The formation environment of the solar nebula as inferred from oxygen isotopes in meteorites

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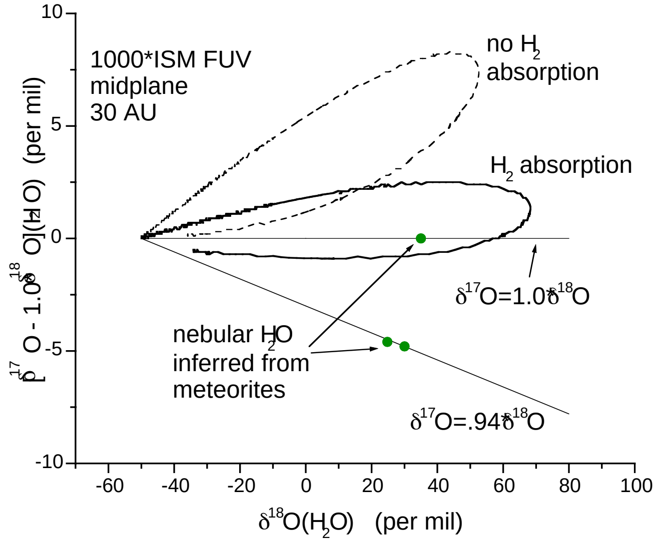
The recent suggestion[1] by Clayton that CO photodissociation is the source of the oxygen isotope anomaly measured in meteorites[2] offers an opportunity to relate a long-standing and fundamental problem in meteoritics to the far-ultraviolet (FUV) environment in which the solar nebula formed. Presently, 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 model[3], the most quantitatively developed of the models, requires an FUV radiation field ~ 1000 times the local interstellar medium (ISM) field *and* vigorous vertical mixing in the disk (viscosity parameter $\alpha \sim .01$). The parent cloud model[4], which does not quantitatively consider ^{17}O, also requires a strongly enhanced FUV field, but presumably places weaker constraints on disk mixing. The X-region scenario[1] benefits from the very high FUV flux near the proto-Sun, but may be problematic due to the high gas temperatures (>1000 K) expected near the X-point[5]. Thus, the two most likely locations for CO photodissociation imply a highly elevated FUV flux, consistent with solar system formation in a star-forming region.

A key test of CO photodissociation as the source of anomalous oxygen isotopes in meteorites is that nebular H_2O (produced from product oxygen atoms) has the ratio of delta-values, $\delta^{17}O/\delta^{18}O$, measured in meteorites. Figure 1 demonstrates that CO photodissociation in the presence of abundant H_2 (i.e., in the solar nebula and/or parent cloud) produces nebular H_2O with $\delta^{17}O/\delta^{18}O \sim 1.0$ (solid curve)[3], similar to measured values, whereas photodissociation of pure CO produces a ratio ~ 1.1 (dotted curve). This provides strong confirmation of the viability of the CO photodissociation mechanism.

Fig.1 Model δ-values for nebular H_2O



References

1. R. N. Clayton, *Nature* 415, 860 (2002).
2. R. N. Clayton et al., *Science* 182, 485 (1973)
3. J. R. Lyons and E. D. Young (submitted).
4. H. Yurimoto and K. Kuramoto, *Science* 305, 1763 (2004).
5. J. R. Lyons and E. D. Young, *LPSC XXXIV* (2003).