Infrared Spectra of Lunar Polar Relevant Hydrocarbons and Brines

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Background

Hydrocarbons & other organics may be an important lunar volatile species:
- Methane detected in lunar samples [1] and in the lunar exosphere [2];
- Dark lag deposits possibly composed of organic residues topping ice in Mercury's polar regions, which serve as analogs to lunar polar deposits [3];
- Carbon-hydrogen bonds detected in lunar glasses prepared to minimize contamination [4];
- Organic detections by LCROSS that impacted a large projectile into the permanently shaded Cabeus crater near the lunar south pole [5]; and
- Observations by KAGUYA of surface-wide carbon ion emissions from the lunar surface [6].

Current/future missions that could study lunar hydrocarbons in the near to mid-infrared:
- Chandrayaan-2 may have the sensitivity to detect these absorptions in shadowed regions indirectly illuminated by reflected sunlight; and
- Lunar Trailblazer mission will carry a spectrometer similar to Chandrayaan-1's Moon Mineralogy Mapper that was used to detect ice in permanent shadow and includes wavelengths throughout the organic region up to 3.6 microns [7].

Data on the spectral reflectances of relevant simulant samples in the near to mid-infrared from frozen brines, hydrous minerals, and alcohols useful for interpretation of data from these missions.

Methods

(1) Liquid samples (Table 1) were passed through an airbrush with a 0.75 mm head into liquid nitrogen (77 K).

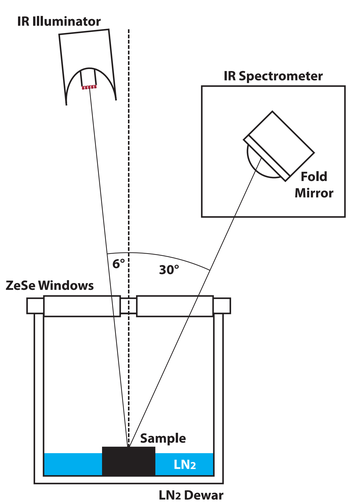

Figure 1: Geometry of the experimental setup.

(2) Samples froze instantaneously upon contact with liquid nitrogen:
- Fine particulate ice produced achieves similar spectral characteristics to materials at the surface of the lunar poles [8][9].

Compound	*Concentration*
Methanol	99.99%
Ethanol	99.99%
2-propanol	99.99%
Ammonium Hydroxide	99.99%
NaCl $MgSO_4$	0.5M in H_2O
NaCl $MgSO_4$	1.0M in H_2O
Sodium Bicarbonate	2.0M in H_2O
Hydrogen Peroxide	3% in H_2O

Table 1: Lunar polar relevant samples.

(3) Samples sieved in liquid nitrogen to ensure particle size was <75 µm, and placed onto a sample cup surrounded by liquid nitrogen.

(4) The Dewar containing the sample was covered by a zinc selenide (ZnSe) window. Liquid nitrogen in the Dewar maintained dry nitrogen gas positive pressure inside the chamber to prevent atmospheric contamination.
- The samples were monitored until all remaining liquid nitrogen evaporated from the sample cup, and then spectra were taken.

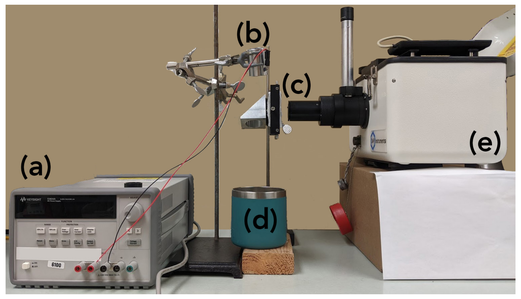

Figure 2: The experimental setup consists of: (a) power supply, (b) IRS-001C Electro Optical Components infrared illuminator, (c) fold mirror, (d) LN_2 Dewar, (e) Designs and Prototypes portable infrared spectrometer.

The measurement system consists of an infrared spectrometer and an infrared illuminator (Figure 1, 2);
- Illuminator is a filament operated at 1200 K with a 1" parabolic reflector to direct the beam.
- Data are normalized to a diffuse Infragold standard.

Results

We obtained a series of infrared spectra of frozen hydrocarbons and salt brine solutions between 2 and 5.3 µm (Figures 3 and 4).

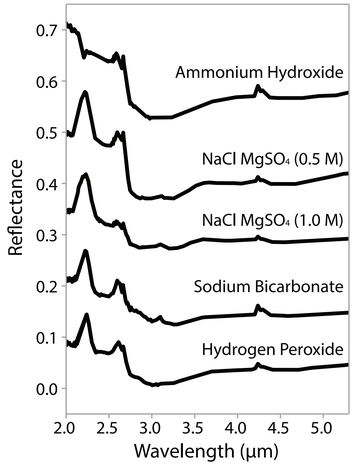

Figure 3: Infrared reflectance spectra of selected salts and other volatiles, offset for clarity.

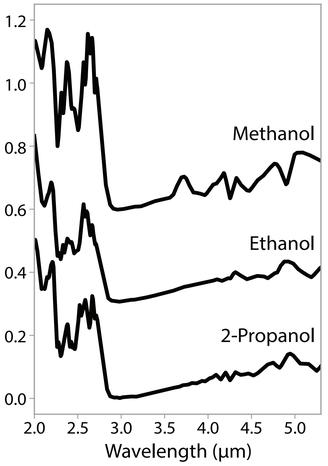

Figure 4: Infrared reflectance spectra of selected alcohols, offset for clarity.

- Ice features are apparent in the NaCl $MgSO_4$, sodium bicarbonate, and hydrogen peroxide solutions at shorter wavelengths, with spectra consistent with that of water ice (Figure 3);
- There is a possible sulfate feature between 4-4.5 µm in the NaCl $MgSO_4$ solution; and
- The feature at 4.2 µm is due to imperfect removal of CO_2 in the test environment.

- The combined effects of organics and hydroxyl are shown by the sharp drop in reflectance between 2.5-3 µm (Figure 4), along with strong organic spectral features in the 2 and 3-5 micron regions.

Discussion

Our experiment can produce and detect samples relevant to lunar polar exploration, important for future mission characterization of surface frosts.

Project next steps are to characterize further organic materials, such as various amino acids, and determine the minimum concentration of relevant solvents our system can detect.

References:
[1] P. I. Abell et al. Proceedings of the 2nd Lunar Science Conference, 2:1843–1863, 1971. [2] P. I. Hodges Jr. Geophys. Res. Lett., 43:6742–6748, 2016. [3] D. A. Paige et al. Science, 339(6117):300–3, 2013. [4] Y. Liu et al. Nature Geoscience, 5(11):779, 2012. [5] A. Colaprete et al. Science, 330(6003):463–8, 2010. [6] S. Yokota et al. Science Advances, 6(19): EABA1050, 2020. [7] S. Li et al. Proceedings of the National Academy of Sciences, 115(36):8907–8912, 2018. [8] D. M. Hudgins et al. Astrophysical Journal Supplement Series, 86(2):713–870, 1993. [9] T. M. Orlando et al. Icarus, 177:528–533, 2005.