

ULTRAVIOLET REFLECTANCE SPECTRA MATERIAL RELEVANT TO AIRLESS BODIES. C. A. Hibbitts¹, M. D. Dyar², A. S. Greenspon³, ¹Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20773, karl.hibbitts@jhuapl.edu; ²Dept. of Astronomy, Mount Holyoke College, 50 College Street, South Hadley, MA 01075; ³School of Engineering and Applied Sciences, Harvard University, 9 Oxford St., Cambridge, MA 02138.

Introduction: Reflectance spectroscopy in the vacuum ultraviolet through visible wavelengths is sensitive to the abundance of opaque materials, especially transition metal cations. While ultraviolet spectroscopy is often used to probe the composition of atmospheres, it has also been used to explore surface composition (1,2). In previous work, we presented UV spectra from the vacuum UV into the visible (130 – 400 nm) of lunar analog glasses (3). That work was consistent with previous laboratory research into the UV reflectance of nonice materials (4,5). Here we further characterize the UV-Vis spectra of these synthetic glasses and relate identifiable spectral features to the chemical composition of each sample as well as to the spectra of anorthite and water ice frost.

Samples: Nine glass samples have been analyzed. The samples are compositionally similar to those in the regolith on the Moon and Mercury, with the notable caveat that some of the iron is oxidized (Table 1). It is known that the oxidation state of iron affects the visible-NIR region of the spectrum and may affect the UV as well. Total iron in the glasses varies from 0 to ~21% when expressed as total FeO, with the fraction of iron as Fe³⁺ varying from 0 to almost 80%, but not correlated to total iron abundance. The abundances of other transition elements are small, with TiO₂ being the most abundant and varying from 0 to about 1.5%. TiO₂ content does not correlate with FeO. Iron is by far the most abundant transition metal, as is typical in most naturally-occurring glasses on Earth and other terres-

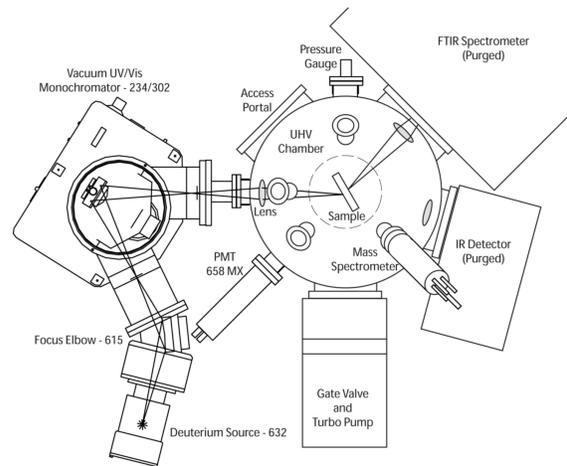


Figure 1. Optical layout including VUV-Vis system, IR system, and vacuum chamber.

trial bodies.

Laboratory Measurements: The glass samples were ground to talc-like consistency (grain sizes <1 μm) for the reflectance measurements. About 100 mg of each sample were placed in a copper sample holder mounted in a vacuum chamber on the end of a cryostat (Figure 1). The sample is vertically oriented and held in place behind a 1 mm thick MgF₂ window, with a thermocouple for accurate temperature measurements. Measurements were obtained with a McPherson 302

Table 1. Glass Compositions Studied

TAS class	rhyolite	dacite	dacite	andesite	basalt	basalt	basalt	basalt	basalt
Wt.% oxide	85-43	83-59	85-3	82-70	K2296 1	K2295 2	K2294 3	K2292 4	K2289 5
SiO ₂	74.94	67.07	66.47	58.81	46.47	46.22	46.28	45.45	50.68
TiO ₂	0.29	0.54	0.74	0.71	0.39	1.58	1.02	0.27	0.00
Al ₂ O ₃	15.80	17.67	18.01	17.07	7.84	14.24	13.15	26.63	13.55
Cr ₂ O ₃	0.00	0.03	0.03	0.00	0.04	0.01	0.00	0.00	0.02
FeO (MS)	1.09	2.73	0.35	2.75	5.58	3.15	4.01	1.11	0.00
Fe ₂ O ₃ (MS)	0.65	0.00	0.56	3.45	15.18	11.73	15.79	3.69	0.00
MgO	0.45	2.48	0.06	6.24	17.33	12.19	6.16	6.83	14.00
CaO	1.81	5.02	4.24	7.83	8.39	10.13	12.18	15.21	21.67
MnO	0.02	0.40	2.52	0.12	0.17	0.10	0.16	0.03	0.00
Na ₂ O	2.57	2.77	3.57	2.14	0.04	0.83	0.36	0.36	0.09
K ₂ O	1.29	0.65	1.72	0.28	0.00	0.11	0.05	0.06	0.00
P ₂ O ₅	0.10	0.14	0.76	0.12	0.02	0.06	0.06	0.02	0.01
H ₂ O (ppm)	12400	3100	14400	n.a.	364	468	658	269	486
F	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.20	0.40	0.37						
Oxide total	100.44	100.20	100.85	99.52	101.52	100.41	99.28	99.68	100.08
%Fe ³⁺	35	0	59	53	71	77	78	75	0
Total Fe as FeO	1.67	2.73	0.86	5.85	19.24	13.70	18.21	4.43	0.00
Total FeO+TiO ₂	1.96	3.27	1.60	6.56	19.63	15.28	19.23	4.70	0.00

