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Conference or Workshop Item

How to cite:

Mortimer, James; Anand, Mahesh; Gilmour, Iain; Pillinger, Colin; Sheridan, Simon and Morse, Andrew (2013). Using stable isotope geochemistry to investigate the source(s) of volatiles in the lunar regolith. In: Geochemistry Group RiP meeting 2013, 14 Mar 2013, Milton Keynes, UK.

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Version: Version of Record

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Using Stable Isotope Geochemistry to Investigate the Source(s) of Volatiles in the Lunar Regolith

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1: Introduction:

- Previous laboratory analyses of lunar soil samples have documented a range of volatile species present within the regolith that blankets the lunar surface.
- Thermal gas release studies (heating soil samples at rates of 4 °C/min to temperatures just exceeding their initial melting points) revealed solid gases, CH₄, CO, CO₂, H₂O, H₂, and subliming species like H₂O and CO₂.[1],[2]. The temperatures at which these gases are released can be tentatively identified from their sources, for example, solar wind-derived hydrogens and hydroxyls are released before 300–700 °C.[1]

2: IonCam 2020 Gas Analysis Mass Spectrometer

- The IonCam 2020 mass spectrometer was purchased from Q-Pal (Ambala, India) in the autumn of 2012.
- It is a miniaturised, "transportable", non-destructive, transient gas chromatograph equipped with a thermal conductivity detector (TCD), a quadrupole mass spectrometer, and a pulsed chemical ionisation mass spectrometer (PCIMS).

3: Detection Limit

- For the purposes of making an isotope measurement, the detection limit of the machine is taken as the smallest amount of sample gas that will enter the mass spectrometer at different times. Initial test runs (using pure 100% methane) conducted recently have shown a detection limit of <10 ng.
- While the detection limit is below the manufacturer's stated sensitivity parameters, thus limiting the accuracy of the measurements, these measurements already take the relative errors in the region of ±0.18 ‰, using a sample size of just 665.5 ng.

4: Stability

- In order to make reliable, precise isotope measurements, the response seen on the detector needs to be as little as possible over the time it takes to make a measurement (in this case, over 5 minutes).
- Given that δ¹³C-values from previous studies of lunar soils range from -30 ‰ to +30 ‰, it is vital to distinguish between different possible sources of carbon, a variation over measurement time of ± 5 ‰ would be ideal.
- To ensure the accuracy of the measurements, the IonCam makes data collected at the detection limits of 100 Torr CO₂, and 5 Torr CH₄.

5: Suitability

- Using these results to make some rough calculations, based on the expected yield of volatiles containing carbon from lunar soils, the IonCam would need around 300 times more mass sample (in the region of hundreds of micrograms per measurement) to make such an isotope measurement as that required to establish high precision established isotope mass spectrometry, used in the open literature, however, the amount of sample gas needed to build up enough pressure (≥ 1 Torr) to detect as little as possible over the time it takes to make a measurement is in the order of 10 μg.
- Further, at least, the detector is capable of making isotope measurements with a variation of ± 5 ‰, knowing that the whole range of possible values for solar system carbon is only ± 30 ‰, it would be impossible to distinguish between different sources of carbon found in lunar soils, using the IonCam as it is currently performing.

6: Other Instrumentation

- There are several well-established instruments at the Open University that are capable of making highly precise isotope measurements on small sample sizes, such as the next possibilities to explore.
- The first of these is "Risoner", a custom-built instrument which incorporates a series of 6-way/3-position/3-port valves, with three dedicated static mass-mixing processes to perform the four-stage temperature step for Ma'at and Dyonisus.[3],[4],[5].

7: References
