Indian J. Phys. **65A** (6), 579-581 (1991)

Charged particle activation analysis of niobium in geological matrix

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Abstract: On alpha-particle activation of traces of niobium, preconcentrated from some specific varieties of phosphate rocks, with a 40 MeV alpha beam from the Variable Energy Cyclotron, different radionuclides, namely, ^{96}Tc, ^{95m}Tc, ^{95}Tc, ^{94m}Tc, ^{94}Tc and ^{93m}Tc, formed by the nuclear reactions, (α, n), (α, $2n$), (α, $3n$) and (α, $4n$) were detected. The feasibility of utilisation of more than one isotope formed at different depths of the thick target matrix has been critically investigated.

Keywords: Activation analysis, niobium, preconcentration, geological material.

PACS No: 82.80.Jp, 93.85.+q

1. Introduction

Geological materials are complex heterogeneous mixtures of minerals which vary widely in composition and are often fine grained. Generally such materials are mechanically incompetent for use as self-supporting sections. Therefore it is almost impossible to prepare thin samples that could be used to minimize background radiations and maximise trace element sensitivity. Besides non-nuclear techniques like X-ray fluorescence (Giauque *et al* 1986), atomic absorption (Donaldson and Leaver 1990) and optical spectroscopy, neutron and photon activation analysis (Yoshioka *et al* 1988) have been applied with considerable success. In recent years, accelerator based nuclear or atomic techniques are being developed to investigate such problems. Thus particle induced X-ray emission or the complementary method of particle induced gamma emission (Brissaud *et al* 1986) are used for such analysis. In some cases direct charged particle activation analysis (Barrandon 1986) can give very high sensitivity. However the efficiency of CPAPA depends on various parameters such as nature of the projectile, characteristic nuclear properties of the target, the target matrix, etc.

Trace of tantalum in some specific varieties of phosphate rocks had been determined through neutron activation analysis (Das and Bhattacharyya 1980, 1982) following a separation procedure developed earlier. Possible existence of niobium in the sample could not be established since this element is not amenable to NAA. On the other hand the excitation functions (α, xn) reactions of niobium

(Ramamoorthy *et al* 1986) indicate fairly high cross sections for the production of technitium isotopes of suitable halflives with an energy range of about 40 MeV for the projectiles. With this background, an attempt was made to utilise more than one radionuclides produced by alpha activation of traces of niobium in a suitable matrix bombarded by 40 MeV α-beam at Variable Energy Cyclotron Centre, Calcutta.

2. Experimental

Phosphate rocks originating in the District of Purulia, West Bengal, were supplied by the West Bengal Mineral Development and Trading Corporation, Traces of niobium in the rock samples were preconcentrated in Al_2O_3 following a chemical procedure developed earlier. The samples were encased with aluminium foils and irradiated with an alpha beam of 40 MeV under specific experimental conditions at Variable Energy Cyclotron Centre, Calcutta. A HPGe detector in conjunction with a ND 65 8 K multichannel analyser was used for monitoring the radioactive products formed in the target matrix by alpha irradiation.

3. Discussion

Unlike neutrons or photons, charged particles of several MeV energy are completely absorbed within a range of several microns of a thick target sample producing different reactions at different layers with varying cross sections. Analysis of the irradiated samples indicates the formation of different radionuclides such as ^{96}Tc, ^{95m}Tc, ^{95}Tc, ^{94m}Tc, ^{94}Tc and ^{92m}Nb produced by different nuclear reactions in the experimental matrix in a single run (Das *et al* 1987). However, the end product of each of the three reactions, (α, n), (α, 2n) and (α, 3n), namely, ^{96}Tc, ^{95}Tc and ^{94}Tc were used quite independently for quantitative estimation of traces of niobium distributed uniformly in the target material. Results obtained for different isotopes are shown in Table 1.

Table 1. Determination of niobium in a phosphate rock sample through different nuclear reactions.

Nuclear reaction	Selected gamma energy, keV	Half life T1/2	Concentration of niobium, ppm
^{93}Nb (α, 3n) ^{94}Tc	702.7	293 m	2.9
^{93}Nb (α, 2n) ^{95}Tc	765.9	20 h	3.1
^{93}Nb (α, n) ^{96}Tc	778.2	4.3 d	2.9

The isotopes utilised for determination of niobium such as ^{94}Tc, ^{95}Tc and ^{96}Tc have been characterised by several gamma rays. However, the gamma rays were selected on the basis of their relative intensity as well as freedom from any serious interference from neighbouring gamma rays.

The other irradiation products from niobium such as ^{95m}Tc, ^{94m}Tc and ^{92m}Nb having either short or too long halflives are somewhat difficult to utilise for

analysis of niobium because of some overlapping of common gamma energies as well as presence of some interfering lines due to some contaminants. The characteristic energy regions were calibrated by the technitium isotopes produced by alpha irradiation of pure niobium foil under identical conditions.

The results obtained through individual reactions are in good agreement with each other. The consistency of the data indicates the efficiency and reliability of CPAA in the determination of niobium even in ppm level in geological materials.

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