THE X-RAY MODE OF THE ALPHA PARTICLE ANALYTICAL INSTRUMENT

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The Alpha Particle Instrument with its alpha, proton, x-ray, and now, the new gamma ray modes, is a versatile analytical instrument that can provide the most complete in-situ chemical analyses of samples on planetary missions. The instrument is based on interactions of radiation with matter that are well understood and it can be easily calibrated in the laboratory before being sent into space. Its performance has been proven during space missions in the past.

The excitation of characteristic x-rays in the Alpha Particle instrument is caused by two mechanisms: 1) by the alpha particles from the curium radioactive source - the same source that is used in the alpha, proton and the gamma modes - and, 2) by the plutonium L x-ray lines (14-22 keV) which are more effective than alpha particles in exciting higher Z elements. Such excitation is sufficient to obtain good analyses for all the major elements in relatively short counting periods. To enhance the sensitivity for certain minor and trace elements, additional auxiliary x-ray excitation sources can be utilized (e.g ^{109}Cd , ^{241}Am, etc).

In the past, (e.g. on the recent Soviet Phobos mission), the X-ray mode of this instrument was implemented by using a cryogenically cooled Si(Li) detector. However, for many missions, including a mission to Mars, such cooling is impractical or impossible. In such cases ambient temperature x-ray detectors are needed. (J. Iwanczyk et al, 1986, 1989).

We report here the first preliminary results obtained using an x-ray probe containing an ambient temperature HgI_2 x-ray detector attached to the Alpha Particle instrument as shown in Fig. 1. The detector used in this work had an area of 5 mm^2 with about 500 mm depletion depth . It was biased at -800V. The detector and the first stage FET transistor were slightly cooled to about 0° C by small Peltier coolers. Such cooling will not be necessary for most missions . The detector was exposed to the x-rays from the sample in vacuum and acted therefore as a windowless detector. A 3.5 mm parylene N type film was coated directly on to the HgI_2 crystal to prevent contamination and to enable the detector to operate properly in vacuum. The total energy resolution of the x-ray system was 225 eV at 6.04 keV of Fe K_a line The electronic noise was 187 eV.

With this arrangement we were able to detect the very low x-ray energies that even the best laboratory silicon detector with thin Be window have difficulties detecting. Fig. 2 shows the x-ray spectrum obtained from a Na_2CO_3 sample. The sodium line at 1.04 keV is clearly above the noise level of the system. Fig.3 shows the x-ray spectrum obtained from a sample of an Allende meteorite There, the 1.25 keV Mg K_a line is well separated from 1.74 keV Si K_a line. With proper line fitting algorithms even a line from about 1.7 % aluminum (1.49 keV) sample can be detected in the presence of 15% Mg and 13% Si present in the Allende meteorite . The other lines are due to sulphur, calcium, titanium,chromium,manganese,iron and nickel. Notice that the Fe K_b line is very well separated from the Ni Ka line. Fig.4 shows for comparison a similar spectrum obtained with the Phobos x-ray instrument that utilized cooled Si(Li) detectors (Hovestadt et.al.,1988.).

Although the first results of the x-ray mode of the Alpha Particle instrument using ambient temperature HgI_2 x-ray detectors were much better than we had expected in terms of resolution and sensitivity to low energies, it can be seen that the Phobos instrument with similar energy resolution has slightly better sensitivity to elements present in low concentration This is due to the higher background in the present arrangement. As can be seen from Fig.1, the source-sample-detector geometry of the x -ray probe is less than optimal in this experimental setup. By mounting the x-ray detector inside the Alpha instrument, the sample to detector distance can be decreased from the present 65 mm to less than 25 mm. This will increase the useful x-ray counting rate by almost a factor of seven while the background will not change significantly. This will dramatically improve the sensitivity of the instrument to low concentration elements. Future experiments will concentrate on investigating the best design geometries, detector sizes and the best auxiliary excitation sources.

