Interstellar Chemistry in the Astrobiological Context

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The past 40 years of molecular-line astronomy has demonstrated that interstellar space has a varied and rich chemical content, with an ever increasing amount of molecular material being discovered. Molecules are present in material associated with star and solar system formation, including the generation of proto-planetary disks and reservoirs of planetesimals. Molecules are also trace the pathways of dying stars, following stellar evolution through the giant branches and into the planetary nebulae (PNe) phase. Understanding the relationship of molecular material in the various stages of the ISM - from circumstellar ejecta of dying stars to nascent solar systems - and how these phases may set the stage for prebiotic chemistry on planet surfaces, is crucial in evaluating the origin of life. Using the millimeter/sub-mm telescopes of the Arizona Radio Observatory, observations of molecules with biogenic elements such as carbon, phosphorus, oxygen, and nitrogen have been carried out, along with supporting laboratory spectroscopic measurements. Through molecular-line surveys, we have probed the chemistry of circumstellar envelopes of evolved stars. Some of these envelopes are quite carbon-rich in molecular content, but others are not. Is this carbon-enrichment somehow preserved? It is uncertain what becomes of this organic material as the star evolves into a hot, UV-emitting white dwarf in the PNe stage. Detailed observations of C-containing molecules in a large sample of planetary nebulae are therefore being conducted. Our measurements thus far have shown that both H2CO, HCN, CCH, and HCO+ have widespread distributions and significant abundances in the Helix Nebula, one of the oldest known PNe. HCN and HCO+ have also been newly-detected towards various PNe in the age range 800 – 11,000 years, including Hb5, K3-17, K3-58, M1-7, M4-14, M3-28,

M3-55, M2-9, NGC 2440, M2-48, and K4-47. The abundances of both species appear to remain relatively constant with nebular age over a 10,000 year time span, and probably survive in dense clumps under pressure equilibrium. These data suggest that PNe ejecta contain significant amounts of C-bearing molecules that are subsequently transport into the diffuse ISM, seeding the organic chemistry of dense clouds. The extent of the chemical complexity in dense clouds is uncertain. Organic species such as acetamide and methyl amine are present in such objects, but organophosphorus compounds have yet to be detected. Based on our recent studies of carbon and nitrogen isotope ratios, circumstellar molecular material appears to become incorporated into meteorites. It is therefore likely that interstellar chemistry had a major influence on prebiotic chemistry on planet surfaces.