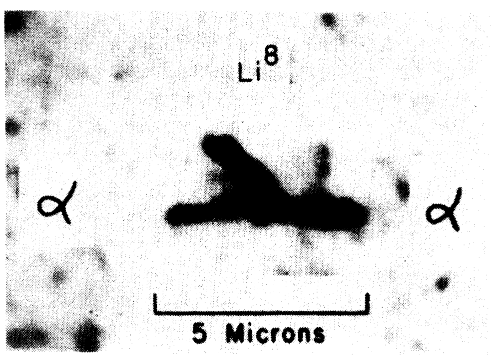

FIG. 1. Photo-micrograph of γ-ray induced "hammer" track in Ilford E1 emulsion.

In a search of 12 cm^2 of this plate 5 "hammer" tracks were found, of which one is shown in Fig. 1. The two equal and opposite tracks have the grain density characteristic of α-particles, while the third track is considerably denser. Such a configuration, which is well known in cosmic-ray work, is here attributed to the photo-disintegration of a constituent of the emulsion with the ejection of a Li^8 nucleus. After coming to rest, the Li^8 decays by β-emission to the broad C Mev excited level of Be^8, which then breaks up into two α-particles.

From mass considerations the emission of a Li^8 nucleus in any photo-nuclear reaction involving the light elements (carbon, nitrogen, oxygen, and sulfur) in the emulsion requires an energy of 29 Mev or greater, and such reactions are therefore ruled out by the fact that this exceeds the maximum γ-ray energy available. The simple photo-emission of Li^8 from any of the heavy elements (silver, bromine, and iodine) in the emulsion is, however, energentically possible, and Table I shows the threshold energies for such reactions as calculated from the semi-empirical mass formulas of Weizsaecker[2] and Feenberg.[3] Though the emission of neutrons or singly charged ions simultaneously with the Li^8 ion would not be seen, these reactions would require 8 Mev or more of additional energy, and hence are energetically impossible.

Certain considerations favor silver as the probable source of the Li^8 nuclei. The energies of the Li^8 ions in the 5 events were estimated from the general range-energy relationship for charged particles[1] and two range-energy values for Li^7 obtained by Farragi.[4] The energies obtained were 1.0, 2.8, 4.0, 4.9, and 5.7 Mev; thus, on an energy basis, only one of these events could be attributed to bromine (Table I). While all events are energetically possible if silver or iodine is involved, the occurrence of iodine in the emulsion is only 2.5 percent of that of silver, and therefore the cross section for the photo-disintegration of iodine would have to be more than one order of magnitude greater than that for the corresponding reaction in silver in order to have a comparable yield. Thus silver is regarded as the most probable origin of the Li^8 nuclei.

Assuming that silver isotopes are the parent nuclei, and that the range of γ-ray energies effective in causing this reaction is 22 to 26.7 Mev, the cross section for the reaction is of the order of 10^{-30} cm^2.

TABLE I. Calculated energy thresholds for (γ, Li^8) reactions.

Reaction	Threshold energy (Mev) Feenberg's formula	Weizsaecker's formula
$Br^{79}(\gamma, Li^8)Ge^{71}$	25.2	25.8
$Br^{81}(\gamma, Li^8)Ge^{73}$	25.0	25.0
$Ag^{107}(\gamma, Li^8)Ru^{99}$	22.3	22.0
$Ag^{109}(\gamma, Li^8)Ru^{101}$	21.4	21.5
$I^{127}(\gamma, Li^8)Sn^{119}$	19.1	19.0

We should like to thank Dr. R. N. H. Haslam and his coworkers at the University of Saskatchewan for making the betatron irradiations, Dr. B. W. Sargent for his interest and advice, and Mr. R. G. Hayman for his assistance in searching the plate.

[1] C. H. Millar and A. G. W. Cameron, Phys. Rev. **78**, 78 (1950).
[2] E. Feenberg, Rev. Mod. Phys. **19**, 239 (1947).
[3] As quoted by E. Fermi in *Nuclear Physics* (University of Chicago Press, Chicago, 1950) p. 7.
[4] H. Farragi, Comptes rendus **229**, 1223 (1949).

