Sugars and its related compounds in space and on the early Earth

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Sugars are essential components of life, employing as substrates in nucleic acid formation and working as energy resource in numerous biological reactions. The distribution of sugars, particularly bio-important pentoses and hexose, in space including the Earth would be important for the origin of life.

Carbonaceous chondrites contain many bio-important molecules such as amino acids and nucleobases [e.g., 1,2]. Thus, they were a source of building blocks of life on the prebiotic Earth. The detection of glucose, mannose, arabinose, and xylose by paper chromatography in carbonaceous and enstatite chondrites was originally reported in 1960's [3,4]. However, the paper chromatography has not sufficient resolution to identify any sugar isomers, and these reports were not clear proof on their extraterrestrial origin. Thus, a review concluded that the origin of these reported sugars were terrestrial contamination [5]. More recently, Cooper's group have intensively investigated sugars and their related compounds in Murchison and Mary carbonaceous chondrites. They found 3-carbon sugar, dihydroxyacetone, several sugar acids, and several sugar alcohols by gas chromatography/mass spectrometry (GC/MS) (Fig. 1) [6,7]. Some of the detected compounds were confirmed on those extraterrestrial origins by compound-specific carbon isotope analysis. However, the presence of meteoritic bio-important sugars remained unclear.

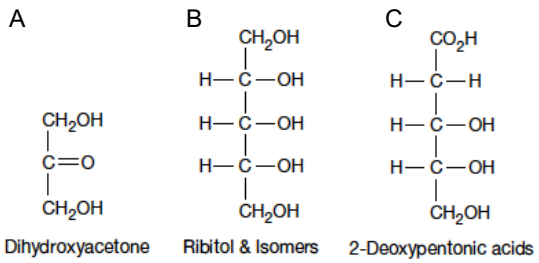

Fig. 1: Structures of sugar, sugar acids and sugar alcohols detected in meteorites. A) dihydroxyace tone, B) ribonic acid, and C) 2-Deoxypentantonic acid. Cooper *et al.*, 2001.

The formose-like reaction is a plausible process to form sugars in meteorite parent bodies, on interstellar dusts, and on the prebiotic Earth. In the Formose reaction, the condensation of formaldehyde forms numerous sugars, simultaneously. Ribose is an intermediate product of this reaction. However, characterization of the product "formose" remained insufficient so far, which causes ambiguity in the potential availability of sugars in space.

We developed a protocol to effectively extract sugars from mineral assemblages. Then, we found multiple sugars in carbonaceous chondrites with GC/MS. The carbon isotopic composition of individual sugars in meteorite extracts was determined by gas chromatography/isotope ratio mass spectrometry (GC/IRMS). For comparison, we analyzed the products of typical Formose reaction simulating meteorite parent bodies. Insoluble organic matter (IOM) was extracted from the same chondrites by demineralization with inorganic acids, and the carbon and nitrogen isotopic compositions of bulk chondrite and IOM were determined. These carbonaceous chondrites were also investigated by scanning electron microscopy (SEM) to evaluate the aqueous alteration levels. In this talk, we will present our preliminary results of these analyses for sugars in carbonaceous chondrites as well as in several experimental Formose reaction products, and will discuss the availability of sugars in space including Earth.

References

[1] Glavine. D. et al. 2011. Meteoritics & Planetary Science 45: 1948-1972. [2] Callahan M. et al. 2011. Proceedings of the National Academy of Sciences USA 108: 13995-13998. [3] Degens E.T., Bajor M. 1962. Naturwiss. 49: 605-606. [4] Kaplan I.R., Degens E.T., Reuter J.H., Geochim. Cosmochim. Acta 27: 805-834. [5] Hayes J.M., 1967. Geochimica et Cosmochimica Acta 31: 1395-1440. [6] Cooper G. et al. 2001. Nature 414: 879–883. [7] Cooper G. and Rioss A.C. 2016. Proceedings of the National Academy of Sciences USA. 113: E3322-31.