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Solar Gases in the Earth by Solar Wind Irradiation?

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The pattern of noble gas elemental abundances in many undifferentiated meteorites is similar to that in the Earth's atmosphere, and the atmospheric inventory (per unit mass of planet) of noble gases is within the meteoritic range. These observations led to the concept of "planetary" noble gases as describing both the Earth and meteorites (1). No quantitative explanation for the origin of planetary noble gases in meteorites has gained wide acceptance, but for much of the history of modern cosmochemistry it could at least be supposed that the atmosphere formed by degassing of accreted solids which acquired their noble gases the same way that meteorites did. The concept of a common origin of terrestrial and meteoritic noble gases is challenged by the conclusion that most of the light trapped noble gases (He and Ne) in undifferentiated meteorites are actually exotic components imported in presolar solids (2) rather than a domestic component acquired during early solar system history, and by the inference that the Earth's mantle contains "solar" Ne (3) rather than "planetary" Ne, as distinguished on the basis of their different $^{20}Ne/^{22}Ne$ ratios. Acquisition of the Earth's noble gases then becomes a separate problem from the origin of meteoritic planetary gases. One possible way to account for solar noble gases in the Earth, one which seems favored in recent models (e.g. (4,5)), is acquisition of a "primary" atmosphere by gravitational capture of ambient gas from the solar nebula (6). This interpretation has to be part of some more general model of volatile inventory and evolution, since the Earth does not now have a primary atmosphere. Without attempting to discredit such models, we wish here to urge consideration of an alternative hypothesis which seems not to have received as much attention as it deserves: that the Earth acquired solar noble gases, particularly Ne, by solar wind irradiation of solids as smaller bodies before they accreted to form the Earth. We explore parameter space to assess the feasibility that the Earth's inventory of solar Ne can have been acquired through exposure to solar wind. As one benchmark, consider that solar Ne could have been acquired by exposure of uniform-size pre-accretionary spheres to present solar wind flux for 1 Ma if the radius of the spheres were of order 3 km, perhaps surprisingly large compared to intuitive expectation. For a more realistic power-law distribution of pre-accretionary planetesimal sizes, the requisite Ne could be acquired for effective geometric mean radius in the range ten to a hundred km. The postulated planetesimal mass distributions would not be self-shielding against solar wind irradiation. Planetesimal sizes could be larger, or the required exposure time smaller, if solar wind intensity was greater than at present, as seems likely. One clear difference between the irradiation and capture models is that in order to capture nebular gas gravitationally the Earth must grow to a substantial fraction of its present mass before nebular gas is dispersed, whereas in order to acquire gas by solar wind irradiation a substantial fraction of the present mass must remain as small dispersed planetesimals until after nebular gas is dispersed. A priori prediction of whether solar wind irradiation or gravitational capture is more likely to have been the dominant source of solar-type noble gases in the Earth requires a more detailed and robust understanding of both the distribution and evolution of pre-accretionary planetesimal sizes, and of the fate of nebular gas, than we can now command. We conclude that neither scenario can be excluded on the basis of current models.

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