CHEMICAL COMPOSITION OF MARTIAN SURFACE AND ROCKS ON PATHFINDER MISSION: THE ALPHA-PROTON-X-RAY SPECTROMETER; T. Economou, A. Turkevich, Laboratory for Astrophysics and Space Research, University of Chicago, 933 E. 56th Street, Chicago, IL. 60637, USA; R. Rieder, H. Wänke, Max-Planck Institut für Chemie, 23 Saarstrasse, D-5000, Mainz, Germany.

Although the Mars pathfinder mission is primarily designed as an engineering precursor, pioneering a new approach for landing-type missions to Mars, it is also intended to obtain a significant amount of scientific information. The Alpha-Proton-X-Ray Spectrometer (APXS) is designed to provide a complete and detailed chemical analysis of the Martian soil and rocks near the landing site. All elements (except H) present in amounts above a fraction of a percent and, in many cases, greater than several hundred ppm will be identified and their elemental abundance determined. The APXS will be transported on the Martian surface by a microrover which will enable the APXS to select and analyze multiple soil and rock samples.

The APXS instrument, designed for the Mars Pathfinder mission, consists of a complex sensor head and the instrument electronics. The sensor head houses nine Cm-244 sources in a ring-type geometry and three detectors for the measurement of the three components: a telescope of two Si-detectors for the measurement of alpha-particles and protons and a silicon PIN X-ray detector. The sensor head is deployed to the Martian surface by a simple but sophisticated deployment mechanism that can place the APXS sensor head in pre-selected position with high accuracy. The sensor head will be outside the microrover Warm Electronics Box (WEB) and it will be exposed to the full diurnal temperature range of Martian environment. The instrument electronics contains the alpha, proton and x-ray analog signal processors, all the digital, control and logic circuitry, a microcontroller-based pulse height analyzer, RAM and ROM containing the APXS experiment software.

The principle of the APXS technique, employed to obtain compositional information, is based on three interaction of alpha particles from a radioisotope (Cm-244) with matter: a/ simple Rutherford backscattering, b/ production of protons from \((a,p)\) reactions on light elements, and c/ generation of characteristic x-rays, as a consequence of excitation of the atomic structure during bombardment and subsequent x-ray emission. Measurement of the intensity and energy distribution of these three components yields information on the elemental chemical composition of the sample. In terms of sensitivity and selectivity, data are partly redundant and partly complementary: Alpha backscattering is superior for light elements (C, O), while proton emission is mainly sensitive to Na, Al, Si and Mg, and X-ray emission is more sensitive to heavier elements (Na to Fe and beyond). A combination of all three measurements enables determination of all elements (with the exception of H) present at concentration levels as stated above.

The alpha and proton modes of the APXS instrument have been described in detail in other occasions (1-3). The X-ray mode of the instrument utilizes solid state detectors that do not require active cooling for proper operation, although the energy resolution is a function of operating temperature. For the Pathfinder, as well as for the Russian Mars-96 missions, additional improvements in the performance of the x-ray mode have been achieved by replacing the HgI2 x-ray detector with the newly developed hermetically sealed silicon PIN diodes. Silicon, in addition
to being much more reliable material, has many other advantages over the highly unstable HgI₂ material. The very low noise-to-signal ratio of the silicon x-ray system enhances significantly the capability of the instrument to determine many minor and trace elements.

Fig. 1 shows a typical x-ray spectrum of Allende meteorite obtained in the laboratory with the APXS flight instrument using 50 mCi of Cm-244 as an excitation source and moderately cooling the x-ray detector (~ -20°C). All the elements heavier than Na, present in the Allende meteorite above several hundreds of ppm, are identified with marks showing their characteristic x-ray lines. As an example of the excellent sensitivity of the instrument can be seen when comparing the goodness of the fit between the observed Allende data and calculated spectra including potassium (Fig. 1a) and without it (Fig. 1b). The bottom part of Fig. 1 in both cases shows the residual spectrum between observed and calculated spectrum. From the goodness of the fit, the χ² and the differences in the residual spectra, it is obvious, that much lower than 300 ppm of K that is present in Allende meteorite can be easily determined in any unknown sample.

![Fig. 1a](image1.png)  ![Fig. 1b](image2.png)

As built for the Pathfinder, the APXS, including the sensor head, all electronics, cables, connectors and mounting box weighs 550 grams, has a volume of about 450 cm³, operates from a ±7.5 V power supply and consumes less than 330 mW.

The paper will present a detailed description of the techniques employed, the design of the instrument and the results of environmental tests and laboratory measurements.