Branching ratios in VUV induced dissociation of CO and N_2: Implications for isotopic compositions of the Sun

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NASA's Genesis mission reveals that the rare isotope ^{15}N is ~7 times more enriched than the rare isotopes ^{17}O and ^{18}O in the terrestrial planets relative to the Sun. Here we explain this peculiar observation under the framework of CO and N_2 vacuum ultraviolet (VUV) photodissociation and self-shielding. We first document the direct observation of $C(^3P)$ + $O(^1D)$ from CO predissociation. This observation shows that the dissociation channel $C(^3P)$ + $O(^1D)$ that violates the electron spin conservation rule can be induced through spin-orbit coupling with triplet valence states that connect to potential curves correlating to this photoproduct channel. We have then determined the branching ratios for all product channels induced by VUV photodissociation of CO and N_2 over the entire VUV photon energy ranges relevant to isotopic self-shielding. We demonstrate that the atoms in excited $O(^1D)$ and $N(^2D)$ states induced by VUV are significantly more reactive than those in the ground $O(^3P)$ and $N(^4S)$ states. Branching ratios between these states were determined to quantitatively evaluate the efficiency of locking in isotopic effects from self-shielding. Weighted by absorption cross sections, mutual shielding by H_2, and considering the CO/N_2 ratio and the partition of O and N among gas, ice, and dust phases in the solar nebula, we find that the ultimate trapping of $N(^2D)$ via hydrogenation is favored over that of $O(^1D)$ by a factor of >5.1 from self-shielding. This is consistent with the Genesis results and supports the self-shielding model as the primary mechanism for generating isotopic anomalies of O and N in the early solar nebula.