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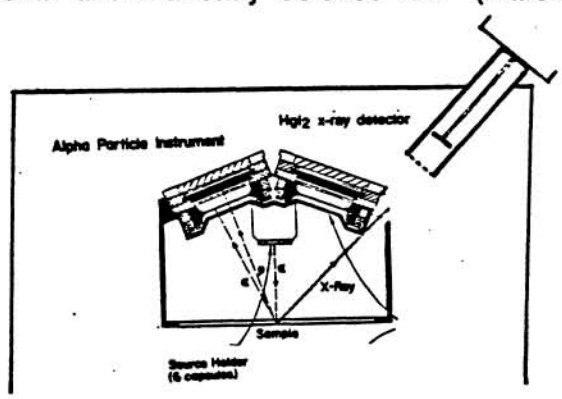

Fig. 1: Geometrical relationship of HgI_2 detector probe attached to the Alpha Particle Instrument.

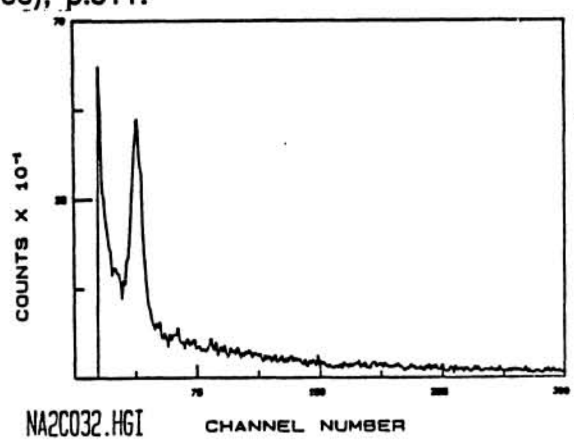

Fig. 2: Sodium K_a line at 1.04 keV from Na_2CO_3 sample. The resolution of the line is 180 eV.

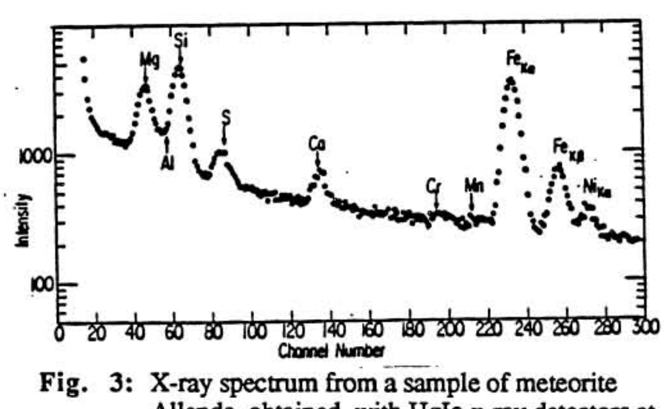

Fig. 3: X-ray spectrum from a sample of meteorite Allende, obtained with HgI_2 x-ray detectors at ambient temperature . The sample was excited with 40 mCi of ^{244}Cm alpha source that is used by the Alpha Particle instrument.

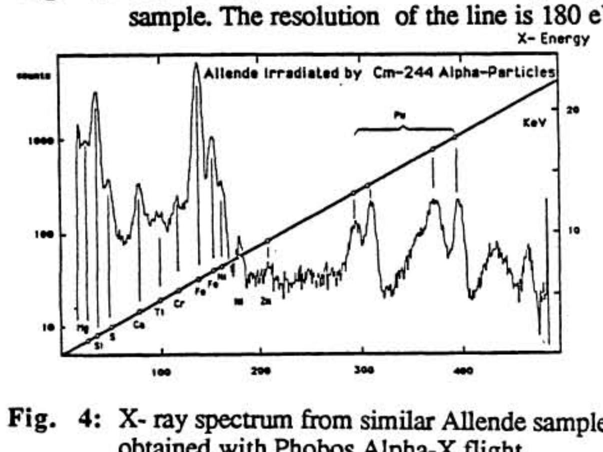

Fig. 4: X- ray spectrum from similar Allende sample obtained with Phobos Alpha-X flight instrument that utilized cooled Si(Li) detector and ^{244}Cm source excitation.