Metallofullerene and Fullerene Formation from Condensing Carbon Gas under Conditions of Stellar Outflows and Implication to Stardust

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Results and Discussion

Carbonaceous presolar grains of supernovae origin have long been isolated and are determined to be the carrier of anomalous ^{22}Ne in ancient meteorites. That exotic ^{22}Ne is the decay product of relatively short-lived ^{22}Na formed by explosive nucleosynthesis, and therefore, a selective and rapid Na physical trapping mechanism must take place during carbon condensation in supernova ejecta. Elucidation of the processes that trap Na and produce large carbon molecules should yield insight into carbon stardust enrichment and formation. Here, we demonstrate that Na effectively nucleates formation of Na@C_{60} (see Figure 1) and other metallofullerenes during carbon condensation under highly energetic conditions in oxygen- and hydrogen-rich environments. The fundamental carbon chemistry leading to trapping of Na is revealed, and should be directly applicable to gas-phase chemistry involving stellar environments, such as supernova ejecta. The results indicate that, in addition to empty fullerenes, metallofullerenes should be constituents of stellar/circumstellar and interstellar space. In addition, gas-phase reactions of fullerenes with polycyclic aromatic hydrocarbons (PAHs) are investigated to probe "build up" and formation of carbon stardust, and provide insight into fullerene astrochemistry.

We find that metallofullerenes form as readily as empty cages and thus, like fullerenes, should be important constituents of (circum)stellar/interstellar space. Element trapping by metallofullerene formation is shown to be selective and rapid, which can explain long-standing astrophysical puzzles such as the anomalous element enrichment of stardust. Infrared spectroscopic signatures of metallofullerenres are simulated to provide a distinct observational test for metallofullerenes in space.

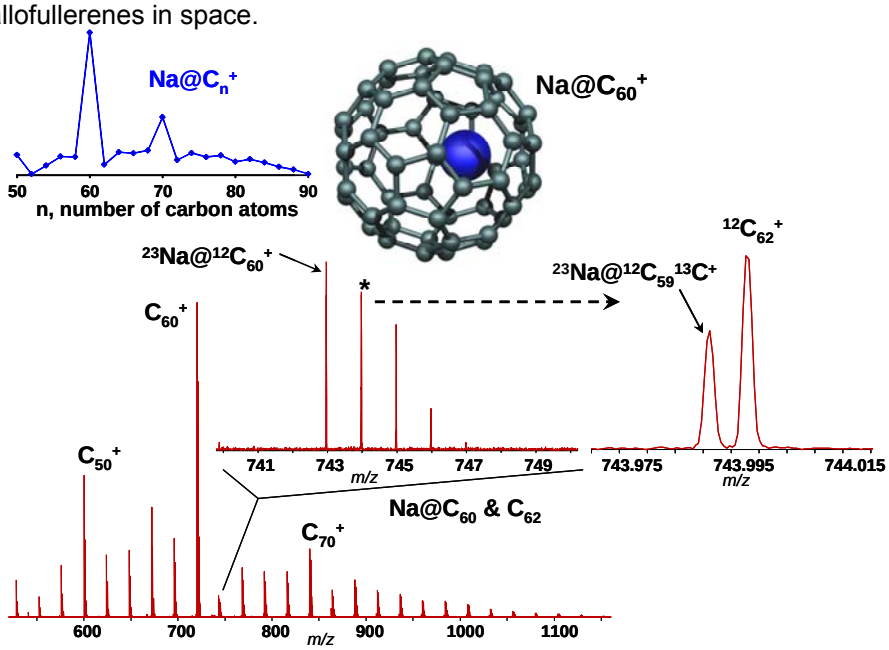

Figure 1. FT-ICR mass spectrum of cluster cations that spontaneously form in condensing carbon vapor seeded with Na (10 psi He gas flow, ~35 mJ·cm^{-2} fluence). The insets show Na@C_{60} clearly resolved from empty C_{62} and the relative abundance of Na@C_{2n} species.

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References

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