Commentary

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Similarities between Interstellar and Cometary Ices and Comparisons of Gas Phase Compounds in Astrochemistry

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Description

Astrochemistry is the study of the Universe's abundance of molecules, their reactions, and their interaction with radiation. Astrochemistry is a combination of astronomy and chemistry. The Solar System and the interstellar medium both fall under the category of Astrochemistry. Cosmo chemistry also studies the abundance of elements and isotope ratios in Solar System objects like meteorites, while molecular astrophysics studies interstellar atoms and molecules and how they interact with radiation. Because solar systems are formed from these clouds, the formation, atomic and chemical composition, evolution, and fate of molecular gas clouds are of particular interest.

Absorption and Emission of Light from Molecules and Atoms

Using telescopes to measure the absorption and emission of light from molecules and atoms in various environments, spectroscopy is one particularly significant experimental tool in Astrochemistry. Astrochemists are able to infer the elemental abundances, chemical composition, and temperatures of stars and interstellar clouds by comparing laboratory measurements with astronomical observations. Ions, atoms, and molecules all have distinct spectra, making this possible: that is, the ingestion and emanation of specific frequencies (shades) of light, frequently not apparent to the natural eye. These measurements, however, are constrained by a variety of radiation types (radio, infrared, visible, ultraviolet and so on) able to only detect particular species, depending on the molecules' chemical properties. The first organic molecule that was found in the interstellar medium was formaldehyde from interstellar sources. Radio astronomy, which has resulted in the detection of over a hundred interstellar species, including radicals and ions, as well as organic (*i.e.,* carbon-based) compounds like alcohols, acids, aldehydes and ketones, is perhaps the most effective method for the detection of individual chemical species. CO (carbon monoxide) is one of the most common molecules in interstellar space and one of the easiest to detect with radio waves due to its strong electric dipole moment. In fact, CO is used to map out molecular regions because it is a common interstellar molecule. The radio discovery of interstellar glycine, the simplest amino acid, has sparked a lot of debate. One of the reasons this discovery was controversial was that radio and other techniques like rotational spectroscopy are good for identifying simple species with large dipole moments, but they are less sensitive to more complex molecules, even ones that are relatively small. Furthermore, these techniques are completely insensitive to molecules devoid of dipoles. H_2 (hydrogen gas), for instance, is the most common molecule in the universe. However, because it lacks a dipole moment, radio telescopes cannot see it. Additionally, these techniques are unable to identify species that are not in the gas phase. Due to the extreme cold of dense molecular clouds Except for hydrogen, most of their molecules are frozen, or solid, at temperatures between 441.7°F and 369.7°F. Other wavelengths of light, on the other hand, are used to detect hydrogen and these other molecules. Because it absorbs and emits light, hydrogen can be easily seen in the visible and ultraviolet wavelengths the hydrogen line. In addition, the majority of organic compounds absorb and emit light in the Infrared (IR), so an IR ground-based telescope, NASA's 3-meter infrared telescope facility atop Mauna Kea, Hawaii, was used to detect methane on Mars. For their observations, research, and scientific operations, NASA researchers use the airborne IR telescope SOFIA and the space telescope Spitzer. This is somewhat related to the recent discovery of methane in the atmosphere of Mars. In June 2012, Christopher Oze and his colleagues from the University of Canterbury in New Zealand said that measuring the ratio of hydrogen and methane levels on Mars could help figure out if there is life there. The scientists said that "low H_2/CH_4 ratios (less than approximately 40) indicate that life is likely present and active. Methods for detecting hydrogen and methane in extra-terrestrial atmospheres have recently been reported by other researchers. Infrared astronomy has also shown that the interstellar medium contains polyaromatic hydrocarbons, also known as PAHs or PACs, a group of complex gas-phase carbon compounds. It is said that these molecules are the most common type of carbon compound in the galaxy. They are mostly made up of neutral or ionized carbon fused rings. They are also the most prevalent type of carbon molecule in meteorites, as well as in cosmic dust (cometary and asteroidal dust). Meteorites contain a wide variety of compounds, including amino acids, nucleobases and many others, all of which contain extremely rare carbon, nitrogen, and oxygen isotopes and deuterium, indicating their extra-terrestrial origin. It is thought that hot circumstellar environments around dying, carbon-rich red giant stars are where the PAHs start to form.

Comparisons of Gas Phase Compounds

Additionally, the composition of the interstellar medium's solid materials, such as ices, kerogen-like carbon-rich solids, and silicates, has been examined through infrared astronomy. This is because, in contrast to visible light, which is scattered or absorbed by solid particles, IR radiation can pass through microscopic interstellar particles and produce absorptions at specific wavelengths that are indicative of the grains' composition. Like radio astronomy, there are limitations, such as the fact that N_2 is difficult to detect. According to these infrared observations, the microscopic particles in dense clouds, where there are enough particles to block harmful UV rays, are coated by thin ice layers, allowing for low-temperature chemistry. These ices' initial chemistry is determined by the chemistry of hydrogen, which is the most abundant molecule in the universe. The H atoms react with the available O, C and N atoms to form reduced species like H_2O, CH_4, and NH_3, if the hydrogen is atomic. However, the heavier atoms can react or remain bonded together, resulting in the production of CO, CO_2, CN, *etc.,* if the hydrogen is molecular and not reactive. Complex radiation-driven chemistry is produced when these mixed-molecular ices are subjected to ultraviolet and cosmic ray radiation. Lab experiments on the photochemistry of simple interstellar ices have produced amino acids. The similarities between interstellar and cometary ices and comparisons of gas phase compounds have been used as indicators of a connection between interstellar and cometary chemistry. The minerals also revealed a surprising contribution from high-temperature chemistry in the solar nebula, which is supported in part by the findings of the analysis of the organics from the Stardust mission's comet samples.