LIFETIME OF A TRANSIENT ATMOSPHERE PRODUCED BY LUNAR VOLCANISM. O. J. Tucker[1], R. M. Killen[1], R. E. Johnson[2] and P. Saxena[1], [1] NASA Goddard Space Flight Center, Greenbelt, Maryland 20771, [2]University of Virginia, Charlottesville, Virginia 48109 (orenthal.j.tucker@nasa.gov).

Introduction: Needham and Kring (2017), hereafter NK17, postulated that lunar volcanism would have produced a transient atmosphere, and that the abundance of released volatiles would have been consistent with Mars' current surface pressure during the peak eruption epoch ~3.5 Gyr ago. For their peak surface pressure they estimated a lifetime of 70 million years using a thermal escape rate of ~10^4 g s^{-1} (10 kg/s). This rate was derived earlier for an atmosphere assumed to be composed of atomic oxygen (16 amu) with a much lower surface pressure, 10^{-17} – 10^{-10} bar (Vondrak 1974). However, the NK17 surface pressures were on the order of several mbar and the primary constituent was CO, mass 28 amu. Despite these differences, recent studies have adopted the Vondrak (1974) mass loss rate (Aleinov et al. 2019; Wilson, et al. 2019; Schulze-Makuch and Crawford 2018). Although NK17 estimated an atmosphere column of the order of the present Mars-like atmosphere, the Moon has a surface binding energy 0.22 times that of Mars, and it orbits on average ~0.5 AU closer to the Sun, so atmospheric escape occurs more efficiently at the Moon. To date the processes determining the escape of a past millibar like atmosphere on the Moon have not been considered in detail. Therefore, we examine the applicability of the Vondrak escape rate, and then examine those thermal and nonthermal processes by which the Moon would actually lose a Mars-like atmosphere.

Summary: Both thermal and nonthermal escape processes are evaluated as a function of the total atmospheric mass as well as the effect of the presence of a light constituent such as H_2 Table 1. We show that the often used surface Jeans calculation carried out in Vondrak (1974) is not applicable for an atmosphere of the scale and composition of the hypothetical NK17 atmospheres. Solar driven non-thermal escape could remove a CO millibar atmosphere similar to the present Mars atmosphere on the order of Myrs since escape is much more efficient on the Moon. This result, of course, depends on the efficiency of solar UV/EUV absorption heating the upper atmosphere and powering escape. We show that hypothetical CO atmospheres with average exobase temperatures < ~275 K would have been relatively stable against thermal escape. In this case atmospheric loss is driven by non-thermal escape. Whereas if thermal heating of the upper atmosphere by solar UV/EUV absorption results in average exobase temperatures > ~325 K, thermal escape increasingly dominates the loss rate. We also estimate a minimum accumulation rate of > ~3 kg/s if such atmospheres were the source of hydrogen to the polar surface regions.

Table 1: Thermal/Nonthermal Loss Lifetimes

Escape Process (300 K)	Mass Loss (kg/s)	Lifetime (Myr)
NK17	60	0.2
Thermal (CO,H_2)	0.9, 59	13
Energy Limited	~10^4 – 10^5	58 – 110 Yr
Sputtering (CO)	7	2
Photochemical (CO)	10	1

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