Argon Content of the Martian Atmosphere at the Viking 1 Landing Site: Analysis by X-ray Fluorescence Spectroscopy

Abstract. *The argon content of the martian atmosphere at the Viking 1 landing site is ≤ 0.15 millibar or ≤ 2 percent by volume (95 percent confidence level).*

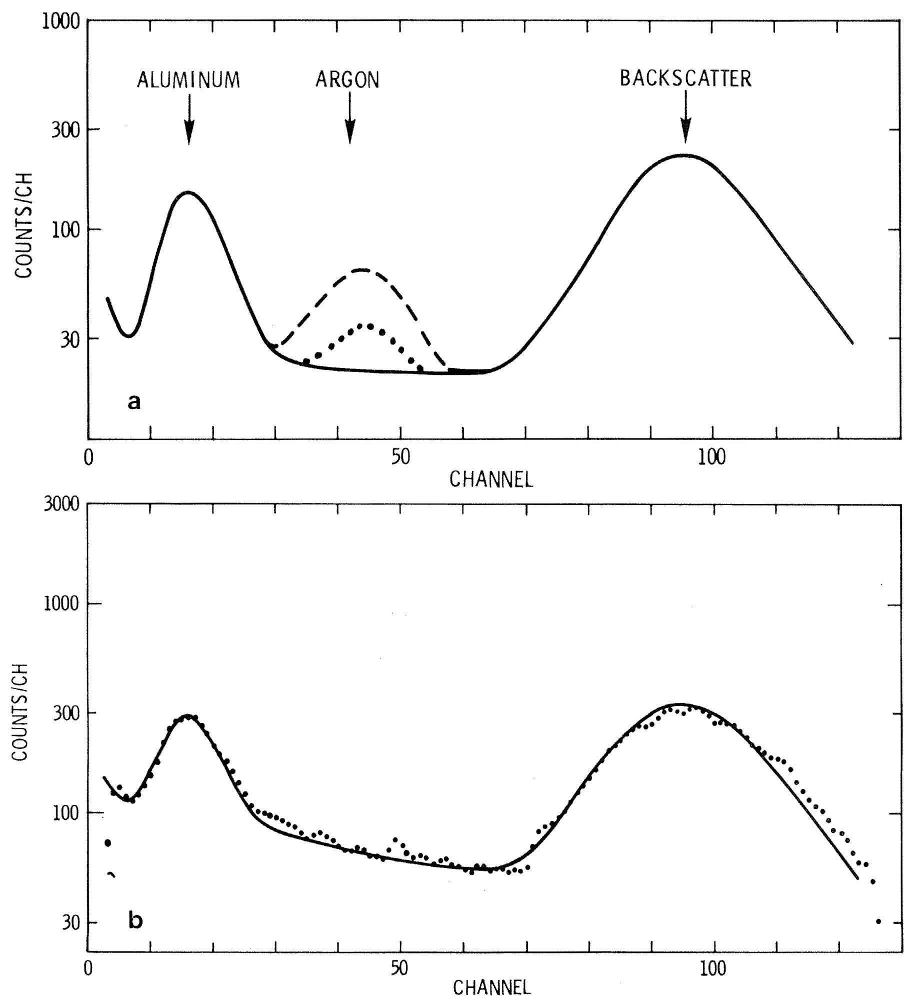
The Viking x-ray fluorescence spectrometer (*1*), although designed for elemental analysis of martian surface soil, also detects the gaseous elements within its sensitivity range. Operation in the calibration mode, that is, without a soil sample in the analysis chamber, thus provides data on the abundance of elements with $Z > 12$ in the martian atmosphere.

The analysis chamber is a hollow square prism 2.5 cm on a side, with thin windows on two adjacent sides which permit x-rays from radioactive ^{55}Fe and ^{109}Cd sources to irradiate its interior. Backscattered and fluorescent x-rays from the chamber are detected by sealed, gas-filled proportional counters flanking the radioactive sources. The chamber walls opposite the windows have calibration plaques that produce reference spectra when the instrument is operated without a sample.

