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

James Mortimer*, Mahesh Anand, Jia Gilmour, Colin Pillinger, Simon Sheridan, Andrew Morse

*James.mortimer@open.ac.uk

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 6 °C/min to temperatures just exceeding their initial melting points) revealed solid gaseous, CO, CO₂, H₂O, H₂S, and sublimating species H₂S, SO₂, etc.
- The temperatures at which these gaseous species are released can be used to tentatively identify their sources, for example, solar wind-derived hydrogens and heliums before are released from between 300-350 °C.

2: IonCam 2020 Gas Analysis Mass Spectrometer:

- The IonCam 2020 mass spectrometer was purchased from OAI (Analysts of Alabama, USA) in the autumn of 2012.
- It is a modular, transportable, non-scanning mass spectrometer, allowing for simultaneous detection of all masses present in gas samples.
- The IonCam detector (Charge-Coupled Device) within the machine is described as pressure independent, and highly linear, suggesting that it should function well with small amounts of gas (ideal for lunar soil samples). A linear response would mean that gas flow (measured as gas intensity at the detector) should be proportional to pressure squared.
- It is capable of performing fast analyses of samples, which allow transient processes to be monitored and highly responsive.

3: Detection Limit:

- For the purposes of making an isotope measurement, the detection limit of the machine is taken as the smallest amount of gas needed to generate a peak, measurable peak (as a mass spectrum for the least abundant isotope, in this case 4He, over 3 seconds).
- By logging mass spectra at a range of different pressures (as measured by the gauge on the reference gas line), starting at 2 mbar and increasing in steps to 300 mbar, we found that the peak for mass 46 disappears at around 750 mbar, which is where the machine goes sub-linear on this particular setup. This trend requires further investigation.
- By logging mass spectra at a range of different pressures (as measured by the gauge on the reference gas line), starting at 2 mbar and increasing in steps to 300 mbar, we found that the peak for mass 46 disappears at around 750 mbar, which is where the machine goes sub-linear on this particular setup. This trend requires further investigation.

4: Stability:

- In order to make reliable, precise isotope measurements, the response seen on the detector needs to stay as little as possible over the times taken to make a measurement (in this case, over 5 minutes).
- Given that 6°C values from previous studies of lunar soils range from −30 ‰ to +30 ‰, it is critical to distinguish between different potential sources of carbon, a variation over measurement time of ± 3 ‰ would be ideal.
- To assess the variability in the measurements the IonCam makes, data collected at the University of California at Berkeley was used.
- The real-time counts of mass 40, 44, and 46 were collected from the “T” function (which had logged 2000 frames of data) and mass 40, 40/44, and 44/46 were then converted into isotope ratios (40/44 and 44/46) and 2 isotope ratios calculated for the following groups of 100 frames, in a “no-reconstruction” calculation.
- For the purposes of making an isotope measurement, the detection limit of the machine is taken as the smallest amount of gas needed to generate a peak, measurable peak (as a mass spectrum for the least abundant isotope, in this case 4He, over 3 seconds).
- By logging mass spectra at a range of different pressures (as measured by the gauge on the reference gas line), starting at 2 mbar and increasing in steps to 300 mbar, we found that the peak for mass 46 disappears at around 750 mbar, which is where the machine goes sub-linear on this particular setup. This trend requires further investigation.

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 than sample (in the region of hundreds of micrograms) per measurement to take on any isotopic measurements that either high precision established isotope mass spectrometrist used in the present approach. However, the amount of sample gas needed to build up enough pressure to 500 mbar (such as an isotope measurement must be taken into account, this takes the amount of liquid need up to twice of grams, for example 5% to 20% of a sample, and then for analysis of 10% of the sample, and therefore for analysis of 10% of the sample from 10% of a sample, and therefore for analysis of 10% of the sample).
- Further, at least, the detector is capable of making isotope measurements with a variation of ±0.001 ‰. Knowing that the range of whole values for possible solar system sources of carbon is only ±0.1 ‰, it would be impossible to distinguish between different sources for the carbon found in lunar soils, using the IonCam as it is currently performing.
- There are also a number of issues surrounding the use of the IonCam instrument for astrobiological use, one of which is poor resolution between peaks of similar mass, leading to peaks which interfere with the measured intensities of neighbouring peaks. Another potential problem is the occasional presence of a ‘slightly’ stepped response from the detector; this is possibly a feature of a gas individual peaks within the instrument.
- To conclude, in its current configuration, the IonCam 2020 instrument is not suitable for use with lunar soil samples. Making some fairly easy, quick changes, such as reducing the intensity value of the reference gas line, and making isotopic measurements over a shorter time period would reduce the sample amount needed by a factor of 100. For example, but to fully resolve the machine’s various sources, in real depth multistate (perhaps using the gas chromatographic mass spectrometer) the statement should be performed by the machine’s various sources, in real depth multistate (perhaps using the gas chromatographic mass spectrometer).

6: Other Instrumentation:

- There are several well-established instruments at the Open University that are capable of making highly precise isotopic measurements on small sample sizes, these will be the next possibilities to explore.
- The first of these is Riken, a custom-built instrument which incorporates on-five permil-combustion of samples, with three dedicated static mass make spectrometers to simultaneously collect data for carbon and nitrogen species. The standard reference gas used to characterise the machine’s performance was carbon dioxide (CO₂).
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7: References: