EVOLVED GAS ANALYSIS OF TWO LUNAR SIMULANTS, APOLLO 16 REGOLITH AND A CARBONACEOUS METEORITE (MURCHISON) USING VAPoR. I. L. ten Kate[1,2], D. P. Glavin[1], and the VAPoR team, [1]NASA Goddard Space Flight Center, Code 699, Greenbelt, MD 20771, Inge.L.tenKate@NASA.gov, [2]Goddard Earth Science and Technology Center, University of Maryland Baltimore County, Baltimore, MD 21228.

Introduction: *In situ* analyses of the chemical and isotopic composition of the lunar regolith will be required to establish the abundance, origin, and distribution of water-ice and other volatiles at the lunar poles. Volatile Analysis by Pyrolysis of Regolith (VAPoR) on the Moon using mass spectrometry is one technique that should be considered. The VAPoR pyrolysis-mass spectrometer (pyr-MS) instrument concept study was recently selected for funding by the NASA Lunar Sortie Science Opportunities (LSSO) and Astrobiology Science and Technology Instrument Development (ASTID) Programs.

There are at least three key lunar science measurement objectives that can be achieved by the VAPoR instrument: (1) Measure the isotope ratios of carbon, hydrogen, oxygen, and nitrogen (CHON)-containing volatiles including water in polar regolith to establish their origin, (2) Understand the processes by which terrestrial organic compounds are dispersed and/or destroyed on the surface of the Moon to prepare for future human exploration and life detection on Mars, and (3) Measure the abundance of volatiles that can be released from lunar regolith for *in situ* resource utilization (ISRU) technology development.

Instrument Concept: The VAPoR instrument suite will include a sample manipulation system (SMS) and vacuum pyrolysis unit, gas processing system, and mass spectrometer. All of these components can be integrated into an autonomous robotic or human deployed package that would require minimal resources. The resource requirements for VAPoR (mass: 7-15 kg; avg. power: 20-25 W; volume: 15”x11”x7”; telemetry rate: 1 kbps) are scaled-down estimates based on the SAM instrument suite.

Lunar regolith surface or subsurface samples could be delivered to the VAPoR instrument solid sample inlet robotically by a lander/rover scoop or drill, or collected and delivered to the inlet by an astronaut. The VAPoR SMS consists of a 6-cup exchangeable carousel mechanism designed to receive lunar regolith samples and heat the samples to elevated temperatures. Vacuum pyrolysis at temperatures up to 1400ºC has been shown to be an efficient way to release volatiles from lunar regolith [1]. Development and testing of a vacuum pyrolysis system at Goddard has shown that O_2 can be released from lunar analog materials under vacuum at temperatures above 1200ºC [2].

Breadboard development: In order to test the different components of the VAPoR instrument package as well as to provide first calibration data a breadboard has been built (Fig. 1), consisting of a stainless steel vacuum chamber equipped with a modified Knudsen cell (K-cell), which serves as pyrolysis unit, and a residual gas analyzer (RGA; RGA300, Stanford Research Systems). The breadboard will evolve in time with the addition of flight prototype hardware.

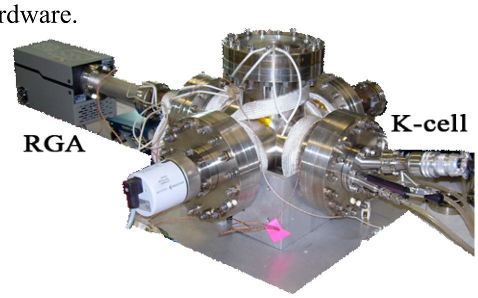

Figure 1. The VAPoR breadboard, equipped with the Residual Gas Analyzer (RGA) and the K-cell.

Experiments: A wide range of tests and experiments have been conducted in which different samples of ~60 mg have been pyrolyzed at rates of 5 °C per min to 1200 °C, while the RGA continuously recorded spectra of the evolving gases. The samples used in these experiments included the lunar simulants GSC1 [3] and JSC1A [4], Apollo 16 lunar regolith, and a Murchison meteorite sample.

Results: The preliminary results from the pyrolysis experiments are shown in Figs. 3, 4, 5, and 6. These graphs show the partial pressure of the detected compounds as function of pyrolysis time, with a black line representing the temperature profile as function of time.

