ transition, where j_2 is the spherical Bessel function of order 2, $Q=|k_{\text{in}}-k_{\text{out}}|$ is the momentum change of the scattered particle, and R is the nuclear radius. The same angular distribution would be expected from the work of Austern, Butler, and McManus. The main difference between the two treatments should be in the prediction of the value for the cross section if the excited state is formed by the scattering of α particles instead of nucleons. The large momentum transfer required to scatter an α by an angle of twenty or thirty degrees would eject the recoiling nucleon in the single-particle description from the nucleus. Consequently the cross section for the excitation of a low-lying state may be very small. In a collective description, the α interacts with the surface and there is a large probability that it will excite surface vibrations.

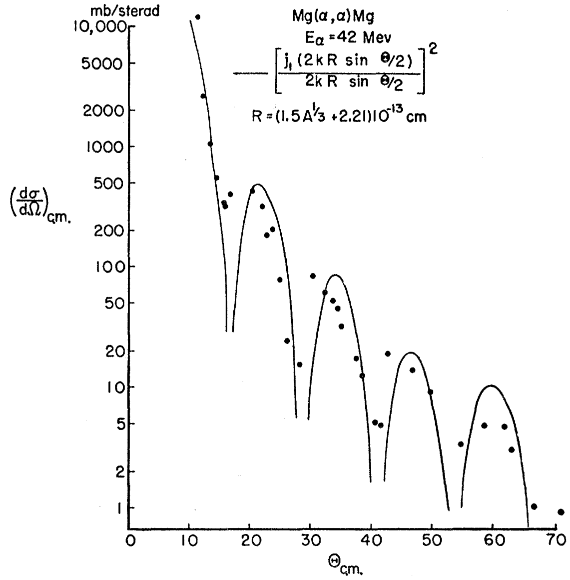

FIG. 1. Differential cross section for the elastic scattering of 42-Mev α particles by Mg.

The Born approximation calculation gives the differential cross section for the 0 to 2^+ transition:

$$\frac{d\sigma}{d\Omega}=\frac{5R^6V^2m_\alpha^2}{\hbar^4}\frac{k_{\text{out}}}{k_{\text{in}}}\left(\frac{Q_0}{3ZR^2}\right)^2[j_2(QR)]^2,$$

where Q_0 is the intrinsic quadrupole moment, R is the nuclear radius, and V is the interaction potential of the α with the surface.

In this experiment 42-Mev α particles were scattered by Mg^{24}, exciting the 2^+ level at 1.37 Mev. Mg^{24} seems to have collective properties even though it is a light nucleus.[6]

Figure 1 shows the observed angular distribution of