Isotopic Anomalies in Primitive Solar System Matter: Spin-state dependent fractionation of Nitrogen and Deuterium in interstellar clouds

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Organic material found in meteorites and interplanetary dust particles is enriched in D and ^{15}N. This is consistent with the idea that the functional groups carrying these isotopic anomalies, nitriles and amines, were formed by ion-molecule chemistry in the protosolar core [1]. Theoretical models of interstellar fractionation at low temperatures predict large enrichments in both D and ^{15}N and can account for the largest isotopic enrichments measured in carbonaceous meteorites. However, more recent measurements have shown that, in some primitive samples, a large ^{15}N enrichment does not correlate with one in D, and that some D-enriched primitive material displays little, if any, ^{15}N enrichment. By considering the spin-state dependence in ion-molecule reactions involving the ortho and para forms of H_2, we show that ammonia and related molecules can exhibit such a wide range of fractionation for both ^{15}N and D in dense cloud cores. We also show that while the nitriles, HCN and HNC, contain the greatest ^{15}N enrichment, this is not expected to correlate with extreme D enrichment. These calculations therefore support the view that Solar System ^{15}N and D isotopic anomalies have an interstellar heritage. We also compare our results to existing astronomical observations and briefly discuss future tests of this model.

[1] Mumma, M.J. & Charnley, S. B. 2011, ARA&A, 49, 471524