Impact-induced methane formation on early Mars and Earth

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Methane CH_4 have been proposed as a potential greenhouse gas to greatly warm early Earth and Mars atmospheres, but no abiotic process has been shown to supply methane at a rate high enough to withstand rapid destruction by UV photochemistry. Previous studies based on constant-pressure *P* calculations [1] [2] have revealed that chondritic impactors would produce CH_4 only at temperatures *T* below ~1000K at planetary atmospheric *P*, requiring catalysts for CH_4 formation. However, catalyst availability is unknown.

If gas source is impact-induced vapor plumes, nevererthelesss, they follow isentropes as they expand. Because isentropes have high *P* at high *T*, CH_4 is more stable during the early stage of expansion than constant-*P* models predict. Thus, impact-induced vapor may produce a significant amount of CH_4 without catalytic reactions.

In order to explore this possibility quantitatively, we theoretically assessed the molecular composition within impact-induced vapor that cools adiabatically. We calculated the equilibirum molecular compositions of gas and condensed phase in equilibrium with CI chondritic composition along isentropes (3.5 – 6 kJ/K/kg), covering impact velocities from 7 km/s on Mars to 25 km/s on Earth. Details of the calculations are given in [3].

Calculations show that the CH_4 stability does not change drastically along each isentrope. If CH_4 is stable in expanding vapor, it tends to be stable from the beginning through the end of the expansion. Thus, no catalysit is required for CH_4 formation. The CH_4 stability depends more on entropy in impact vapor. Higher entropy, resulting from higher impact velocities and high target impedance, leads to lower CH_4 stability, and lower entropy leads to higher CH_4 stability. More specifically, 100's ppm to a few % of CH_4 is stable in a wide *T* range including typical quenching *T* of carbon-bearing gases under impact conditions for Mars and ocean-covered Earth. Thus, impact vapor from such conditions would release a large amount of CH_4. Thus, impact-generated atmospheres, which may have appeared on early Mars and Earth, may have been rich in CH_4. This may have contributed greatly to greenhouse effect on these planetary atmospheres.

[1] Hashimoto G.L, et al. (2007) *J Geophys Res.*,**112**, E05010. [2] Schaefer L. & Fegley B (2010), *Icarus* **208**, 438-448. [3] Kuwahara, H. and S. Sugita (2015), *Icarus*, in review.