The second purpose is linked with absolute measurements. An arbitrary mc dose does not permit us to use with confidence the factors necessary for calculating energy absorption in tissue (rep). Discrepancies in primary absolute measurements are considerable. We may have to wait until these discrepancies are resolved, and until the disintegration scheme of I-131 is thoroughly established. However, there is another solution. We could take, for instance, the New York mc and measure the energy emitted for such a unit of I-131. If such measurements were available (I believe that they are being made at present), we could calculate dosage in roentgen equivalents, and the mc with its inherent uncertainty would cancel out.

In this connection, I would like to recall to you Failla's suggestion for a unit of radioactive isotopes, which he calls "ruth," for Rutherford: one ruth is the amount of any radioactive isotope that emits ionizing radiation at the rate of one erg per sec. Since I believe that the ionization chamber will replace the G-M tube as a standardization instrument, it seems to me that the disintegration rate unit will lose its usefulness. It is not very practical to use a unit which implies disintegration rate measurements if the actual standardization practice measures the amount of ionization and does not count the number of ionizing events. But this is not the opportunity to recapitulate Failla's arguments, with which I personally agree. The main advantage of the ruth, I think, is that a unit based on energy emission furnishes more directly the information which we, as consumers of atomic energy, ultimately require.

I have attempted to present the material necessary for the evaluation of standardization procedures and for the accomplishment of reproducible comparison measurements. Our main effort in standardization work should be directed toward a uniform standardization, although this may be for the time being on the basis of a standard which is to some extent arbitrary. All of us can contribute to this limited objective.

The question of absolute standardization is the domain of a smaller group. The majority of us will have to wait for their results. But I hope that I may speak for this majority if I define what kind of result we need from absolute measurements: it is a result that will permit us to compute energy absorption of ionizing radiations of radioactive iodine in tissue.

Based on a paper presented at the Symposium on Radioactive Iodine held at Brookhaven National Laboratory, Upton, New York in July 1948.

Interstellar Polarization, Galactic Magnetic Fields, and Ferromagnetism

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OBSERVATIONS by W. A. Hiltner (*5, 6*) and J. S. Hall (*4*) indicate that starlight becomes plane polarized in its passage through interstellar space. The effect increases with increasing distance, and according to Hall's data amounts to about 5 percent ($=e^{0.05}$) difference in intensity between the two plane-polarized components for a star whose color excess is 0.50 magnitude. Since the color excess is known to be about one-ninth the total absorption (which thus amounts to $(2.512)^{-4.5} = e^{-4.1}$ for such a star), the absorption must vary by somewhat more than one percent with the plane of polarization.

Such polarizing absorption would exist if needle-shaped particles, of dimensions comparable with a wavelength of visible light, were present in interstellar space, and were oriented by some force. The ratio of the scattering cross sections of such needles for the two planes of polarization would be appreciable; according to the theory by R. Gans (*3*), for a small prolate spheroid with a length twice its diameter, this ratio is 2.74 if the refractive index in the spheroid equals 2.5. Thus a relatively small number of needles could produce the observed effect.

Two difficulties seem to stand in the way of this explanation: the origin of the needles and their orientation. If we accept as a working hypothesis: (1) the existence of small ferromagnetic particles, which, existing as individual domains, are intensely magnetic; and (2) the existence of magnetic fields in interstellar space with systematic components as great as 10^{-5} gauss; then these difficulties disappear. The first of these suppositions appears reasonable from an exten-

[1] The authors are indebted to Drs. John Turkevitch, John Wheeler, and Eugene P. Wigner for generous and helpful comments.

sion of the theory of J. Oort and H. C. van de Hulst (*8*) on the origin and growth of interstellar grains, while the fields proposed are of the order of those recently postulated by E. Fermi (*2*) in his theory of the origin of cosmic rays.

According to Oort and van de Hulst, the interstellar grains grow by the accretion of atoms and evaporate on mutual impact when two clouds collide. Differences between the different molecules within a grain are not considered in the original form of this theory, but in most collisions the more volatile components must evaporate preferentially, thus concentrating the heavier atoms.

The relative numbers of different atoms other than H inside the grain may be taken as: O—100, C—40, N—40, Fe—10, Si—8, Mg—6, S—6, and others—$\frac{1}{2}$ or less. Most of these elements will be chemically bound with H, which is overwhelmingly the most abundant element in interstellar space, or with O. Thus when the grain is heated, most of these elements will go off as volatile hydrogen or oxygen compounds, leaving primarily Fe and Mg atoms and oxides, and some SiO_2, some Si going off as SiH_4. It is uncertain whether Fe and Mg will be left in the metallic phase, since they may be expected to form oxides by interaction with O or with H_2O before these are lost by evaporation. FeO seems less likely than Fe_3O_4 or Fe_2O_3, in view of the high relative abundance of O. Fe_3O_4 is a well-known ferromagnetic substance, and Fe_2O_3, when precipitated from a water solution, tends to form cubic crystals which are ferromagnetic.[2] Magnesium iron spinel, $MgFe_2O_4$, is also known to be ferromagnetic (*9*). Thus, the production of ferromagnetic grains by this process seems likely.

Theory and observation (*1, 7*) both indicate that small ferromagnetic particles, of radius about 10^{-6} cm or less, form single domains, uniformly magnetized. For somewhat larger particles the information is less definite, but it would appear that ferromagnetic particles of radius 2×10^{-5} cm are likely also to constitute single domains.[3] Furthermore, it is likely that an appreciable number of such particles would stick together on impact and form elongated particles, since the mutual energy involved vastly exceeds the thermal energy. For nearly spherical grains the parallel, end-to-end orientation provides much the larger interaction energy, and is therefore more probable.

Next we consider the orientation of such grains. The energy of orientation of a grain in a magnetic field of strength H is about HIV, where the volume V may be taken as 2×10^{-14} cm^3 for a cylinder 1.5×10^{-5} cm in radius and 3×10^{-5} cm in length. The intensity of magnetization I is about 10^3 gauss in a ferromagnetic domain. With H equal to 10^{-5} gauss, this orientation energy is 2×10^{-16} ergs, as compared with a value of about 10^{-15} ergs for kT at 10° absolute, a not unreasonable value inside a dense obscuring cloud. While Fermi's assumed magnetic fields would have different values in different clouds, the average number of clouds in the line of sight to a star 500 parsecs away is only 3 to 4, and the average net $|H|$ perpendicular to the line of sight should be about $\frac{1}{3}$ the rms H.

It is evident that production and partial orientation of ferromagnetic grains in interstellar space is at least consistent with present astrophysical theory. Since the indices of refraction for pure Fe_2O_3, MgO, and $MgFe_2O_4$ are about 3, 1.7, and 2.3, respectively, such particles would scatter light more effectively than the conventional ice particles discussed by Oort and van de Hulst. Thus the ratio of the number of oriented ferromagnetic needles to the number of unoriented grains of comparable size need be only a small fraction of a percent to explain the polarization observations. Obviously, further observations are needed, and much theoretical work remains to be done, both on the chemistry of the fusion process, and on the subsequent magnetic and optical properties of the resultant grains, before the suggestions presented here can be regarded as more than a working hypothesis. If additional research confirms the present picture, it may become possible to obtain direct experimental evidence on the magnitudes and directions of magnetic fields in interstellar space.

[2] We are indebted to Dr. L. W. McKeehan for this information.

[3] We are indebted to Dr. C. Kittel for this information.

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