

Biogenic hydrogen peroxide as a possible adaptation of life on Mars: the search for biosignatures

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The hypothesis that putative Martian organisms incorporate H_2O_2 into their intracellular liquids (Houtkooper and Schulze-Makuch, 2007) has significant implications, as it explains the Viking observations quite well; it provides a functional adaptation to Martian environmental conditions; and, it is feasible as an adaptation based on the biochemistry of terrestrial organisms.

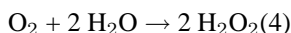
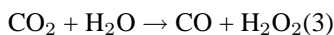
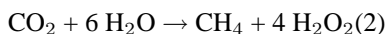
It would explain many of the puzzling Viking observations such as (1) the lack of organics detected by GC-MS, (2) the lack of detected oxidant(s) to support a chemical explanation, (3) evolution of O_2 upon wetting (GEx experiment), (4) limited organic synthesis reactions (PR experiment), and (5) the gas release observations made (LR experiment). An intracellular liquid containing a high concentration of H_2O_2 has advantages such as providing a low freezing point, a source of oxygen, and hygroscopicity, allowing an organism to obtain water vapor from the Martian atmosphere or from the adsorbed layers of water molecules on mineral grains. Perhaps surprisingly, H_2O_2 is used by many terrestrial organisms for diverse purposes, e.g., metabolism (*Acetobacter peroxidans*), as defense mechanism (Bombardier beetle), and also to mediate diverse physiological responses such as cell proliferation, differentiation, and migration.

The detection of H_2O_2 -containing organisms may well suffer from the same problems as the Viking experiments: Because of the excess oxidative contents, as derived from the GEx experiment, the organisms may decompose completely into H_2O , CO_2 , O_2 and N_2 . This can happen when exposed to an excess of water vapor (through hyperhy-

dration), too high a temperature or a combination of both. Therefore, the addition of too much water vapor may be fatal. Moreover, employing pyrolysis in order to detect organic molecules may result in the organisms autooxidizing completely.

Although the instrument suite aboard the Phoenix Lander offers some interesting possibilities (Schulze-Makuch and Houtkooper, 2007),

it may be interesting to consider possible biosignatures in the environment, based on what might be inferred from the putative organisms. The metabolism is constrained by the necessity to produce an excess of H_2O_2 from the environment and the release of possible metabolites. The production of H_2O_2 can be realized from the available constituents in the atmosphere, CO_2 , H_2O and O_2 . The last two components are present as a small fraction of the Martian atmosphere, but so is CO_2 in Earth's atmosphere. Possible overall metabolic pathways are:



These pathways produce the following metabolites: (1) either organic macromolecules, which stay in or at the organisms, or, formaldehyde, released into the atmosphere; (2) methane, released into the atmosphere; (3) carbon monoxide, released into the atmosphere; and (4) only H_2O_2 ; this last pathway is energetically the least costly way to produce H_2O_2 , despite O_2 being a minor component (0.1%) of the atmosphere.

As the amount of biomass in the Martian soil could be as high as 1300 ppm (Houtkooper and Schulze-Makuch, 2007), it might be possible to detect seasonal variations in the metabolic endproducts of formaldehyde, CH_4 , CO and O_2 . Even more interesting would be the observation of local variations in the surface boundary layer, in which diurnal rhythms might be revealed. Since a metabolic pathway would be involved, an additional signature could be the isotopic ratios of carbon and oxygen. Continuous monitoring of the composition, especially of the minor constituents of the atmosphere should therefore have a high priority in future missions to Mars, especially lander missions. Other signatures to be watched for are the spectral absorption of pigments providing UV shielding and photosynthesis.

References:

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