CO self-shielding and oxygen isotopes in the solar nebula

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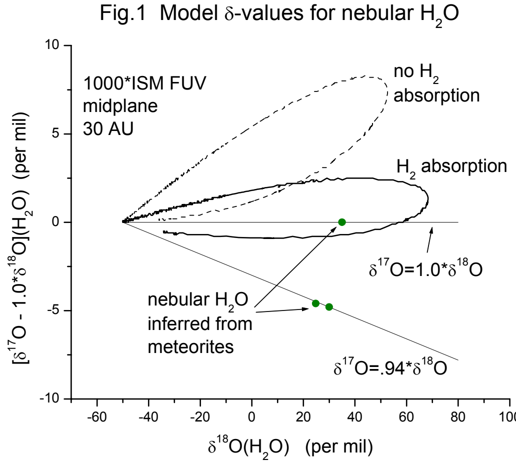
The recent suggestion[1] by Clayton that CO photodissociation is the source of the oxygen isotope anomaly measured in meteorites[2] offers an opportunity to relate a long-standing and fundamental problem in meteoritics to the far-ultraviolet (FUV) environment in which the solar nebula formed. Presently, three locations for CO photodissociation are being considered in models: the X-point region of the solar nebula[1], the surface of the nebula[3], and the parent cloud from which the nebula was formed[4]. The surface disk and parent cloud models require a greatly enhanced FUV radiation field, ~ 1000 times the local interstellar medium (ISM) field, consistent with solar system formation in a star-forming region.

A key test of CO photodissociation as the source of anomalous oxygen isotopes in CAIs is that nebular H_2O (produced from product oxygen atoms) has the $\delta^{17}O/\delta^{18}O$ value measured in CAIs. Figure 1 demonstrates that CO photodissociation in the presence of abundant H_2 produces nebular H_2O with $\delta^{17}O/\delta^{18}O \sim 1.0$ (solid curve), similar to measured values, whereas photodissociation of pure CO produces a ratio ~ 1.1 (dotted curve). This suggests that CO self-shielding in an H_2-rich environment is in fact a viable mechanism for explaining oxygen isotopes in CAIs.

Fig.1 Model δ-values for nebular H_2O



References

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Early solar system timescales

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From our present perspective, in many respects it is useful to think of the formation of the solar system as an *event*, a singular occurrence that happened a long time ago. The current best estimate for the absolute age of that event is usually taken to be 4.567 Ga [1], but in fact the absolute age of the formation of the solar system has been known for more than a generation with sufficient precision and robustness to satisfy any legtimate curiosity.

There is greater interest in viewing the formation of the solar system as a *process*, a series of events linked by cause and effect, extending over some finite time. The events of interest are chiefly dynamical, but dynamical theory is not yet able to predict a robust complete history. Appeal must therefore be made to an empirical history based on geochemical events caused by the dynamic processes, datable by geochronological techniques based on radioactive decay.

For quite some time, the class of refractory-element-rich objects called CAIs has been esteemed the first solid material to have formed in the solar system (e.g. [2]), on the basis of chemical characteristics, stable isotope anomalies that suggest primitiveness, the initial presence of some short-lived (now extinct) radionuclides, and of course on the absence of greater known ages than for any other objects. Typically, the "age of the solar system" means the isotopic closure age of CAIs.

There are two other kinds of geochemical events often thought to date solar nebula processes – the formation of chondrules, and the chemical differentiation by which planetary materials were extracted from a source of cosmic composition. Chondrules (like CAIs) were once thought to have formed in the very earliest stages of nebular history, but are now thought to have formed later and over an exended timescale, a few Ma after CAIs. The chemical compositions of the differentiated meteorite parent bodies are also thought to have been formed a few to several Ma after CAIs.

Recent results [3] for the ^{182}Hf-^{182}W system are reported to indicate chemical events a few Ma *before* formation of CAIs. If this conclusion is substantiated, much of the current picture of what happened in the early solar system will have to be rethought.

References

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