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Planetary Research Talk Abstract

Formation of Methane in Comet Impacts: Implications for Earth, Mars, and Titan

Monika E Kress and Christopher P McKay   -   Icarus 168, 475-483

Solar system formation models attempt to describe how our sun and planets formed around 46 Gyr ago, and how they have evolved to reach their current state   Two of the major results of the accepted theory have serious implications for Earth   The first is that all volatile materials, such as water and most organics, had to form beyond the frost line, which falls between Mars and Jupiter   The second is that ~4 Gyr ago, the sun was approximately 25% fainter than it is today, which would lower the temperature of the Earth significantly and prevent the presence of water in its liquid form The back-of-the-envelope solution to these problems is that volatiles are transported to the terrestrial planets via comets and asteroids, and that the greenhouse effect on Earth accounted for the extra heat necessary to maintain the liquid state of water

The greenhouse solution has some significant stumbling blocks   The abundance of CO_2 in the early atmosphere was insufficient to provide enough warming, but adding small amounts of methane (with a mixing ratio as low as 10^{-4}) could account for the missing greenhouse effect   Typically, biological organisms with a methane waste produce are theorized to have produced this methane   The major flaw in this is: how could these biological organisms be responsible for warming the planet sufficiently for water to be liquid, if all common scientific beliefs indicate they would have needed this liquid water to evolve in the first place?

Kress and McKay take a different approach to the problem of adding CH_4 to the atmosphere   Their paper suggests that large cometary impacts, common during the early formation days of the solar system, could provide chemical conditions favorable to the production of methane   Traditional models suggest that the gas phase reactions necessary to produce CH_4 in an impact are quenched at ~2000K   Thus the fireball that results from an impact cools before CH_4 is available as favored state for carbon, leaving most of the carbon locked as CO   Kress and McKay argue that the hot dusty cloud that results from these impacts actually serves as a catalyst to provide a favored pathway for CO to be converted to CH_4 Covalently bonded molecules such as CO can dissociate on the transition metal catalysts of iron and nickel within this dust cloud, and the resulting catalyzed reactions can produce enough CH_4 to warm the planet

The paper takes the most conservative approach possible to model the quantity of CH_4 that could result from cometary impacts   Their chemistry is modeled after results from industrial use of nickel as a solid catalyst for the production of methane   While a real impact would create more of an iron-silicate smoke, they argue that the reaction chemistry of nickel and iron are virtually the same for this situation   In addition, the difference of the two catalyst states is not significant enough to eliminate the usefulness of the industry model as a rough estimate of impact conditions   The paper they build upon calculated the rates of change of the chemical reactions over a range of temperatures precisely corresponding to those within the cooling fireball   They solved for the time evolution abundances of CH_4 from an impact of an ideal comet of varying size, with a very simple model of the resulting fireball   Using the most pessimistic rates of production of CH_4, they were able to produce enough methane to heat the earth for times prior to the end of the late heavy bombardment period, 38 Gyr ago   Clearly a more detailed model needs to be examined, but these initial results are very promising