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PROMPT GAMMA ACTIVATION ANALYSIS (PGAA): TECHNIQUE OF CHOICE FOR NONDESTRUCTIVE BULK ANALYSIS OF RETURNED COMET SAMPLES? David J. Lindstrom[1] and Richard M. Lindstrom[2] [1]Lockheed Engineering and Sciences Co. C-23, 2400 NASA Rd. 1, Houston, TX 77058; [2]Center for Analytical Chemistry, National Institute of Standards and Technology, Gaithersburg, MD 20899.

Prompt gamma activation analysis is a well-developed analytical technique (1) that might well be the one of choice for multielement bulk analysis of returned comet samples. The technique involves irradiation of samples in an external neutron beam from a nuclear reactor, with simultaneous counting of gamma rays produced in the sample by neutron capture. Capture of neutrons leads to excited nuclei which decay immediately with the emission of energetic gamma rays to the ground state.

PGAA has several advantages over other techniques for the analysis of cometary materials:

1) It is nondestructive. Only a very small proportion of the atoms in the sample are altered. Residual radioactivity is minimal, and changes in isotopic ratios brought about by the irradiation are small and easily corrected for. Since the irradiation is conducted in a neutron beam outside the reactor, the samples can be kept at liquid nitrogen temperature during the measurement.

2) It can be used to determine abundances of a wide variety of elements, including most major and minor elements (Na, Mg, Al, Si, P, K, Ca, Ti, Cr, Mn, Fe, Co, Ni), volatiles (H, C, N, F, Cl, S), and some trace elements (those with high neutron capture cross sections, including B, Cd, Nd, Sm, and Gd). Accuracy is quite good due to the simple physics involved.

3) It is a true bulk analysis technique. Data from Comet Halley (e.g., 2) indicate that cometary material is quite inhomogeneous on the scale of individual grains, and larger inhomogeneities appear likely. Sample volumes as large as several cm^3 are still nearly transparent to the neutrons and gamma rays involved in PGAA; matrix effects are minimal. Optimal sample sizes will probably be in the range of hundreds of milligrams to a few grams, depending on the relative amounts of ices and silicates.

Recent developments should improve the technique's sensitivity and accuracy considerably (3). The major improvement is the use of a "cold neutron" facility instead of a thermal reactor neutron beam. The first major cold neutron facility in this country is now being built at the National Institute of Standards and Technology. The system utilizes a liquid helium cooled block of D_2O ice to produce neutrons with thermal energies of about 60 Kelvin. These neutrons are then piped through neutron guides to an experimental station far from the reactor and far from most sources of instrumental background. The main advantages of cold neutrons are that cross sections are higher by about a factor of three than for "thermal neutrons" at 300 K, interfering reactions due to fast neutrons are minimized, and gamma ray backgrounds are greatly reduced.

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The maximum amount of information might be obtained from the following analytical scheme: 1) Package a bulk sample weighing perhaps two grams in a sealed Teflon bag and do PGAA analyses as described above, maintaining the sample at liquid nitrogen temperature with a stream of helium gas. When that analysis is complete, 2) transfer the sample to a vacuum line, puncture the container, and carefully distill off the volatiles. These volatiles could themselves be analyzed by PGAA for bulk H, C, and perhaps N contents. Residual solids, still in the original Teflon container, could 3) be re-analyzed by PGAA, and 4) irradiated for normal instrumental neutron activation analysis. This procedure would be essentially nondestructive and should produce reliable abundance estimates for some 40 elements. The same solid samples could be analyzed further by scanning electron microscopy and other techniques.

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