O$_2^-$ Ions and the Mars Labeled Release Response

Yen et al. (1) propose that O$_2^-$ ions putatively formed in the soil of Mars, not microorganisms, represent “the most straightforward explanation” of my 1976 Viking labeled release (LR) life detection results. Data from radioactive organic nutrients added to martian soil (2), however, challenge that conclusion.

In the data reported by Yen et al. [figure 3 of (1)], O$_2^-$ radicals lose only 10% of their activity after one hour at 100°C, and still retain 30% activity after an additional hour at 200°C. These results differ sharply from the LR Mars control data. After martian soil samples had responded positively, duplicates of those samples, in accordance with the protocol of the Viking Biology Team, were heated before testing to distinguish between biological and chemical activity. Heating at 160°C for three hours completely inactivated the sample, signifying biology. An added control run strengthened the case: heating at only 51°C produced 95% inactivation.

Yen et al. mention the inconsistency of their results with these data only in note 20 of (1). There, they cite a book by Horowitz (3) that sought to reconcile the heat sensitivity shown by the martian soil in the LR experiment with the soil’s heat resistance, as shown in the Viking gas exchange (GEx) experiment (4). Horowitz conjectured that, when the LR soil was heated in its sealed test chamber, water vapor evolved to inactivate the (putative) chemical oxidant. On the other hand, he proposed that water vapor from soil heated in the GEx test chamber, purged to the atmosphere, did not destroy the oxidant.

However, data (2) not mentioned by Yen et al. are more important. Soils at Viking 1 and 2, samples from each having produced positive LR reactions, were held in their distribution boxes for 141 martian days at 10 to 26°C and for 84 martian days at approximately 7°C, respectively. The box shields the soil from the sun, but is open to the martian atmosphere. Any water vapor evolving from the soil is thus free to escape. After storage, the soils were again tested. Their responses were essentially nil. Inactivation at such low temperatures would seem to render the model relying on activity of O$_2^-$ ions inapplicable to the Mars LR results.

Over the quarter of a century since Viking, there have been more than 20 published attempts to explain the Viking LR results by chemistry or physics. None has reproduced key elements of the LR Mars data, including thermal degradation, a commonly used identifier of chemicals. Conversely, all of the LR data are consistent with a biological agent (5). The years since Viking have seen an ever-increasing number of reports of microorganisms thriving in Mars-like habitats, and evidence of possible fossil microorganisms in martian meteorites has been found. Is it not possible that Ockham’s razor, originally cited against a biological possibility, may now favor the long-delayed conclusion (6) that living microorganisms were detected by the LR experiment?

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Response: “Pluralitas non est ponenda sine necessitate” in William of Ockham’s writings in the 14th century has been loosely translated as “Why assume that things are complex if a simple theory can explain all of the observations?” Yen et al. (1) invoked Ockham’s razor by demonstrating a simple mechanism for explaining the unusual reactivity of the martian soil based only upon raw materials that are known to be present at the surface. Given a combination of atmospheric oxygen, ultraviolet radiation, mineral surfaces, and a dry environment, adsorbed oxygen radicals will form.

In response to Levin’s commentary, we contend that the dynamic balance between reactive oxygen, water molecules, and organic nutrients on the surfaces of unknown mineral phases under variable temperature conditions in the Viking experiments is too complex to be completely unraveled with the limited data that were collected. The extent of superoxide degradation at specific temperatures was established in our laboratory experiments under anhydrous conditions, using a mineral substrate that did not evolve water at elevated temperatures. The Viking experiments, on the other hand, sampled martian soils that released up to 0.2 weight percent water between 50°C and 200°C (2). That quantity of water is orders of magnitude greater than the population of superoxide necessary to explain the Viking results. Soil samples heated in a closed cell, such as in the Viking LR instrument, would easily evolve a sufficient quantity of water vapor to scavenge the reactive oxygen species. This explanation is entirely consistent with the results of the Viking GEx experiment, in which soil retained reactivity after heating under a He purge but showed a response reduced by more than 95% when heated with the exhaust line blocked (3). Thus, the minor differences in heat resistance between our laboratory results and the data obtained from the Viking LR experiment do not challenge superoxide as the reactive agent in the martian soil, but rather point to the need for greater characterization of the abundance of bound and adsorbed water in martian soil samples.

The reduction in soil reactivity observed after extended storage in the distribution box was approximately 87% for VL-1, cycle 4, and 97% for VL-2, cycle 5, but Levin and Straat reported that “for both cycles, some question exists that a complete nutrient volume was in fact delivered because both instruments were low in the supply of nutrient” (4). The VL-2 data are especially suspect because of the uncertain effects of a larger-than-normal sample size and the possibility that the nutrient delivery lines may have ruptured due to freezing. Thus, the reduced reactivity of these samples may simply have been a result of an inadequate supply of organic nutrients to react with the O$_2^-$ adsorbed on the soil grains.

A comprehensive understanding of the chemical nature of the martian surface environment cannot be achieved until further in-situ experiments are conducted. Given the existing data, we firmly believe that the superoxide ions that we have shown to form under martian conditions provide the most complete explanation of the unusual reactivity of the soil.

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