vacuum monochromator with a deuterium source and a PMT detector mounted in front of a MgF_2 window coated with a scintillation material. Each sample was maintained at room temperature and $\sim 10^{-7}$ – 10^{-8} torr. Each sample was heated to $\sim 80^\circ\text{C}$ overnight at this pressure to remove all adsorbed molecular water. Thus, only hydroxyl, either internal or chemisorbed, remained present. A reflectance standard was also in the chamber, mounted immediately below but on the same plane as the sample. Powdered MgF_2 , also behind a 1 mm thick MgF_2 window, was used as the standard because of its high reflectivity through the vacuum UV. This configuration also assured nearly identical optical characteristics for the sample and reference, necessary for acquiring accurate reflectance spectra from diffusely-scattering media such as powdered glass or other granular materials. Although powdered MgF_2 can be used as a standard because it has a flat nearly 100% transmission from ~ 400 to 210 nm, its transmission begins to decrease at shorter wavelengths, reaching $\sim 60\%$ by 120 nm. This darkening of the standard results in an artificial brightening of the calculated reflectance that we correct through an empirically-derived factor based on measurements of materials that are known to not brighten at these wavelengths.

Each spectrum was obtained in three parts because the spectral range covers three orders. The 130 nm – 200 nm range is obtained without an order sorting filter, while the 200 nm – 400 nm and 380 – 550 nm ranges are covered with two band pass filters to block light from the shorter wavelength orders. An overlap of ~ 15 nm is included for each segment.

Results: Reflectance data were collected for nine glass samples, alumina, anorthite, and water frost (Figure 2) using the apparatus described above. The water ice data was collected differently than those from the non-ice samples by placing powdered MgF_2 in the sample holder, cooling the sample down to ~ 120 K, exposing to atmosphere so a thin frost would form, and then evacuating the chamber once more. Water frost accumulated over the surface of the MgF_2 window on the sample holder.

The water ice spectrum is consistent with literature values for fine-grained frost [e.g. 2]. Both water ice and alumina are similar, staying bright into the VUV where single strong absorption feature occurs at ~ 200 nm for alumina and ~ 160 nm for water frost. Silicates behave differently due to the presence of cation and transition elements in their compositions (6,7). Both iron abundance and valence state control the position of the absorption near 300 nm, and are responsible for the NUV slope that has been often reported for these materials (8). Our results demonstrate that as iron con-

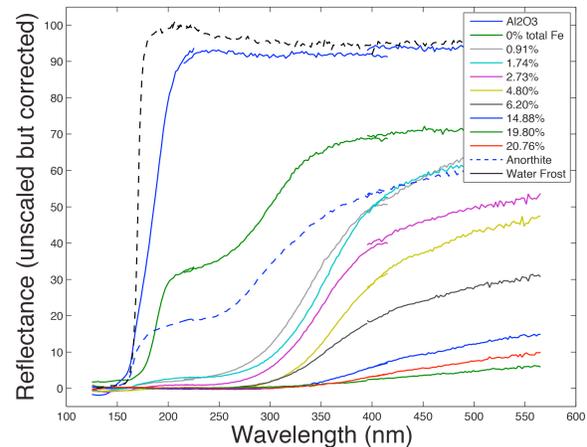


Figure 2. Reflectance spectra of glasses, anorthite, alumina, and water frost. Legend provides total iron (Fe^{2+} and Fe^{3+}) content.

centration decreases, the NUV drop off near 400 nm shifts to shorter wavelengths and the center of the absorption band also shifts shortward. The effects of iron oxidation in the VUV are small compared to the effects of iron abundance. The position of the absorption band near 300 nm and the brightness of the VUV continuum near 225 are both sensitive to changes of a percent or less in iron abundance and may provide an additional means for quantifying the iron abundance of low iron minerals and glasses.

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