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Neutron –Activated Gamma Ray Spectrometer (NAGRS) for the Venus Surface and Atmosphere Geochemical Explorer (SAGE) mission

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Abstract

The surface and atmosphere geochemical explorer (SAGE) is a proposed New Frontier class Venus lander that would study Venus's surface, climate and atmosphere. The neutron-activated gamma ray spectrometer (NAGRS) is one of the instruments on SAGE and would determine bulk elemental composition of the Venus surface by measuring the gamma rays induced by the 14 MeV neutrons. This paper describes the capability of NAGRS and shows the results of a preliminary neutron activation analysis.

1. Introduction

The Neutron-Activated Gamma Ray Spectrometer (NAGRS) determines major, minor, and trace element abundances in the upper 1 m of the subsurface by 1) measuring content of natural radioisotopes, 2) measuring nuclear composition, and 3) estimating hydrogen-bearing elements. NAGRS accomplishes this by measuring decay gamma rays from radioisotopes produced by neutron activation reactions and capture gamma rays from neutron capture reactions. Decay gammas have characteristic times of minutes to days (or even longer), depending on the half-lives of the radioactive products, while capture gammas have characteristic times in the range of μs. Since the neutron activation/capture cross sections, half-lives of radioactive products, characteristic gamma energies and yields are known fairly accurately, we can deduce absolute abundances of elements existing at and around the landing site with the gamma ray spectrum counts. A simple gamma ray spectrometer (GRS) alone can determine the abundances of naturally occurring elements (e.g., Th, K, and U). Adding a neutron pulsing source expands the capability for determining other naturally occurring elements through neutron activation and capture reactions. This measurement technique has been used in previous missions to various planetary bodies (Mars, Moon, or asteroids) and proven to be invaluable in identifying the surface elemental composition remotely (i.e., without surface material sampling). For example, see [1]. [3], [4], [5], and references therein.

2. Description of NAGRS

NAGRS is composed of four major subunits, as shown in Figure 1. A Pulsing Neutron Generator (PNG) produces pulses of high-energy neutrons, which produce secondary afterglow of moderated neutrons and secondary gamma rays from the subsurface. A Set of Neutron Sensors (SNS) detects secondary neutron emission. Secondary gamma rays are measured by GRS. The Central Electronics Unit (CEU) supports instrument logic and operations.

The PNG produces neutrons. The PNG can produce up to 10^7 pulses of 14-MeV neutrons, with 10^7 particles in each pulse using a compact high-voltage D-T accelerator. Commands from the CEU can change pulse frequency from 10 Hz to a single pulse.

The SNS measures the afterglow of thermal neutrons. The SNS contains two ^{3}He counters: one with and the other without a Cadmium (Cd) enclosure surrounding the detector.

The GRS measures the gamma rays from capture and activation reactions. In passive mode, GRS measures the content of natural radioisotopes, K, Th, and U.

The CEU operates all sensors of the instrument, measures time profiles of afterglow counting rate, provides high voltage for sensors, creates data frames, and interfaces with the lander central computer.

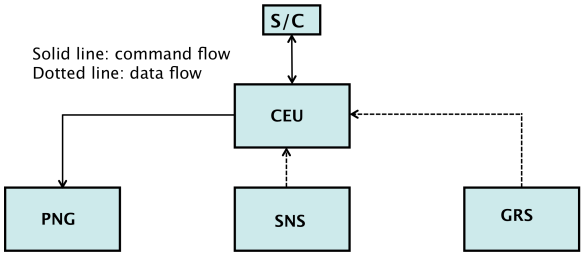

Figure 1: A simple NAGRS block diagram.

3. Preliminary Results of Activation Analysis

An activation analysis was performed for a model soil composition based on several spacecraft measurements (e.g., Vega, Venera) [2], assuming that the PNG operates for a 15-minute period and the GRS is measuring the activation decay gammas for 60-minutes. The analysis was performed using extensively validated Monte Carlo radiation transport code, MCNPX [A General Monte Carlo N-Particle Transport Code, LANL, Los Alamos, NM, USA, https://mcnpx.lanl.gov/]. Figure 2 shows the full gamma spectrum accumulated over the 60-minutes counting period. As shown, NAGRS is able to identify many of the major/minor elements, and naturally occurring elements.

4. Summary and Conclusions

The capability of NAGRS on the proposed SAGE mission to Venus is briefly discussed, especially for its capability to identity the elemental composition of the surface by measuring the gamma rays produced by the high energy neutrons induced activation reactions. More complete description of the analysis process will be presented at the conference along with the results of a laboratory measurement planned during the 2010 summer.

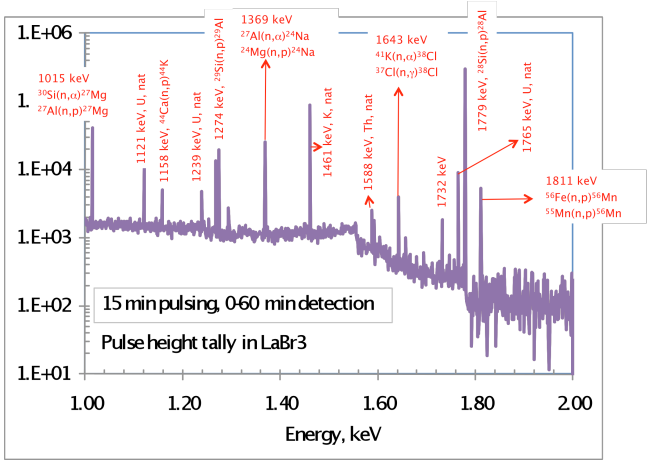

Figure 2: Activation gamma peaks are evident from an analysis performed for a representative Venus soil composition. It is assumed that the PNG is operating for a 15-min and then the GRS is measuring the gammas for a 60-minute period. Also, there are the gamma peaks from the naturally occurring elements. Only the peaks between 1 MeV to 2 MeV are shown, although the analysis covers the gamma energy from 1 keV to 8 MeV. Full results will be presented at the conference.

References

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