Mars as a Prebiotic Chemistry Laboratory: A Martian RNA World?

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Introduction

In the past ten years, a proliferation of information about the Martian environment has resulted from a range of missions, particularly the *Spirit, Opportunity,* and *Curiosity*. Recent results have demonstrated that the Martian surface bears resemblance in many ways to that of Earth, with several key differences, such as the presence of oxychlorine species and the absence of a continuous source of liquid surface water. Recently, Benner, Stephenson, Freeland, and others invoked the availability of borates on the Martian surface as evidence for the possibility that Mars was a suitable environment for an "RNA world."

Perchlorates have now been observed at both polar (Green Valley, Vastitas Borealis) and ancient equatorial sites (Rocknest, Gale Crater). The presence of these compounds in diverse environments on Mars suggests they are present globally, and perhaps been for much of the planet's history. These compounds have been invoked as an attractive means of supporting the presence of transient liquid water, and the presence of such brines in a near-surface environment, such as a cave, could provide or have provided a means to mitigate cosmic and solar radiation.

We suggest that in considering Mars as a prebiotic planet, past or present, the impact of perchlorates must be taken into account. Here we describe our results relating to impact of perchlorates on a hypothetical Martian RNA world.

Perchlorate and biomolecules

While perchlorate may provide such a source of liquid water on Mars, the resulting brines would have extraordinarily high perchlorate concentrations – 8 M or higher. A saturated solution of $NaClO_4$ (~9 M) contains less than three water molecules per Na^+ and ClO_4^- ion.

Perchlorate is an unique ion. It is a powerful oxidizer; its ammonium salt is used as a propellant in solid rocket fuels, and it and the related chlorate ion are used in chemical oxygen generators on aircraft and submarines. Despite its strong oxidation potential, the perchlorate ion itself is metastable for extraordinarily long durations; we have observed solutions of nucleic acids in even saturated perchlorate solutions can be heated to 95 °C without degradation. Thus, from a redox chemistry perspective, perchlorate is not incompatible with prebiotic chemistry, including that on a hypothetical Martian RNA World

A second problem exists, however: perchlorate is a strong chaotrope – that is, on the Hofmeister series, which ranks ions according to their propensity to stabilize or destabilize folded biomolecular structures, perchlorate is highly destabilizing.

An RNA World on Mars?

Here we report our investigations of the behavior of nucleic acids in the presence of a range of simulated Martian environments, including those containing high concentrations of perchlorate as would be expected in perchlorate brines. We further examine the consequences of such environments for the possibility of an RNA world – past or present - on Mars.

Perchlorate-induced Adsorption to Regolith Simulant

Nucleic acids adsorb to silica surfaces in the presence of chaotropes. We have shown this effect is present on Martian regolith simulants such as MMS-1, MMS-2, and MGS-1 (a Rocknest-based simulant). We will discuss the impacts of these perchlorate-induced adsorption effects.