As expected, far more OH is produced by this exchange reaction. (The value for $H_2/H = 10^{-1}$ is an overestimate because of the neglect of $OH + H_2 \rightarrow H_2O + H$). Our results agree roughly with those of Carroll and Salpeter, based on estimated cooling curves. The decrease at the end of the curves in Fig. 1 is produced by reaction (4), the only operative in the cooler regions far behind the shock. Fig. 2 demonstrates that reactions (1) and (3) require at least mach 10 shocks to be effective. Lower shock speeds do not result in sufficient temperatures, while higher speeds do not significantly increase molecule production further. In every case, the production of hydrogen is very small. A magnetic field changes the cooling times somewhat, and thus the molecular production. The minimum value achieved, $OH/H = 2 \times 10^{-7}$ when $H_2/H = 0$, is affected only in that larger fields require larger mach numbers for reactions (1) and (2) to come into equilibrium. The minimum effective mach number ranges from 10 for $B = 0$ to 17 for $B = 10^{-5}$ gauss.

If, with Stecher and Williams[6], we set $H_2/H = 0$, the relevant OH/H from reaction (1) is 2×10^{-7} for shocks of mach 10 or more. This is about two orders of magnitude greater than production by chemical exchange reactions on grains (except near hot stars where radiation pressure accelerates the grains through the gas, increasing the OH production[4]). The postshock value of OH/H is reduced by reaction (4) and by photodissociation, for which the combined lifetime is τ. At time t after shock passage, the ratio has dropped by the factor $e^{-t/\tau}$. When averaged for many shock passages (for which the mean interval is T), the reduction factor is τ/T. T is 6×10^6 yr (ref. 9) and τ (photodissociation) from the f-values of ref. 7 and the standard interstellar radiation field is 6,000 yr (ref. 10). Because this is smaller than that for reaction (4), the latter may be neglected. The reduction factor is therefore 10^{-3}, giving a mean value $OH/H = 2 \times 10^{-10}$, about 100 times the amount caused by grains[4]. It is still, however, 200 times smaller than the observed value, so that reaction (1) behind shocks cannot be solely responsible for the observed OH.

If hydrogen is present, Fig. 2 indicates that the factor of 100 can be recovered only if $H_2/H > 1$ per cent. This is much too high for the mean value of this quantity according to ref. 6. The possibility arises, however, that, in the immediate vicinity of shock fronts, production of hydrogen on grains is so rapid that a considerable abundance of hydrogen builds up. Although Stecher and Williams[6] estimate that H_2/H attains only the value 4×10^{-5} behind shocks, this depends on the details of the postshock cooling. We hope to check this in future calculations.

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G. B. FIELD
P. A. AANNESTAD

Astronomy Department,
University of California,
Berkeley.

P. M. SOLOMON

Astronomy Department,
Columbia University,
New York.

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PLANETARY SCIENCE

Fractionation of Iron in the Solar System

BANERJEE[1] has argued against the influence of ferromagnetism on the aggregation of particulate matter in a theory of Harris and myself[2] on chemical fractionation within the solar system.

His objection is based on one of the more unsatisfactory parts of magnetic theory—the prediction of spin structure. I quote a reference[3] he used (page 367): "Some calculations on small multidomain particles have been made but it is fair to say that to date such particles are not understood" (see also ref. 4, chapter 8). Calculations of the likely magnetization of any system are usually hampered by at least the following uncertainties: (*a*) proper enumeration and comparison of all the possible spin configurations; and (*b*) the occurrence of metastable spin configurations.

Assuming that the exact shape of particles formed in the conditions envisaged in the solar nebula is known, the difficulty of satisfying (*a*) is especially great near the Curie point. The simplified enumeration achieved by assuming a domain structure breaks down because of the extremely small crystalline anisotropy constants in the vicinity of the macroscopic Curie point. For the very slowly cooling particles in the completely thermalized environment postulated in the fractionation theory, metastable spin configurations become a real possibility for any particles much larger than the superparamagnetic size limit.

Thus I am surprised at the faith Banerjee has in his method of multidomain calculation and in the significance of his numerical results for the theory[2]. If the validity of his method is accepted, a trivial adjustment to the theory would remove the numerical discrepancy. It would be wrong, however, to conceal the ignorance that surrounds the magnetization of small particles and therefore the effectiveness of ferromagnetism in enhancing collision rates of ferromagnetic particles. In the conditions envisaged, the ratio of collision cross-section to optical cross-section of ferromagnetic particles probably rises from unity as the size exceeds the superparamagnetic limit, could reach very large values and probably declines towards unity for particles greater than 10^{-4}–10^{-3} cm. This size range probably includes a significant fraction of the particle size distribution of the primary condensate[2].

Fortunately, it is not necessary to take refuge in such ignorance. It was pointed out[2] that without long range ferromagnetic attraction, the binary collision rate of iron particles, if they averaged 10^{-4} cm in size, was of the order 1 per year. It would therefore still be possible for large aggregates to be built up. It seems probable that short range ferromagnetic interactions would create a thermally stable bond between any colliding iron particles of greater than superparamagnetic size. With no mechanism of comparable bonding efficiency between non-ferromagnetic particles a size difference of iron and nonmetallic particle aggregates would occur. This is the essential step in the theory[2].

D. C. TOZER

School of Physics,
University of Newcastle upon Tyne.

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