The question of pressure and concentration of Ar in the martian atmosphere has aroused much interest recently (*2*), largely because of an interpretation of the engineering data from the mass spectrometer on the Soviet probe Mars 6 (*3*). The anomalously high ion-pump current reported was consistent with a large content of inert gas in the atmosphere. From what is known of the geochemistry of Mars, this gas is probably Ar, and contents up to 30 mole percent were implied (*2, 3*). Reevaluation of previous observations and models of the planet and its atmosphere did not preclude such Ar contents (*2*).

In addition to being of scientific interest, the determination of the Ar content of the martian atmosphere at the Viking landing site is of considerable operational importance. The ion pump of the gas chromatograph–mass spectrometer on the lander has a limited tolerance for inert gases; important operational decisions with respect to the use of this instrument for atmospheric analysis depend on knowledge of the partial pressure of Ar and other inert gases. Accordingly, a strategy was developed that would permit the measurement of Ar as early as possible in the Viking mission, first in the upper atmosphere by the Viking entry mass spectrometer (*4, 5*), and then by taking optimum advantage of the independently planned calibration sequence for the x-ray fluorescence spectrometer (*1*). After it was established that the Ar content does not exceed 0.5 mbar, a complete sequence of atmospheric measurements was executed by the lander mass spectrometer (*6, 7*).

Counter 2 of the x-ray fluorescence spectrometer is the most useful for Ar determination because of the absence of calibration target peaks at the Ar emission energy (2.96 kev). The calibration spectrum of counter 2 in vacuo has an Al K_α peak (1.49 kev), mainly from the calibration plaque, and one caused by backscattered Mn K_α x-rays (5.9 kev) emitted by the ^{55}Fe radioisotope source (Fig. 1a).



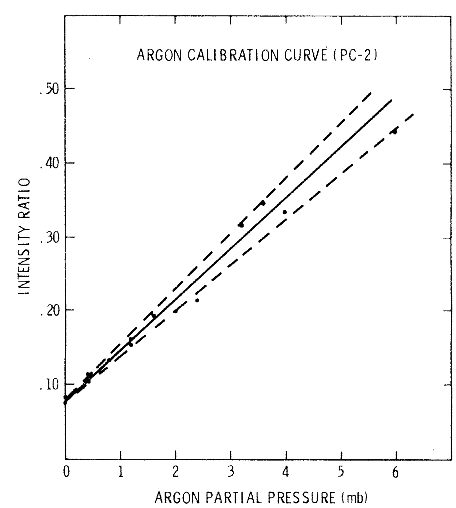


Fig. 1 (left). Spectra used in Ar determinations. (a) Calibration spectra: Solid line, in vacuo; dashed line, 20 percent Ar with CO_2 at 8 mbar; dotted line, 5 percent Ar with CO_2 at 8 mbar. (b) Experimental spectra: Solid line, calibration in Mars orbit prior to separation of the lander; dotted line, data points (three-point sliding average) for spectrum obtained on sol 0 at the Viking 1 landing site on Mars. Fig. 2 (above). Ratio of integrated intensities of Ar peak to backscattered ^{55}Fe radiation versus partial pressure of Ar in laboratory calibration experiments (mixtures of Ar and CO_2).

