Three analytical methods for uranium by neutron activation are described. The methods are based on the substoichiometric separation of barium or lanthanum, which are the fission products of uranium-235 by neutron irradiation. Uranium contents in high purity materials were determined by the methods, which were found to be useful for the determination of a trace amounts of uranium.

Introduction

Uranium is one of the most important elements of geochemical interest and has been determined by various methods over the past years. In recent years, accurate information of the quantity and chemical behaviour of uranium has been required in connection with the nuclear fuel cycle and environmental sanitation. On the other hand, the occurrence of soft-error in an integrated circuit (IC) due to α-particles from an IC package was pointed out by MAI and WOODS in 1978.¹ Determination of uranium and thorium and measurement of α-particles have been required in the field of electronic devices. Concerning this soft-error problem, one of the authors has determined uranium in LSI (Large Scale Integration) constituent materials by instrumental neutron activation analysis (INAA).² In the analysis of samples with low uranium contents, chemical separation is unavoidable. In this case, neutron activation analysis based on substoichiometric principles is the most suitable, because of no correction of chemical yield in the separation procedure is needed. Substoichiometry, however, has hardly been tried on uranium,³ and has never been applied to neutron activation analysis of uranium.
This paper describes the principles of neutron activation analysis for uranium with substoichiometric separation of barium or lanthanum using the following nuclear reaction,

\[ ^{235}\text{U}(n, f)^{140}\text{Ba} \xrightarrow{\beta} ^{140}\text{La} \quad (T = 40.3 \text{ h}) \]

and the determination of uranium in high-purity materials.

**Principles**

When uranium is determined by neutron activation followed by measurement of fission products of \(^{235}\text{U}\), \(^{140}\text{Ba}\) or \(^{140}\text{La}\), which are in radioactive equilibrium with \(^{140}\text{Ba}\), are separated substoichiometrically. There are the following three methods for the determination of uranium using the substoichiometric separation of \(^{140}\text{Ba}\) or \(^{140}\text{La}\).

**METHOD—1: Substoichiometric separation of barium**

\(^{140}\text{Ba}\) is separated substoichiometrically, and left to reach radioactive equilibrium between \(^{140}\text{Ba}\) and \(^{140}\text{La}\). Uranium is determined by measuring the activity of \(^{140}\text{La}\).

In this method, the substoichiometric separation of barium is carried out by precipitation as barium sulfate.

**METHOD—2: Substoichiometric separation of lanthanum after separation of barium**

\(^{140}\text{Ba}\) is separated quantitatively, and left to reach radioactive equilibrium. \(^{140}\text{La}\) is separated substoichiometrically, and uranium is determined by measuring the activity of \(^{140}\text{La}\).

In the substoichiometric separation of lanthanum, the extraction technique with two chelating agents, DTPA (diethylenetriaminopentaacetic acid) and TTA (2-thenoyltrifluoroacetone) has been applied.

In this method, it is necessary to correct the chemical yield of \(^{140}\text{Ba}\), because barium is separated by an ordinary rather than substoichiometric technique. Therefore, a known quantity of \(^{133}\text{Ba}\) tracer is added to the test sample in advance for the determination of chemical yield.