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Sulphur organic aerosols and their contribution to prebiotic chemistry

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Context

Photochemical hazes, which are aerosols formed by photochemical reactions, can be an abundant source of complex organic matter. Titan's aerosols, produced in the N_2/CH_4 atmosphere of the biggest Moon of Saturn, are probably the most relevant example to illustrate the molecular complexity and diversity that can be contained in such hazes (Pernot et al 2010). Many studies performed on analogs of Titan's aerosols synthesized in laboratory called Tholins, have revealed the presence of very diversified $C_xH_yN_z$ aliphatic (nitriles, amines) (Gautier et al 2011) and aromatic (notably N-aromatic) (Maillard et al 2021) organic compounds. Among this complex array of nitrogenous organics, prebiotic molecules such as adenine has already been identified (Neish et al 2010). Moreover, the hydrolysis of such material is also a source of amino acids, and other canonical DNA & RNA bases (Neish et al 2009). These results thus justify the importance of photochemical hazes in prebiotic chemistry. In this perspective, considering other analogs of organic photochemical aerosols appears to be interesting notably for sulfur. Sulfur is indeed one of the fundamental elements of life, the famous C,H,N,O,P,S, but despite its abundance in the molecule of living (in amino acids methionine and cysteine for example), it is still not understood how it could have been incorporated into organic matter. That is why the synthesis of sulfur organic aerosols can give clues for prebiotic sulfur chemistry. But such synthesis also allows to explore the atmospheric chemistry of sulfur which has not been fully studied experimentally so far (He et al 2020) and is very important in the context of the JWST mission. IR signatures of SO_2 have indeed been detected in different types of exoplanets: in the hot Jupiter WASP-39b (Tsai et al 2023), and potentially in two temperate sub-Neptunes TOI-270d (Benneke et al 2024) and WASP-107b (Dyrek et al 2023).

Methods

The objective of this work was to synthesize organic sulfur aerosols to consider their potential input of organic matter for prebiotic chemistry. To do so, several gaseous mixtures based on N_2/CH_4 (95/5), which is very efficient for organic growth, have been considered. More precisely, four different gaseous mixtures of $N_2/CH_4/SO_2$ with varying SO_2 content (0, 0.1, 1, and 10%) were used to produce analogs of aerosol in a DC plasma setup. The solids were then analyzed by elementary analysis, and FT-IR, while the gas phase has been characterized with a quadrupole mass spectrometer.

The FT-IR, and elementary analysis will provide a global characterization of the chemical composition of the solid materials produced to infer their potential organic content potentially interesting for prebiotic chemistry.

First MS results

Considering the MS gas phase analysis, the comparison between the different mass spectra of the four tested gas mixtures reveal big contrasts. The presence of SO₂ appears to be detrimental to organic growth necessary for the formation of organic aerosols. As shown in Figure 1, C3 and C4 nitriles, major gaseous products of this organic growth, are observed especially in the most SO₂ depleted conditions.

