Guided beams of cold neutrons being installed at a number of research reactors may become increasingly available for analytical research. A guided cold beam will provide higher neutron fluence rates and lower background interferences than in present facilities. In an optimized facility, fluence rates of $10^9 \text{n cm}^{-2} \text{s}^{-1}$ are obtainable. Focusing a large area beam onto a small target will further increase the neutron intensity. In addition, the shift to lower neutron energy increases the effective cross sections. The absence of fast neutrons and gamma rays permits detectors to be placed near the sample without intolerable background, and thus the efficiency for counting prompt gamma rays can be much higher than in present systems. Measurements made at the hydrogen cold source of the FRJ-2 (DIDO) reactor at the KFA provide a numerical evaluation of the improvements in PGAA with respect to signal-to-background ratios of important elements and matrices.

Introduction

The use of neutron-capture prompt gamma rays as a method of elemental analysis was introduced twenty years ago /1-3/. With the development of large, high-resolution gamma-ray detectors in the past decade, the method has taken its place alongside conventional neutron activation analysis as a complementary technique. Prompt gamma ray activation analysis (PGAA) is particularly useful for determining, by nondestructive means, elements which absorb neutrons but do not produce radioactive products in doing so. Nuclear parameters and the abundances of the elements in common matrices are such that PGAA finds its greatest applicability in the determination of nonmetals that form the major and minor elements of common matrices (H, C, N, Si, P, S), or
trace elements with high thermal capture cross sections (B, Cd, Gd) that may be poorly determined by other techniques.

The application of PGAA as a routine method of elemental analysis has been pursued to date at only a few laboratories on a full-time basis (for recent reviews see /4,5/), only partly because of the need for continuing access to a reactor neutron beam. The sensitivity of the method for most elements is not as good as conventional neutron activation, limiting most routine applications to the determination of the above mentioned elements. Irradiation times of several hours are required for most samples in which many elements are to be measured, hence the throughput is low because only one sample can be irradiated and measured at a time.

The low sensitivity of PGAA is not due to a low neutron capture rate, but to a low detection efficiency for the resulting gamma rays. If one count/sec of the 1262 keV carbon capture line is measurable, and if this radiation were detected with an efficiency of 0.01 count/photon (that of a point source a few centimeters from a large Ge detector), then at a fluence rate of $10^8$ n/cm$^2$.s the detection limit would be 5 μg. Since the capture cross section of C-12 is only 3.5 mb, most other elements should be determinable at sub-microgram levels. In practice, the gamma-ray detection efficiency is orders of magnitude less than this calculation assumes, partly because of the necessary bulk of active and passive shielding around the detector. This makes the solid angle subtended by the detector $10^{-3}$ or less in present systems, and the counting efficiency of the order of $10^{-5}$ counts/photon. Simply