STABLE HYDROGEN AND CARBON ISOTOPE RATIOS OF EXTRACTABLE HYDROCARBONS IN THE MURCHISON METEORITE;

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Researchers have been engaged for several decades in the study of meteorites, one of the most primitive materials in the solar system, to unravel the mysteries that shroud the origin of the solar system. Detection of organic compounds in a variety of meteorites has opened up new possibilities to look for fresh clues in the cosmochemistry. Evidence for the presence of such important compounds as amino acids, carboxylic acids and hydrocarbons are of particular interest in this context. Recent advances in analytical techniques have made it possible to extract and identify the minute levels at which these compounds exist in the meteorites. As is inevitable in the analysis of such low-level concentrations, these studies have generated some controversy regarding contamination. In simpler terms, the first step is to ensure that the compounds isolated from the meteorites are truly part of the meteorites and are not an artifact introduced by exposure to the terrestrial environment, storage or handling. Previous efforts to answer this question had met with only partial success. In a novel and fairly fool-proof method we have recently addressed this question with a greater degree of success.

We have measured the stable carbon and hydrogen isotope ratios in several of the chemical compounds extracted from the Murchison meteorite that fell in Australia in 1969. The results obtained by us in the study of amino acids in this meteorite gave very unusual hydrogen and carbon isotope ratios. We have now extended the technique to the different classes of hydrocarbons (compounds in which hydrogen atoms are attached to carbon atoms as for example methane). The hydrocarbons were isolated using a variety of separation techniques. As with the amino acids, the method involved the measurement of the ratio of deuterium to hydrogen and carbon-13 to carbon-12, the stable isotopic forms of the elements hydrogen and carbon respectively. Isotopes of different elements have similar chemical properties for all practical purposes except that they differ in their atomic weight. For instance, deuterium has an atomic weight of 2 compared to hydrogen's 1. Geochemists have known for a long time that ,despite their identical chemical properties, isotopes do behave somewhat differently during various physical and chemical processes that take place in nature. This behavior or fractionation is a very small effect but measurable to a high precision using modern mass-spectrometers. As an example, when water which is made up of hydrogen and oxygen atoms evaporates from the oceans or lakes the vapor phase is less enriched in deuterium and O-18(the heavier isotope of oxygen). During condensation of the vapor back into liquid water as in the form of rain, the reverse takes place with deuterium and O-18 concentrating in the liquid phase. Similarly, one of the most important processes in nature namely photosynthesis results in the plants preferentially utilizing C-12, the lighter isotope of carbon so that all plant material found in nature, living or dead, reflects this characteristics. As a general rule, the end product of all the biologic processes taking place on the earth are seen to be enriched in the lighter isotopes of carbon and hydrogen. The end product may be the various molecules synthesized by plants or animals when they are alive or those generated by the geochemical and geophysical alteration of living things.

Our isotopic investigation showed that several of the hydrocarbons isolated from the Murchison meteorite have higher deuterium to hydrogen ratios, most unlike that for any similar compounds found on the earth. Such an enrichment in deuterium in these compounds provides the first compelling evidence that they are a part of the meteorite and are not introduced from any terrestrial source. Simultaneous measurement of the stable carbon isotope ratio of the hydrocarbons also showed a concomitant enrichment in the heavier isotope, although to a lesser degree than that of deuterium.

The above findings have great significance as to the origin of these organic molecules, because several of these compounds such as aldehydes, ketones, alcohols etc have also been observed in the dense interstellar cloud. This would support the contention that these compounds themselves or the basic units that make them up were created outside of the solar system somewhere in the interstellar space. It may be also recalled that astronomers have provided evidence for the existence of simple organic molecules in the interstellar space although evidence for higher order molecules such as amino acids has thus far been elusive. Since the cold reaches of the interstellar space appear to be much less conducive to chemical reactions that could produce viable compounds such as amino acids and hydrocarbons, special types of reactions known as ion-molecule reactions are thought to be a likely means of carrying out the necessary chemistry. One of the interesting observations to be made is that these hydrocarbons, as with the amino acids analyzed in the Murchison meteorite previously, have survived severe alterations since their formation. If not, they would have acquired the hydrogen isotope imprint of cosmic hydrogen or that in the dominant fraction of the meteorite matrix, both of which show no unusual deuterium enrichment. To strike a note of caution, our knowledge regarding the synthesis and incorporation of the various chemical entities in the Murchison or other meteorites is far from complete, but the detection of an unusual isotopic identity is a major step towards achieving that goal.