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Influence of Mars-Relevant Minerals on the Thermal Stability of the Biomolecule NAD+

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The search for signs of biological activity on Mars is among the main objectives of Mars exploration programs [1]. Here, molecular biosignatures, i. e. molecular traces of life such as biomolecules, are of particular interest. It has to be noted though that biomolecules are highly susceptible to alteration by extreme conditions on extraterrestrial bodies. On Mars specifically, such conditions include ionizing radiation, UV radiation, and strong oxidants in the regolith. Especially in early martian history, heat was also important. It was caused, for example, by intense volcanism in the Noachian and Hesperian periods (4.8–2.6 billion years ago). Given the susceptibility of biomolecules to chemical alteration under extreme conditions, a thorough investigation of stabilities, detection limits and alteration products of potential molecular biosignatures is crucial [2, 3]. In this context, one type of studies consists of Earth-based simulation experiments [2].
Given the above-mentioned long history of martian volcanic activity, we investigated the thermal stability of the biomolecule nicotinamide adenine dinucleotide (NAD+) and identified its decomposition products. A particular focus was on the influence of the mineral environment on the thermal decomposition. Five Mars-relevant mineral matrices were selected for the heating experiments: sodium chloride (NaCl), calcium sulphate ($CaSO_4$), basalt, the Martian regolith simulant JSC Mars-1A, and a mixture of JSC Mars-1A and sodium chloride. The solid residues of the thermolysis experiments were analyzed by infrared spectroscopy and X-ray powder diffraction.
Initial results include: (i) alteration and decomposition of neat NAD+ starts at around 200 ℃ and is preceded by a stepwise loss of crystal water between 100 and 180 ℃; (ii) exposure of a NAD+/NaCl mixture to temperatures above 180 ℃ first leads to the formation of sodium cyclo-triphosphate ($Na_3P_3O_9$); (iii) later (above 500 ℃) sodium diphosphate ($Na_4P_2O_7$) is formed. Diphosphate minerals are rare and cyclo-triphosphate minerals are apparently unknown, at least on Earth. Therefore, these oligophosphates may potentially serve as "secondary"biosignatures.

References

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