ATMOSPHERIC CHEMISTRY AS A TOOL FOR MARS EXPLORATION AND DISCOVERY

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A big question for Solar System exploration

- Mars has long thought to be a cold, dead planet.
- However, new observations open the question

IS MARS ALIVE?
Is Mars alive? Geologically?

- Active geological processes imply extant subsurface habitability

- There is observational evidence for recent volcanic activity
  - Garvin et al. (2000): <1-20 Ma
  - Roberts et al. (2007): < few tens of years ago

- There is observational evidence for recent surface water flows
  - McEwen et al. (2011)

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This document has been reviewed and determined not to contain controlled technical data.
Is Mars alive? Biologically?

• Active geological processes can support extant subsurface life

• Life very persistent if conditions at all hospitable to existence of life

• If Mars ever supported life, there still may exist oases, albeit below surface, habitable and inhabited.
Remote detection of life on another planet was considered over 40 years ago (at JPL in fact) and focused on the analysis of atmospheric composition. Methane was suggested to be a useful atmospheric marker of extant biology.
Modern atmospheric analysis

- Reported detection of methane by Mumma et al. (2009) raises the question of extant active subsurface processes on Mars, heretofore assumed not to be present.

- Question: How many different subsurface processes might be active today?

- Search to answer this question not limited to methane: Must necessarily be comprehensive— a broad chemical survey that is global in scale and needs to encompass all climate seasons.
Similar to terrestrial counterparts, Martian magmas expected to contain dissolved volatiles that become supersaturated during emplacement in the shallow crust or eruption. Volatiles can be transferred to the atmosphere through several processes:

- direct degassing
- degassing into shallow hydrothermal systems
- interaction of rocks with hydrothermal solutions or ground waters

Molecular composition of volatiles released from Martian magmas likely differs from terrestrial magmas and will depend on several variables:

- temperature of equilibration
  - high temperature: CO and H₂
  - low temperature: H₂S, S₂, H₂O, CH₄, NH₃
- pressure of degassing
- oxidation state
  - oxidized: SO₂

**Signatures of geological activity**

Pre-decisional – for planning and discussion purposes only
Terrestrial microorganisms produce a wide variety of gases as products of both energy-yielding oxidation-reduction (redox) reactions and synthesis and decomposition of organic matter. These processes include:

- Fermentation and anaerobic respiration under strongly reducing conditions: hydrogen-rich compounds, e.g., CH₄, NH₃, H₂S, volatile hydrocarbons, alkylated amines and sulfides.
- Nitrogen redox reactions: nitrogen oxides (NO and NO₂), and N₂O.
- Microbially-mediated decomposition of sedimentary organic matter using sulfate as an oxidant: H₂S and potentially other reduced sulfur gases.
Is methane biogenic or abiogenic?-1

- Ratios of isotopologues can be ambiguous

\[ \delta^{2}H_{CH4} \]
\[ \delta^{13}C_{CH4} \]

microbial reduction of CO\textsubscript{2} with hydrogen (dark green), microbial fermentation (light green), thermogenic (black)
hot water-rock (red), cold water-rock (blue)

Pre-decisional – for planning and discussion purposes only
Is methane biogenic or abiogenic?-2

- Ratios of chemical species may be more definitive

![Graph showing ratios of chemical species including microbial reduction of CO₂ with hydrogen (dark green), microbial fermentation (light green), thermogenic (black), hot water-rock (red), cold water-rock (blue).]

Pre-decisional – for planning and discussion purposes only
Is methane biogenic or abiogenic?-3

- Isotopic patterns in δ2H and δ13C as a function of alkane carbon number may even be more unique

Alkanes derived from thermogenesis (black); abiotic alkanes derived from water-rock reactions (blue)
Solar occultation: signature science measurement

- From an orbiting spacecraft
  - Bright light source
  - Long sample cell
  - 2 latitudes sampled every orbit
- Vertical profiles derived from observing the sun rise and set behind the atmosphere
Simultaneous measurement of multiple chemical species

Low dust

155 km
23.7 km
16.5 km
9.2 km
1.9 km

Moderate dust

155 km
37.9 km
30.8 km
23.7 km