SPECTRAL CHEMISTRY OF GREEN GLASS-BEARING 15426 REGOLITH
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The distinctive composition of Apollo 15 green glasses, typified by clods of spherules in soils collected near the Apennine Front, has focussed recent laboratory research onto studies of phase equilibria, petrogenesis, and physical properties of these Fe-rich Ti-poor silicate glasses. The laboratory investigations have centered on synthetic analogues simulating Apollo 15 green glass compositions equilibrated at appropriately low oxygen fugacities. However, there is always the question of how closely the valence and coordination symmetry of iron in the synthetic phases match those in pristine lunar samples. Our earlier Mossbauer and visible-region spectral measurements of synthetic glasses corresponding to Apollo 15 green glass and Luna 24 brown glass compositions suggested that significant proportions of ferric iron are present in specimens equilibrated at $P_{O_2} = 10^{-14}$ atmos. If such high Fe$^{3+}$ ion concentrations do occur in lunar glass samples, their presence would have profound implications for redox conditions that existed during the evolution of the Moon's regolith. Therefore, it was desirable to search for similar Fe$^{3+}$ spectral features in Mossbauer spectra of a pristine Apollo 15 green glass-bearing regolith sample, and such a study is reported here. Although ferric iron was not detected in the lunar green glass sample, other problems were encountered which have a bearing on interpretations of iron coordination chemistry and reflectance spectral profiles of glass-bearing regoliths.

Room temperature Mossbauer spectra illustrated in Fig. 1 were measured on a green glass spherule concentrate, extracted from breccia 15426. Some of the spherules contain abundant crystallites of olivine (Fa$_{25}$). Mossbauer spectra were also obtained for three synthetic glasses: (1) a green glass (simulating the composition of the spherules in sample 15426) made at $P_{O_2} = 10^{-14}$ atmos in a Fe crucible (Fig. 2); (2) a homogeneous Fe-Ti silicate glass, designated as F$_3$T$_1$, quenched from 1400°C and $P_{O_2} = 10^{-9}$ atmos; and (3) devitrified F$_3$T$_1$ glass, which was quenched from 1250°C and $P_{O_2} = 10^{-9}$ atmos, and contained crystallites of olivine, Fa$_{10}$.

The spectrum envelopes of each glass show two regions of comparable absorption (peak areas) at approx. zero and 2 mm sec$^{-1}$, indicating that Fe$^{2+}$ ions predominate in all of the glass samples. The two additional "spikes" at approx. -0.3 and +2.5 mm sec$^{-1}$ in the spectrum of the green glass 15426 spherules (Fig. 1) correlate with the presence of the olivine Fa$_{25}$ crystallites. Similar "spikes" are present in the devitrified F$_3$T$_1$ glass spectrum. Problems arose, however, with fitting of the remainder of the Apollo 15 green glass spectrum because of uncertainties about line shapes of Fe$^{2+}$ quadrupole doublets in short-range ordered glass structures. One approach is to fit the spectra to several closely spaced doublets with Lorentzian line-shape. Another approach is to fit the glass spectra to peaks having a hybrid Lorentzian-Gaussian line-shape. Statistical analyses of the synthetic green glass fitted spectrum (Fig. 2) indicated that a 60% Lorentzian-40% Gaussian line-shape gave the lowest $\chi^2$ value. However, the low velocity ($0$ mm sec$^{-1}$) and high velocity (2 mm sec$^{-1}$) peaks having different heights and halfwidths but comparable integrated areas. The presence of ferric iron in a glass would be indicated if the low velocity peak has a higher integrated area than the high velocity peak. The peak area data show no evidence for Fe$^{3+}$ ions in any of the four glasses reported here.

The results of the present study indicate the absence of significant
ferric iron (i.e. below the 1% detectability limit of Mossbauer spectroscopy) in green glass spherules from sample 15426 and in a synthetic green glass of similar composition synthesized at $P_{O_2} = 10^{-14}$ atm. The absence of Fe$^{3+}$ ions also in Fe-Ti-bearing glasses, including the Apollo 17 orange spherules from sample 74220$^{10,11}$ and in synthetic analogues which all contain detectable Ti$^{3+}$ ions, may be attributed to the incompatibility of coexisting Fe$^{3+}$ and Ti$^{3+}$ in silicate glasses. However, all available spectral evidence (Mossbauer and visible-region spectra) suggests that substantial amounts of ferric iron do exist in the glasses simulating Luna 24 brown glass compositions. Confirmatory experiments are required however on a pristine 100 mg regolith sample from Mare Crisium.$^{12}$

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**Fig. 1.** Mossbauer spectrum of green glass spherules from breccia 15426.  
[Peaks 1 & 2: olivine, Fe$^{2+}$ (δ = 1.118 mm/s relative to Fe foil; Δ = 2.844 mm/s; Π = 0.25 mm/s; %A = 12). Peaks 3 & 4: Fe$^{2+}$ in glass (δ = 1.039 mm/s; Δ = 1.966 mm/s; Π = 0.69 & 0.97 mm/s; %A = 42 & 46; % gaussian = 40). $\chi^2 = 600$]  

**Fig. 2.** Mossbauer spectrum of synthetic green glass.  
[Peaks 1 & 2: Fe$^{2+}$ in glass (δ = 1.014 mm/s; Δ = 1.913 mm/s; Π = 0.67 & 0.90 mm/s; %A = 48 & 52; $\chi^2 = 537$ for 40% gau; 562 for 30% & 50% gau; 1100 for 0% gau)]