Sulfur multiple isotopes of the Moon: ^{33}S and ^{36}S abundances relative to Canon Diablo Troilite. J. Farquhar and B. A. Wing, Earth System Science Interdisciplinary Center and Department of Geology, University of Maryland, College Park, MD 20742, jfarquha@essic.umd.edu, wing@essic.umd.edu.

Abstract: We are measuring sulfur multiple isotope abundances in 10 lunar basalts, a suite of terrestrial igneous rocks, and samples of Canon Diablo Troilite (CDT). Ongoing measurements suggest that the acid volatile sulfur (AVS) in lunar basalts is only slightly enriched in ^{34}S relative to CDT, confirming earlier results [1, 2]. High-precision sulfur multiple isotope measurements also indicate that lunar AVS falls on a fractionation line defined by the bulk composition of CDT and a slope of 0.515.

Methods: We extract acid volatile sulfur from rock and mineral powders following established protocols [1, 3]. Briefly, powders are reacted with 6N HCl under flowing N_2 gas. The evolved H_2S bubbles through condensor, then through a milli-Q water trap and into a Cd acetate solution, where the H_2S is trapped as CdS. We convert the CdS to Ag_2S by addition of an ~3% $AgNO_3$ solution. The Ag_2S is filtered, rinsed with milli-Q water and a 1M NH_4OH solution, and then dried. Samples of Ag_2S of ~1-3 mg are reacted with pure F_2 at ~240°C for ~12 hours. The resulting SF_6 is purified cryogenically and chromatographically, and isotopic abundances are determined by monitoring m/z = 127, 128, 129, and 131 ($^{32}SF_5^+$, $^{33}SF_5^+$, $^{34}SF_5^+$, and $^{36}SF_5^+$) on a ThermoFinnigan 253 mass spectrometer. Samples of powdered Canon Diablo Troilite (USNM 6275) are subject to the extraction procedure outlined above, and their measured isotopic abundances are used as references for δ values of concurrently measured samples. Uncertainties in the sulfur multiple isotope measurements are estimated from repeat analyses of high-purity international standards; $\delta^{34}S$ - 1σ =0.08‰, $\Delta^{33}S$ - 1σ =0.005 ‰, $\Delta^{36}S$ - 1σ = 0.08 ‰.

Results and comparisons: Sulfur multiple isotope and total sulfur abundances obtained so far are reported in Table 1.

TABLE 1. LUNAR SULFUR MULTIPLE ISOTOPE AND TOTAL SULFUR ABUNDANCES

Sample	$\delta^{34}S$ (‰)[a]	$\Delta'^{33}S$ (‰)[b]	$\Delta'^{36}S$ (‰)[c]	[S] (ppm)[d]
10049.97	t.b.d.	t.b.d.	t.b.d.	2131
10057.27	-0.71	-0.003	-0.01	2074
12018.248	t.b.d.	t.b.d.	t.b.d.	546
12021.592	t.b.d.	t.b.d.	t.b.d.	626
12022.28	0.47	0.025	-0.01	1028
70017.52	0.52	-0.001	0.04	1254
70215.321	t.b.d.	t.b.d.	t.b.d.	1721
74275.207	t.b.d.	t.b.d.	t.b.d.	1174
75035.219	t.b.d.	t.b.d.	t.b.d.	1556
75075.16	t.b.d.	t.b.d.	t.b.d.	1374

Note: t.b.d indicates that sulfur multiple isotope composition is to be determined.

[a]All δ values reported relative to measured isotopic abundances of CDT (USNM 6275)

[b]$\Delta'^{33}S = \ln(\delta^{33}S/1000+1) - 0.515\times\ln(\delta^{34}S/1000+1)$

[c]$\Delta'^{36}S = \ln(\delta^{36}S/1000+1) - 1.9\times\ln(\delta^{34}S/1000+1)$

[d]Reported S contents are **minimums** because of material loss during sample transfer from filters used in rinse procedure. Precision on reported numbers is O(10 ppm), and results from weighing errors only.

Previous Lunar Measurements. Lunar basalts sampled during Apollo 11 and 12 have AVS with an average sulfur multiple isotope composition of $\delta^{34}S$ = 0.53 (0.13), $\Delta^{33}S$= -0.03 (0.06), and $\Delta^{36}S$ = -0.35 (0.62) [1,2]. Our new measurements are within uncertainty of these results.

Measurements from the meteoritical record. Previous studies, most notably by Gao and Thiemens [3-5} have documented a striking homogeneity for $\Delta^{33}S$ and $\Delta^{36}S$. Their measurements of troilite from 13 iron meteorites yielded a mean of 0.05 ‰ and –0.1 ‰ relative to CDT and measurements of acid volatile sulfur from ordinary chondrites, enstatite chondrites, and carbonaceous chondrites yields similar values with a range of –0.021 to 0.013 ‰ and –0.05 to 0.13 ‰ for $\Delta^{33}S$ and $\Delta^{36}S$, respectively. Small, but meaureable $\Delta^{33}S$ variations of 0.04 to 0.16 ‰ for sulfides some achondritic meteorites have been reported [6]. Our measurements suggest that lunar $\Delta^{33}S$ and $\Delta^{36}S$ are similar to the $\Delta^{33}S$ and $\Delta^{36}S$ of CDT.

Measurements from the terrestrial record. Repeat analyses of internationl standards yield $\Delta'^{33}S$= 0.078 (0.006) and $\Delta'^{36}S$ = -0.61 (0.08), iaea-s1; $\Delta'^{33}S$= 0.023 (0.003) and $\Delta'^{36}S$ = -0.37 (0.06), iaea-s2; $\Delta'^{33}S$= 0.057 (0.007), and $\Delta'^{36}S$ = -0.42 (0.07), iaea-s3.

References: [1] Rees and Thode (1974) 5th PLPSC 1963-1973; [2] Thode and Rees (1971) EPSL 434; [3] Gao and Thiemens (1991) GCA, 55, 2671-2679; [4] Gao and Thiemens (1991) GCA, 57, 3159-3169; [5] Gao and Thiemens (1993, GCA, 57, 3171-3176 [6] Farquhar et al. GCA 64, 1819.