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IN-SITU XRF AND GAMMA RAY SPECTROMETER FOR MARS SAMPLE
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We propose a combined in-situ x-ray fluorescence (XRF) and
passive gamma-ray spectrometer instrument for the chemical
elemental analysis of various Martian surfaces and samples. The
combined instrument can be carried on board a rover. The passive
γ-ray or the neutron-excited γ-ray system would be used to
determine the elemental composition of the Martian surface while
the rover is in motion. The XRF system would be used to perform
analysis either on the Martian surface or on collected samples
when the rover is stationary. This latter function is important
both in cataloguing the collected samples and in the selection of
samples to be returned to earth. For both systems, data
accumulation time would be on the order of 30 minutes. No sample
preparation would be necessary.

XRF is a well-established and successful technique in
performing in-situ chemical analysis of planetary surface
samples. In previous planetary missions such as Viking and
Venera, XRF measurements were made using radioisotopes as
excitation sources and proportional counters as energy-dispersive
detectors. Although our instrument does not preclude the use of
radioisotopes we emphasize here the use of a miniature x-ray
generator as the excitation source and mercuric iodide as the
energy-dispersive detector.

A low-power (10 W) battery-operated x-ray generator was
developed at Goddard Space Flight Center several years ago. The
x-ray generator weighs 6 kg, is capable of supplying 68 kV and
100 microamps of anode current, and is powered by a 18-V battery.
It has a grounded anode with no high-voltage cables. Such an x-
ray generator with variable spectral distribution can provide far
higher x-ray fluxes than radioactive sources. Recently, similar
battery-operated x-ray generators have also become commercially
available.

The energy resolution of room-temperature mercuric iodide
detectors has been improving steadily in recent years. Under
laboratory conditions it is now gradually approaching the
resolution of cooled Si(Li) detectors. However, presently
available mercuric iodide detectors with good stability and
acceptable energy resolution for the Mars sample return mission
have sensitive areas of only a few mm^2. Such small detection
areas need not be a problem with the proposed XRF instrument
because of the high x-ray flux available from the x-ray
generator. Therefore the combination of a miniature x-ray
generator with a mercuric iodide detector should provide an in-
situ XRF instrument with energy resolution and detection

efficiency not achievable by previous planetary instruments.

Table I lists some of the elements which can be detected by a passive τ-ray spectrometer using a 7.5x7.5 cm NaI(Tl) crystal. The expected integration time for each element to reach 10% uncertainty is calculated using methods similar to those in Evans and Squyres[1]. The neutron spatial and energy distribution, and consequently the τ-ray flux, is highly sensitive to the H content. Therefore calculations were carried out for different cases of soil and H_2O: with 1% H_2O, with 25% H_2O, and with a "dry" layer of soil with 1% H_2O covering soil with 25% H_2O for three different thicknesses of the top layer. Table I shows that while the rover is in motion integration time on the order of 30 minutes could provide sufficient information concerning H, K, and Fe. When the rover is stationary, most of the elements in Table I could be analyzed in a few hours. Of course, if weight and power constraints permit the use of a neutron generator, the integration times in Table I could be reduced substantially, and additional elements could be detected.

Table I. Integration time (hours) to measure an element to 10% uncertainty by the passive τ-ray spectrometer

Element	Mode*	Homogeneous soil + H_2O		Layer soil with 1%H_2O over soil+25%H_2O Thickness of upper layer		
		soil+ 1%H_2O	soil+ 25%H_2O	20g/cm²	50g/cm²	100g/cm²
Fe	C	0.7	0.3	0.5	1.1	1.1
Si	C	4.0	1.6	2.8	7.6	7.8
Cl	C	3.5	1.4	2.3	5.8	5.9
H	C	68.0	0.03	0.3	5.7	74.0
Si	I	0.1	0.5	0.2	0.1	0.1
Mg	I	2.1	11.0	3.7	2.5	2.1
Fe	I	0.2	1.0	0.3	0.2	0.2
K	R	0.3	0.5	0.4	0.3	0.3
Th	R	6.0	9.4	7.0	6.0	6.0

*Mode: C — τ rays produced by neutron capture
      I — τ rays produced by neutron inelastic scattering
      R — τ rays produced by natural radioactivity

It should be noted that both the XRF and the τ-ray spectrometer will share much of the analyzing electronics beyond their respective amplifier stage. Because of the relatively coarse resolution of the NaI(Tl) spectrometer, a single analog-to-digital converter will be sufficient to accommodate both XRF and τ-ray spectra. Thus economy in both weight and cost can be realized in such a combined XRF and τ-ray instrument.

1. Evans, L.G. and Squyres, S.W. (1987) J. Geophys. Res., 92, 9153-9167.