The puzzle of HCN in comets: Is it both a product and a primary species?

M. Mumma[1], B. Bonev[1,2], S. Charnley[1], M. Cordiner[1,2], M. DiSanti[1], E. Gibb[3], K. Magee-Sauer[4], L. Paganini[1,2], and G. Villanueva[1,2]

[1]Goddard Center for Astrobiology, NASA-GSFC, Greenbelt, MD, USA.
[2]Department of Physics, Catholic University of America, Washington, DC, USA.
[3]Department of Physics & Astronomy, University of Missouri, St. Louis, MI, USA.
[4]Department of Physics & Astronomy, Rowan University, Glassboro, NJ USA.

Hydrogen cyanide has long been regarded as a primary volatile in comets, stemming from its presence in dense molecular-cloud cores and its supposed storage in the cometary nucleus. Here, we examine the observational evidence for and against that hypothesis, and argue that HCN may also result from near-nucleus chemical reactions in the coma. The distinction (product vs. primary species) is important for multiple reasons:

1. HCN is often used as a proxy for water when the dominant species (H_2O) is not available for simultaneous measurement, as at radio wavelengths. If much HCN is sometimes produced in the coma, its adoption as a water proxy could introduce unwanted bias to taxonomies based on composition.

2. HCN is one of the few volatile carriers of nitrogen accessible to remote sensing, with NH_3 being the dominant nitrile. If HCN is mainly a product species, its precursor becomes the more important metric for compiling a taxonomic classification based on nitrogen chemistry.

3. The stereoisomer HNC is regarded as a product species, thought to result from coma chemistry involving HCN. But, could another reaction of a primary precursor (X-CN) with a hydrocarbon co-produce both HNC and HCN?

4. The production rate for CN greatly exceeds the possible production from HCN in some comets, demonstrating the presence of another (more important) precursor of CN radicals in them.

5. The production rates of HCN measured through rotational (radio) and vibrational (infrared) spectroscopy agree in some comets, but in others the infrared rate exceeds the radio rate substantially. Is prompt emission from vibrationally excited HCN responsible?

6. With its strong dipole moment and H-bonding character, HCN should be linked more strongly in the nuclear ice to other molecules with similar properties (H_2O, CH_3OH), but instead its spatial release in some comets seems strongly coupled to volatiles that lack a dipole moment and thus do not form H-bonds (methane, ethane).

We will present the evidence for and against these points, and suggest ways to test the primary and product origins of cometary HCN.

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