

which we have experimental values of the exchange energy⁴. Since the exchange energy arises from the overlap of the band electrons with the unpaired atomic-like electrons we wish to estimate the exchange integral:

$$J\alpha \int \psi_A(r_1)\psi_B(r_2) \frac{e^2}{r_{12}} \psi_A(r_2)\psi_B(r_1) d\tau |^2 / E_F \quad (1)$$

where the subscript *A* denotes the unpaired atomic-like electron wave function and the subscript *B* the overlapping band electron wave function and E_F is the Fermi energy. For the normal ferromagnetic form of iron these are the unpaired 3*d* and the '3*d*-4*s*' band electrons respectively, while for our postulated high-pressure form of iron these are the 3*p* and the '3*d*-4*s*' band electrons respectively. Since the overlapping electrons at the bottom of the band in iron are extended quite far radially (Wood, J. W., unpublished results) we can assume ψ_B is constant throughout the atomic cell for both the normal and high-pressure phases. This term alone would lead to a ratio of ~ 6.5 for the values of *J* in the high-pressure and normal phases while the Fermi energy in the denominator (55 eV versus ~ 10 eV) reduces this to ~ 1.2 . This leaves the evaluation of the r_{12} term for the unpaired 3*p* and 3*d* electrons respectively, and this must surely be greater for the former since they are more compressed radially. It is estimated that their contribution to *J* would lead to a ratio approximately of the order of their one electron energies (-5.3 Rydbergs versus -1.3 Rydbergs) or about a factor of 4. This roughly gives an overall factor of 4 for the ratio of *J* in the high-pressure and normal phases or a value of 0.04 eV for the high-pressure phase. (If we apply equation 1 to the normal cases of ferromagnetic iron and gadolinium, where in the latter case ψ_A refers to the 4*f* electrons, one obtains a ratio of ~ 40 for the *J* values as compared with the observed value of ~ 50 .)

From statistical mechanics a close-packed structure with nearest neighbour exchange interactions⁴ ($S = 1$) has a value of $J/kT_c = 0.08$, leading to an estimated value of the Curie temperature of our high-pressure form:

$$T_c \approx J/0.08k = 5,500^\circ \text{K}$$

which is well above the inner-outer core interface temperature of $\sim 4,000^\circ \text{K}$.

If this crude order of magnitude estimate is correct there are several consequences of note:

(1) If the planets contain cores similar in composition to the Earth only those of mass approximately equal to or greater than the Earth would develop sufficient gravitational pressure to create the high-pressure magnetic phase. Thus we would expect no magnetic field on Mercury, Mars, Venus and the Moon, but would expect magnetic fields on Uranus, Neptune, Saturn and Jupiter.

(2) If the inner core were saturated (a single magnetic domain) the magnetic field at the Earth's surface would be about ~ 150 gauss. The observed value of ~ 1 gauss is thus typical of the residual magnetization of an unmagnetized piece of iron.

(3) Magnetostrictive effects (spin-orbit coupling) can cause variations in the magnitude and direction of the Earth's magnetic field depending on the variation of the distribution of pressure on the surface of the inner core. Because the anisotropy energy is small compared with the compressional energy only small changes in pressure are necessary to effect changes in magnetic domain orientation.

(4) Inasmuch as static pressures of $\sim 0.5 \times 10^{12}$ dynes/cm² have been reached in the laboratory⁵, it is probable that materials and techniques will improve sufficiently to reach this suggested critical pressure of $\sim 3.5 \times 10^{12}$ dynes/cm² for the onset of the high-pressure

magnetic phase of iron. Thus this hypothesis is probably capable of laboratory refutation.

R. J. WEISS*

Department of Mathematics,
Imperial College of Science and Technology, London.

* On leave of absence from the U.S. Army Materials Research Agency Watertown.

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GEOCHEMISTRY

Evidence of an Extraterrestrial Origin for Some Organic Constituents of Meteorites

THE presence of organic matter within samples of carbonaceous chondrites is now well established¹⁻⁵. However, it has been suggested from several sources that considerable terrestrial contamination of these meteorites may have occurred and that the organic matter is not indigenous. The experiments reported in this communication were conducted to determine whether the isotopic composition of the meteorite organic matter afforded any evidence regarding the origin of the compounds.

Samples of Orgueil, Murray, Mokoia and Haripura meteorites were extracted separately for 6 h in a Soxhlet apparatus with a 9 : 1 benzene-methanol mixture. The solvent was evaporated from the extract and the isotopic composition determined of the hydrogen, carbon and sulphur of residues from each meteorite by mass spectrograph. Results of these determinations are shown in Table 1.

Meteorite	Deuterium (%)	Carbon-13 (‰)	Sulphur-34 (‰)
Orgueil	+ 27.5	- 10.1	+ 3.14
Murray	+ 8.4	- 4.0	+ 2.86
Mokoia	+ 21.2	- 17.9	+ 1.09
Haripura	- 1.5	- 3.1	+ 2.51

Standards: Deuterium and carbon, Craig (ref. 6); sulphur, Thode *et al.* (ref. 7).

A comparison of these isotopic values with those for non-carbonaceous meteorites and for various terrestrial materials⁶ reveals that the organic matter from three of the carbonaceous chondrites shows a considerable deuterium enrichment, while the carbon shows a lack of carbon-13 similar to terrestrial biogenic material. The small enrichment of sulphur-34 is the opposite fractionation to that occurring in sulphur bacteria and terrestrial inorganic processes. It is apparent that the isotopic composition of meteorite organic matter is quite unlike that of any terrestrial substances.

The evidence presented here is indicative of an extraterrestrial origin for a major fraction of the organic constituents of carbonaceous chondrites.

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MICHAEL H. BRIGGS

Jet Propulsion Laboratory,
California Institute of Technology,
Pasadena, California, and Department of Geology,
Victoria University of Wellington, New Zealand.

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