Table 1 shows the allocation of different masses to different species.

Table 1. Mass allocation of different peaks

2	He	12	C
14	N	16	O
17,18	H_2O	28	CO, N_2
29	N_2	30,39,43	hydrocarbons
44	CO_2	48,64	SO_2

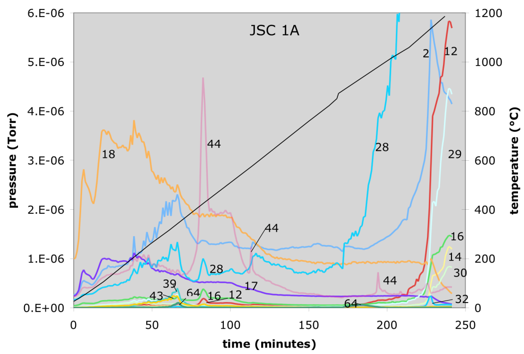

Figure 3. The gases evolved as a function of pyrolysis time from a ~60 mg JSC1A lunar regolith analogue sample.

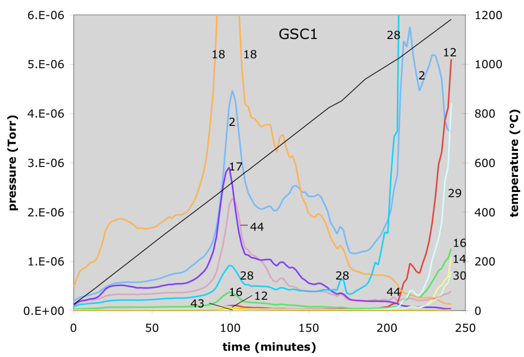

Figure 4. The gases evolved as a function of pyrolysis time from a ~60 mg GSC1 lunar regolith analogue sample.

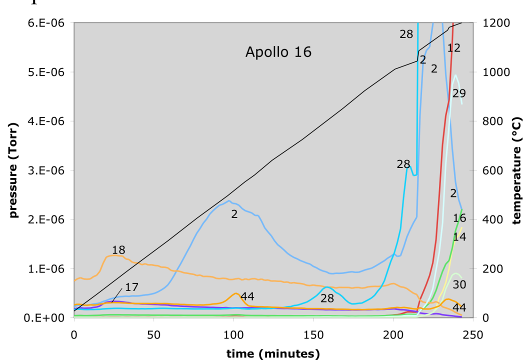

Figure 5. The gases evolved as a function of pyrolysis time from a ~60 mg Apollo 16 sample.

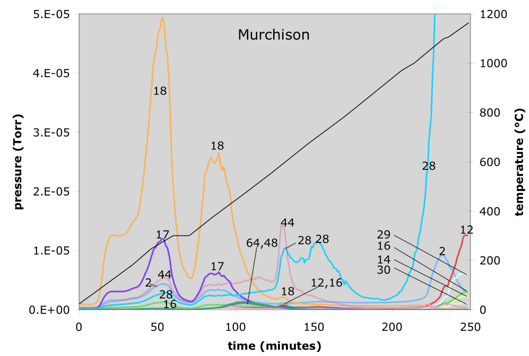

Figure 6. The gases evolved as a function of pyrolysis time from a ~30 mg Murchison sample. Due to extensive outgassing of the Murchison sample the temperature was held constant at 300 °C for 10 minutes, to prevent the RGA from saturation.

Conclusion: Evolved gas measurements by VAPoR will be critical for establishing the abundance, nature and distribution of volatiles in the lunar regolith. Furthermore, VAPoR can determine variations in the bulk chemistry of lunar regolith samples and detect any significant meteoritic contribution to the regolith. Compared to the Apollo 16 regolith, our data suggests that both lunar simulants, JSC1A and GSC1, are not good lunar analogues from a bulk chemical composition perspective. The Apollo 16 regolith has a unique distribution of evolved hydrogen compared to the lunar simulants, which may indicate a solar wind implanted hydrogen component. We are currently testing a much higher resolution time of flight mass spectrometer designed to measure the isotopic ratio of deuterium to hydrogen. These measurements will be important for establishing the origin of any water or hydrogen detected on the Moon.

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