A GAMMA RAY MODE OF THE ALPHA PARTICLE ANALYTICAL INSTRUMENT

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The Alpha Particle Analytical Instrument provided the first relatively complete analyses of lunar surface material at three locations on the moon during the Surveyor Missions in 1967 and 1968 using only the classical alpha and proton modes of the technique. The capabilities have since been expanded by measuring the fluorescent x-rays produced by the interaction of the source radiations with the sample surface. Such versions of the instrument were flown on the ill-fated Soviet Phobos missions in 1988. The alpha sources used in such instruments are also neutron emitters due to spontaneous fission branches in the alpha decay and due to the interaction of the alpha particles with nearby materials. These neutrons can react with surrounding materials to produce gamma rays. Inclusion of a gamma ray detector in the Alpha Particle instrument can enhance the analytical capabilities of the package by providing a direct sensitivity for hydrogen, by providing a bulk analysis for several elements that are determined in the surface material, and by providing some isotopic information. This possibilitiy of determining several elements by different modes can remove ambiguities about the applicability of a surface analysis to represent bulk composition. Thus, an alpha particle package with alpha, proton, x-ray and gamma modes can provide the most complete in situ chemical analysis of an extraterrestrial body that is presently possible.

In order to test these ideas a 50 mCi ^{244}Cm alpha source, mounted on stainless steel, has been used in an arrangement where the alpha (neutron) source was approximately 20 cm away from a cooled 30 cm^3 GeLi crystal. Samples of various materials, varying in mass from 2 to 15 Kg were interposed between the source and detector and the resultant gamma rays measured. The experimental situation differs from that of Bruckner et al (1) in using relatively low energy neutrons (less than 4 MeV cf 14 MeV) and rather thick targets.

As an example of the type of results obtained, Figure 1 compares the response of the gamma detector to a sample of $NaHCO_3$ with that when Na_2CO_3 is the sample. Figure 1a shows the energy region between 420 and 500 KeV. Also shown is the detector response when no sample is present. Clearly seen in both carbonate samples is the 439 KeV gamma ray line due to inelastic neutron scattering on ^{23}Na. In the NaHCO3 sample there is, barely visible, the 472 keV neutron capture line in ^{23}Na. This line is not seen in the Na_2CO_3 sample presumably because of neutron leakage before capture.

Figure 1b shows the spectra in the 2 MeV region. The 2.22 MeV neutron capture line of hydrogen is visible in the bicarbonate sample. The neutron capture lines of H and ^{23}Na are greatly enhanced by addition of surrounding paraffin.

Table I lists the samples that have been measured so far, the gamma rays identified and their relative intensities as recorded. These preliminary results should be used with caution since the intensities will depend on the actual geometrical situation which, in this work, was quite different from that to be encountered on either a surface or penetrator type space mission.

The gamma rays detected so far are pretty much those expected by calculations of the type of Evans et al (2) although some significant differences are noted. For example, in the magnesium run, the lines at 1.369, 1.612 and 1.809 MeV are not in the ratios given by Evans et al (2), and the 1.612 MeV line is hardly visible in our measurements. In addition, the detector system used here had a cut off at 6.1 MeV and was too small to have a good efficiency for gamma rays above about 4 MeV.

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On a space mission with alpha sources of the strength needed for the alpha and proton modes of the Alpha Particle Instrument, the gamma ray rates should be at least comparable to those expected from cosmic rays. They could easily be enhanced by up to a factor of ten by use of a Be shutter over the alpha sources or with higher intensity, encapsulated, alpha sources.

There are several disadvantages to using such neutron sources for exciting gamma rays for analytical purposes and these have to be investigated. However, advantages would be the presence of a neutron source of constant and known strength and energy distribution, the response to which could be adequately calibrated on earth. This would make the analytical results quantifiable in a way hard to do with cosmic ray activation.

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References: (1) J. Bruckner, R.C. Reedy and H. Wanke, Lunar and Planetary Sci. XV, Abstract p. 98 (1984). (2) L.G. Evans, J.I. Trombka and W.V. Boynton, Lunar and Planetary Sci. XVI, J. Geophys. Res. 91, D525 (1986).

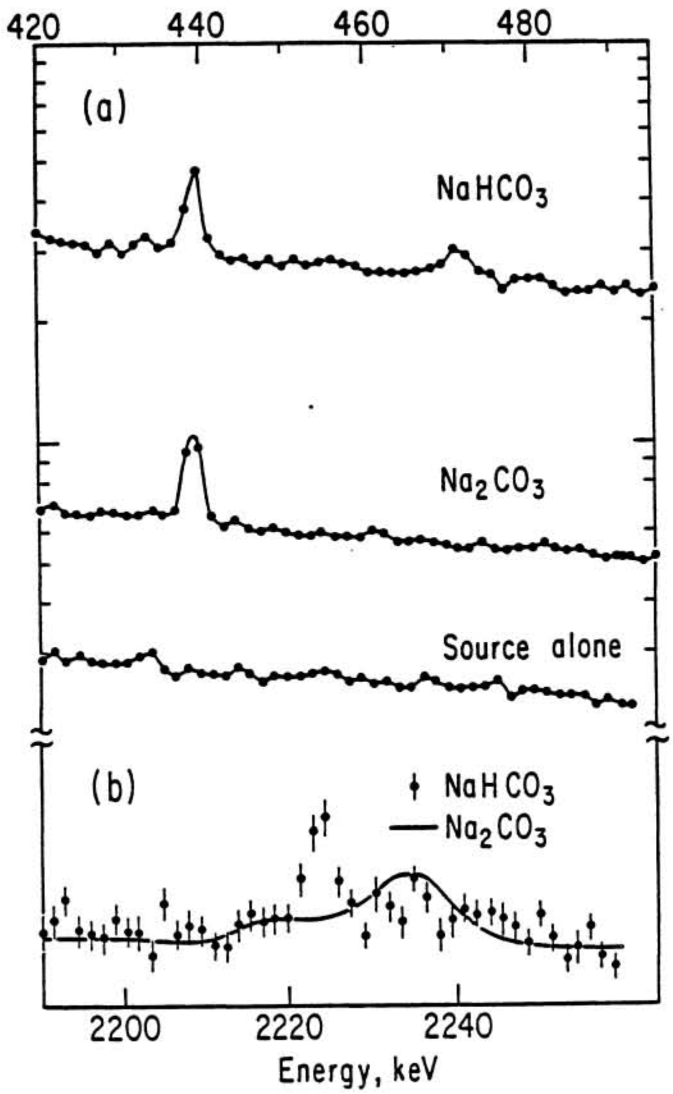

Fig.1 Response of Ge(Li) detector to carbonate samples exposed to 50 mCi ^{244}Cm. 1a: Energy region 420-500 keV. 1b: Energy region 2150 -2260 keV

TABLE I

Sample	Weight (kg)	Line	Isotope (keV)	Relative Intensity (c/1000 min)
Plexiglas	5.9	2,223	H	3936 ± 70
Na_2 CO3	12.0	439	^{23}Na	5088 ± 146
NaHCO3	10.0	439	^{23}Na	802 ± 52
		472	^{23}Na	263 ± 47
		2,223	H	70 ± 13
Mg	5.4	1,369	^{24}Mg	1355 ± 74
		1,612	^{25}Mg	236 ± 22
		1,819	^{26}Mg	263 ± 47
Al	15.0	2,210	^{27}Al	167 ± 16
SiC	2.8	1,779	^{28}Si	288 ± 28
		1,273	^{29}Si	717 ± 47
		2,235	^{30}Si	746 ± 31