COMETARY CHEMICAL ANALYSIS BY PASSIVE IN SITU GAMMA-RAY SPECTROSCOPY IN A PENETRATOR. Jacob I. Trombka, NASA Goddard Space Flight Center, Greenbelt, MD 20771, and Larry G. Evans, Computer Sciences Corporation, Silver Spring, MD 20910.

Introduction. Measurements of discrete line X-ray and gamma-ray emission from condensed bodies in space can be used to obtain both qualitative and quantitative chemical composition information. Discrete line emission in the energy range of 0.2 keV to 10 MeV can be attributed to a number of processes such as natural radioactivity, solar X-ray fluorscence, and cosmic-ray primary and secondary induced activity. X-ray and gamma-ray specrometers have been successfully flown on a number of planetary spaceflight missions. This has included the U.S. Apollo (1) and Viking (2) flights and the Soviet Luna, Mars, and Venera missions (3).

The extension of this technique using a gamma-ray detector in a penetrator for a cometary rendezvous mission is being studied (4). Penetrators are instrumented hard lander systems which can deliver a detector to a depth of approximately a meter below the surface of the body under investigation. This approach is of particular interest for a comet, since the top layer of material may be considerably modified in chemical composition compared to the material further below the surface. This lower material may more nearly reflect the chemistry of the primordial matter from which the body was formed.

Gamma-Ray Production. Gamma-ray methods as applied to chemical mapping of planetary bodies depend on the measurement of characteristic gamma-ray emissions from the bodies. The characteristic radiation is produced mainly by the decay of naturally radioactive nuclear species and by the prompt or delayed emission stimulated by particle interactions with the planetary materials. The major source of these particles are primary cosmic rays and secondary neutrons created in the planetary materials. A complete listing of expected gamma-rays from planetary bodies can found in (5).

In order to predict the expected gamma-ray flux from a condensed body, the neutron spatial and energy distributions must be determined. These quantities, however, depend on the composition of the body, particularly of the hydrogen content and the macroscopic thermal-neutron absorption cross-section (6). Thus, models are used to estimate the composition, and neutron and gamma-ray transport codes are used to calculate the expected flux of gamma-rays from the body.

Mission Description. A gamma-ray spectrometer/penetrator system is proposed for the planned comet rendezvous/astroid flyby mission. Among the objectives of the mission is to determine the physical and chemical nature of the nucleus of comet Kopff. The penetrator would be launched into the nucleus some time after the February, 1994 rendezvous with the comet near 3 A.U. from the sun. It is planned that the battery-powered gamma-ray spectrometer would collect data for at least 5 days while imbedded in the comet.

Detection Limits. The minimum detectable limits (MDL) were calculated using a model of 50% CI Chondrite, 23% H2O, 21% CO2 and 6%

HCN. Both prompt gamma-rays from neutron inelastic scatter and from neutron capture were considered in determining the MDL. Also, gamma-rays from natural radioactive isotopes were included. The continuum on which the discrete line gamma-rays are superimposed was estimated from the shape of the lunar spectrum (7), and then scaled using the neutron/gamma tranport results. The MDL for isotopes that were less than the model composition are shown in Table 1. These results are for a detector at 100 g/cm^2 below the surface and for a counting time of 102 hours.

Table 1

ISOTOPE	MDL(1-sigma) (wt. %)	MODEL COMPOSITION (wt. %)
^{1}H	1.0E-4	3.9
^{12}C	.091*	10.0
^{14}N	.22	0.32
^{16}O	.37	59.
^{23}Na	.068	0.30
^{24}Mg	.068	3.8
^{25}Mg	.076	0.48
^{26}Mg	.032	0.53
^{27}Al	.13	0.40
^{28}Si	.071	4.9
^{32}S	.042	2.7
^{35}Cl	1.5E-3	0.013
^{40}Ca	.053	0.39
^{48}Ti	6.2E-3	0.015
^{52}Cr	.068	0.084
^{53}Cr	3.0E-3	9.5E-3
^{55}Mn	.012	0.10
^{54}Fe	.090	0.50
^{56}Fe	.024	8.4
^{59}Co	6.3E-3	0.024
^{58}Ni	8.2E-3	0.34
^{60}Ni	.081	0.13
^{113}Cd	5.8E-6	6.0E-6
^{40}K	1.2E-3	2.8E-2
^{232}Th	2.1E-6	2.0E-4
^{238}U	1.9E-6	1.0E-4

*Detection of ^{12}C is more difficult than these numbers indicate due to doppler broadening of the peak.

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