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Introduction: The remarkable O MIF signatures seen in acid-insoluble organic matter (IOM) from a CR2 meteorite [1] show some correlation with enhanced $\delta^{13}C$ values, suggesting that both enrichments may be a result of CO photochemistry. $^2H$ and $^{15}N$ enrichments in the same IOM do not correlate with $^{17}O$ and $^{18}O$ and/or $^{13}C$ enrichments, but do show some correlation with each other [1]. Both N and H isotopes have been shown to be strongly fractionated by ion-molecule reactions in molecular clouds [2, 3]. Here, the question I address is whether these results, particularly those for meteorite IOM [1], are consistent with expected photochemical and ion-molecule processes.

Discussion: It is well established that in model calculations CO self-shielding produces large enrichment in product $^{17}O$ and $^{18}O$, which are then stored in H$_2$O. Product C is similarly enriched in $^{13}C$, although by a factor of ~2 less than the enrichment in $^{17}O$ and $^{18}O$ [4]. Self-shielding enrichment of $^{13}C$ is predicted by photochemical models of disks [5], but CO exchange with C$^-$ and CO condensation [6, 7], are also important. Disk model calculations, including $^{13}C$ at temperatures well above CO condensation (> 20 K), are in progress using the oxygen isotope code of [8]. Shielding functions from [4] are used for C$^{13}O$.

As with CO, N$_2$ also undergoes self-shielding, producing enriched N and N($^2D$), with the N stored in HCN. The N($^2D$) rapidly forms NH, leading to reformation of N$_2$ by reaction of N and NH, and thus erasing much of the photo-induced fractionation. Large initial $^{15}N$ enrichments are possible by N$_2$ self-shielding, but the total amount of enriched material produced is small [9]. The relatively small $^{15}N$ enrichment in HCN, and the large error bars on $^{15}N$ of Jupiter (Fig. 1), means that N$_2$ self-shielding cannot be used to rule out CO self-shielding in the outer solar system, based on comparing the Sun and Jupiter.

Preliminary $\Delta^{17}O$ values (not shown) for grain-bound CO$_2$, H$_2$CO and CH$_3$OH have also been computed. CO$_{2gr}$ and CH$_3$OH$_{gr}$ have $\Delta^{17}O > 0$ due to reactions with OH, but H$_2$CO$_{gr}$ has $\Delta^{17}O < 0$ due to formation from CO gas. (Note that formation of CH$_3$OH from H$_2$CO on grains is not yet included in these calculations.) These results argue that exchange of IOM oxygen with nebula water is necessary to explain the high $\Delta^{17}O$ values measured in [1] for IOM from a CR2 meteorite. Or, alternatively, the oxygen in meteorite IOM derived from reactions of O atoms with hydrocarbon ions, which would yield O-containing organics with $\Delta^{13}O > 0$.

H$_2$ also has a line-type absorption spectrum, and so also undergoes self-shielding at the edges of clouds and high surface of disks. At greater depths into these objects, where CO and N$_2$ self-shielding become important, H$_2$ lines are highly broadened and will partially shield HD lines, thus reducing D enrichment. But not all HD lines will be shielded, suggesting that HD photodissociation could be a significant source of H isotope fractionation. Thus, the IOM results of [1] are consistent with a photochemical origin for O and (possibly) C isotopes signatures in IOM, and ion-molecule origin for N isotopes signatures.

Fig. 1 Results of solar nebula modeling at 30 AU and for $G_0 \sim 1000$. Enrichment in $\delta^{15}N_{air}$ in HCN$_{gr}$ (HCN on grains) due to N$_2$ self-shielding at the FUV surface of the nebula. Values for the Sun, TiN in CAIs, and Jupiter are shown also. The relatively small enrichment in $\delta^{15}N_{air}$ for HCN$_{tot}$ and the large error bars for Jupiter, do not allow comparisons between Jupiter and the Sun to be used to rule out CO self-shielding in the outer solar system.