Spectra taken in the terrestrial atmosphere and in laboratory mixtures of varying proportions of CO_2 and Ar show a strong peak at 2.96 kev that is caused by Ar K_α x-rays (Fig. 1a). Calibration of the instrument for Ar determinations (Fig. 2) was made by introducing mixtures of CO_2 and Ar in various proportions and at different pressures into a vacuum chamber in which a flight-type x-ray fluorescence spectrometer was installed. Spectra were obtained at three combinations of total pressure and seven different ratios of Ar to CO_2. Appropriate integration limits for the Ar K_α and ^{55}Fe backscatter peak were chosen by inspection. In addition, the instrument on Viking 1 lander was calibrated in an atmosphere (6.9 ± 0.13 mbar) of pure Ar prior to being installed on the spacecraft. After correction for source decay (2.60-year half-life of ^{55}Fe), the instrument sensitivity was 471 count/mbar (69.1 seconds, channels 35 to 50) at the time of landing. The spectral characteristics for 5 percent and 20 percent Ar in CO_2 (8 mbar total pressure) are shown in Fig. 1a. Two days prior to landing a baseline spectrum was taken of the instrument on Viking 1 lander to verify instrument settings. This spectrum, which because of mission constraints was taken at a lower gain than the bulk of the landed spectra, was mathematically expanded and normalized to the backscatter peak. It is presented as a solid line in Fig. 1b for comparison with a smooth curve of the pooled data from three separate scans after landing. No Ar peak is apparent in the spectrum taken after the instrument was landed on Mars. Also not detected are gases containing chlorine (channel 36) or sulfur (channel 30). Over the total measurement period of 6 hours, the temperature at the sample cavity slowly dropped from 25° to 19°C (calibration was at 28°C). Integrated over the Ar peak, the total count measured in situ was virtually identical to that prior to landing. When the above Ar sensitivity is combined with the background count, the Ar concentration determined at the landing site of the Viking 1 lander is less than 0.15 mbar at the 95 percent confidence level. The reported 7.7 mbar total pressure (*8*) at the landing site would place the Ar concentration at not more than 2 percent by volume. This result is in good agreement with the data reported by the entry mass spectrometer (*5*) and the mass spectrometer on the lander (*7*), which reported 1.5 percent and 1 to 2 percent by volume, respectively.

The abundance of Ar in the martian atmosphere reflects (i) the original abundance and (ii) the balance of processes supplying and removing the element from the atmosphere. Because of the high $^{40}Ar/^{36}Ar$ ratio (*5, 7*), most of the atmospheric Ar is radiogenic in origin, having been formed by decay of ^{40}K. Clearly, considerable importance will be attached to the K contents of the martian surface materials analyzed by the x-ray fluorescence spectrometer on the lander, and it is hoped that clues can be provided by the x-ray fluorescence data not only regarding the internal and surficial differentiation of Mars but also regarding the evolution of its atmosphere.

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9. Essential contributions to the design, construction, and operation of the Viking x-ray fluorescence spectrometer were made by A. Castro and W. Kelliher. R. R. Moore ran laboratory argon calibrations. C. D. Rowe and R. P. Christian performed data reduction. J. L. Gooding and P. H. Evans assisted in analyzing the calibration data. This work was supported in part by NASA (Viking Program), grants NAS 1-11855, NAS 1-11858, L-9717, and NAS 1-9000. We thank S. Dwornik for his continuing help and assistance.

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Physical Properties of the Martian Surface from the Viking 1 Lander: Preliminary Results

Abstract. *The purpose of the physical properties experiment is to determine the characteristics of the martian "soil" based on the use of the Viking lander imaging system, the surface sampler, and engineering sensors. Viking 1 lander made physical contact with the surface of Mars at 11:53:07.1 hours on 20 July 1976 G. M. T. Twenty-five seconds later a high-resolution image sequence of the area around a footpad was started which contained the first information about surface conditions on Mars. The next image is a survey of the martian landscape in front of the lander, including a view of the top support of two of the landing legs. Each leg has a stroke gauge which extends from the top of the leg support an amount equal to the crushing experienced by the shock absorbers during touchdown. Subsequent images provided views of all three stroke gauges which, together with the knowledge of the impact velocity, allow determination of "soil" properties. In the images there is evidence of surface erosion from the engines. Several laboratory tests were carried out prior to the mission with a descent engine to determine what surface alterations might occur during a Mars landing. On sol 2 the shroud, which protected the surface sampler collector head from biological contamination, was ejected onto the surface. Later a cylindrical pin which dropped from the boom housing of the surface sampler during the modified unlatching sequence produced a crater (the second Mars penetrometer experiment). These two experiments provided further insight into the physical properties of the martian surface.*

General description of the landing area. The specific physical properties of the martian surface at the landing site relevant to the physical properties of the martian surface must be considered in the broader context based on the use of Viking orbiter images and the general scene viewed by the lander cameras in order to achieve balanced interpretations (*1*). Orbital images of the entire Chryse