The Hydromagnetic Equations

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May 18, 1950

COSMIC fluids, being electrical conductors, can carry electric currents and their magnetic fields. These phenomena are of interest for solar, stellar and sunspot magnetism, geomagnetism, magnetic fields in stellar atmospheres and in interstellar space and the related problems of galactic radio noise and the origin of cosmic rays.

In this note as previously[1] we confine ourselves to "Maxwellian" electrodynamics where the relations between the vectors **D**, **E** and **B**, **H** have the familiar scalar and isotropic form; this excludes certain classes of phenomena in rarefied gases. The interaction between the velocity field **V** and the magnetic field **B** is described by the hydrodynamic equations together with the electromagnetic field equations, both containing proper coupling terms.[2] In the field equations the displacement current is omitted; the hydrodynamic equations are simplified by assuming incompressibility. We have,

$$d\mathbf{V}/dt+(\mathbf{V}\cdot\nabla)\mathbf{V}=-\nabla p/\rho-\lambda\mathbf{B}\times(\nabla\times\mathbf{B})+\nu\nabla^2\mathbf{V}$$
$$d\mathbf{B}/dt=\nabla\times(V\times\mathbf{B})+\nu_m\nabla^2\mathbf{B}$$

where ν is the conventional specific viscosity and

$$\lambda=(4\pi\mu\rho)^{-1},\quad \nu_m=(4\pi\mu\sigma)^{-1}.$$

(μ susceptibility, ρ density). The quantity ν_m is the "magnetic" viscosity.[1] We now transorm these equations as follows: (a) take their sum and difference, respectively; (b) introduce new variables defined by the equations

$$\mathbf{P}=\mathbf{V}+\lambda^{\frac{1}{2}}\mathbf{B},\quad \mathbf{Q}=\mathbf{V}-\lambda^{\frac{1}{2}}\mathbf{B},$$
$$\nu_1=\nu+\nu_m,\quad \nu_2=\nu-\nu_m,$$
$$q=p/\rho+(\mathbf{P}-\mathbf{Q})^2/8;$$

(c) by virtue of some straightforward transformations using known vectorial identities the new equations can be written

$$d\mathbf{P}/dt+(\mathbf{Q}\cdot\nabla)\mathbf{P}=-\nabla q+\nabla^2(\nu_1\mathbf{P}+\nu_2\mathbf{Q})$$
$$d\mathbf{Q}/dt+(\mathbf{P}\cdot\nabla)\mathbf{Q}=-\nabla q+\nabla^2(\nu_2\mathbf{P}+\nu_1\mathbf{Q}).$$

For vanishing field, **P** = **Q**, the two equations become identical and go over into the Stokes-Navier equations of hydrodynamics.

The remarkable symmetry of these equations and their analogy to the ordinary hydrodynamic equations is apparent. One might, in particular, expect that phenomena of turbulence will occur in hydromagnetic systems, similar to those in ordinary hydrodynamics and at mechanical or "magnetic"[1] Reynolds numbers of comparable magnitude. They will no doubt give rise to a "turbulent" magnetic field coupled with the mechanical motion.

The case of compressible fluids is of considerable physical interest. Truesdell[3] has recently shown that the conservation theorem of the magnetic flux can be extended to compressible fluids on replacing **B** by $\mathbf{B}/\rho$ throughout. In the above equations, however, there appears the combination $\mathbf{B}/\rho^{\frac{1}{2}}$, and this is necessary on dimensional grounds; we have thus been unable to ascertain whether similarly simple, symmetrized equations exist for the compressible case.

[1] W. M. Elsasser, Rev. Mod. Phys. **22**, 1 (1950).
[2] Reference 1, Eqs. (35) and (41).
[3] C. Truesdell, Phys. Rev. **78**, 823 (1950).