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EXPERIMENTAL STUDIES OF GAS TRAPPING IN AMORPHOUS ICE AND THERMAL MODELLING OF COMETS - IMPLICATIONS FOR ROSETTA

Akiva Bar-Nun, Department of Geophysics and Planetary Sciences, Tel Aviv University, Tel Aviv, 69978, Israel.

The trapping of mixtures of CO, CH_4, N_2 and Ar in amorphous water ice was studied experimentally, by flowing 1:1 gas: water vapor mixtures at 2×10^{-5} Torr onto a cold plate at 25 - 100K. This mixture was used, since the ratio $(CO+CH_4)/H_2O$ vapor in the solar nebula was close to 1. The amount of trapped gas in the ice was found to drop by 6 orders of magnitude between deposition temperatures of 25 and 100K. Hence, the gas content of comets can serve as a very sensitive cosmothermometer. It was found that in order to trap 3.5% (parent) CO in the ice, as found for comet Halley, the comet had to be formed at $48 \pm 5K$. CH_4 was found to be trapped in the ice ~100 times more efficiently than CO. Hence, in order to trap in Halley's ice 3.5% CO and only ~1% CH_4, the CO/CH_4 ratio in the region of Halley's formation had to be ~100.

The ice particles could <u>not</u> have been formed at a higher temperature and, subsequently, cool down. Experiments where ice was deposited at elevated temperatures, then cooled down and gas was flowed into the ice, showed that the amount of trapped gas depends only on the highest temperature at which the ice was formed, or resided, prior to cooling and gas flow into it. Consequently, the cometary ice had to be formed at ~48K and the ice is therefor amorphous.

Duncan et al. (1988) and Delsemme (1988) propose that the short period comets were formed in an extended dust shell - the "Kuiper

Belt", at ~40K and remained there unpreturbed, whereas the long period comets were formed in the Uranus - Neptune region, at ~ -80K, and were ejected from there into the Oort cloud. Similar circumstellar dust shells were found by IRAS to have the following temperatures: α P_sA - 55K; ε Eri - 45K; α Lyr - 85K and β Pic 100K. In the first two, comets with Halley's gas content can be formed whereas in the last two the gas content would be $\sim 10^{-4}$ - 10^{-5}.

Similar experimental studies were carried out on the trapping of the noble gases Ar: Kr: Xe - 10,000: 8:1 (like in the solar nebula) at 50- 75K. They showed that the enrichment factors earth/solar: $Kr/^{36}Ar$ = 74 and $Xe/^{36}Ar$ = 48, can be obtained by bringing these gases to earth by comets which were formed at ~50-55K. If all the terrestrial ^{36}Ar, Kr and Xe were delivered only by such comets, the amount of water delivered by them should have been $\sim 10^{-4}$ of the total amount of free and bound water ($\sim 2 \times 10^{24}$ g). A hundred fold dilution of the noble gases by CO did not alter these enrichment factors.

The thermal profile of a comet in Halley's orbit was calculated, including the build-up of an insulating dust layer. It was found that an insulating dust layer few cm thick is enough to choke most of the water emission from the surface. Also, a layer about 40 m thick of crystalline ice is formed at the surface by solar heating above 137K - the temperature of transformation from amorphous to cubic ice. During this transformation, large quantities of trapped gases are released from the amorphous ice and accumulate in pockets in the crystalline ice. Explosions of these pockets can explain the sporadic small explosions, which were observed on Halley from the ground, as well as the formation of the large active craters which were photographed by

Giotto's camera.

A similar thermal model was calculated for comet P/Temple-1, a candidate for both CRAF and Rosetta (CNSR) missions. The temperature at a depth of 10 m is ~160K for all models considered and, hence, the ice at this depth is crystalline. A crystalline ice layer 40-240 m thick (depending upon the parameters used) was found to overly the gas-laden amorphous ice. Consequently, it should be difficult for the probes of the two comet missions to sample pristine amorphous ice, unless they are aimed at the bottom of an active crater.