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Some Improvements of Gamma-ray Measurement for the Determination of the Boron Content

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붕소 함량결정을 위한 즉발 감마선 계측법의 개선

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Abstract

The detection limit of boron has been lowered further in the capture gamma-ray measurement after preconcentration of boron by placing natural lithium brick in front of Ge(Li) detector. The experimental detection limit is found to be 0.30ppm, 0.18ppm, 0.045ppm and 0.090ppm for the samples of aluminum, steel, uranium dioxide and graphite, respectively. An alternate counting technique has been also used for neglecting the error caused by the fluctuation of neutron flux during counting.

요 약

붕소의 사전 농축후 포획감마선 계측법에서 자연 리티움 벽돌을 Ge(Li) 검출기 앞에 설치하므로서 붕소의 검출한계를 더욱 낮출 수 있었다. 실험상 검출한계는 알루미늄, 철강, 이산화우라늄 그리고 그라파이트 시료에 대해서 각각 0.30ppm, 0.18ppm, 0.045ppm 그리고 0.090ppm이었다. 또한 계측중 중성자 속의 변화에 의한 오차를 없애기 위하여 교대로 계측하는 방법을 사용하였다.

1. Introduction

As an alternative technique for elemental activation analysis, many authors[1-5] have used the capture gamma-ray measurement method for the determination of boron but the detection limits are relatively too high to determine the contents in reactor grade materials. In previous works[6,7], the preconcentration of boron was carried out by using a cation exchange resin column to improve the detection limit of boron.

Main peaks in the capture gamma-ray spectrum originate within the detector, as germanium in detector captures neutrons which are entered into the detector by scattering on the sample

and the sample holder. The preconcentration of boron in sample can reduce the sample size and neutrons scattered into the detector and then lower the detection limit. But the germanium peaks still remain as the main peaks in the spectrum obtained after the preconcentration.

In the present work, the capture gamma-ray measurement system is improved by inserting natural lithium brick between sample and detector in order to reduce the neutrons scattered into detector and to lower the detection limit less than those of previous works[6,7]. The counting method is also changed as to eliminate the error caused by flux variation during counting.

2. Experimental

2-1. Experimental Set-up

As shown in Fig. 1, the experimental set-up is same as that of the previous work,[6-7] except that the natural lithium metal brick was inserted between the sample holder and the detector.

A collimated beam of neutron, of which flux is $1.2\times10^{6}n\cdot cm^{-2}\cdot sec^{-1}$ at target position, has been extracted out of the beam port of TRIGA Mark III reactor. The Ge(Li) detector was shielded with lead bricks of 10cm thickness and the mixture of paraffine and boric acid of 10cm thickness. The front face of lead castle, which has a hole of 8.5cm diameter, is covered with 3mm thick sintered borate plate with a hole of 12cm diameter. The hole of 8.5cm diameter in lead castle is filled with natural lithium metal brick of 5cm thickness. The sample holder was made by two thin polyethylene wires.

2-2. Preconcentration of Boron and Capture Gamma-ray Measurement.

The standard boron and the preconcentrated boron from sample were, respectively, made by the method as mentioned in previous papers.[6,7] For the preconcentrated sample and the standard boron, the capture gamma-ray measurement was done for 200 sec. alternately for the sample and the blank. The alternate counting was continued until the counting time was summed to 4000 sec. for the sample and the blank, respectively.

3. Results and Discussion

As shown in previous papers,[6-7] the neutrons scattered into detector were still remained and had capture reaction with germanium although the preconcentration of boron was applied. These germanium peaks were shown as dominent peaks in the capture gamma-ray spectrum and caused the high count rate of Compton spectrum between 470keV~490keV, in which 478keV peak of boron was appeared.

As one of the methods lowering the detection limit of boron further, natural lithium brick of 5cm thickness is placed in front of detector as shown in Fig. 1. The flux of neutron in postion of detector is reduced less than one-third compared to that of previous papers. The capture gamma-ray spectrum of the preconcentrated boron from aluminum and uranium dioxide are shown in Fig. 2. Germanium peaks are still remained but the count rates of the peaks and the Compton background are much lower than

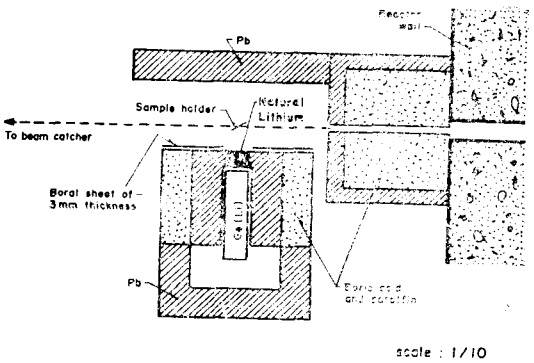

Fig. 1. Top View of the Capture Gamma-ray Apparatus

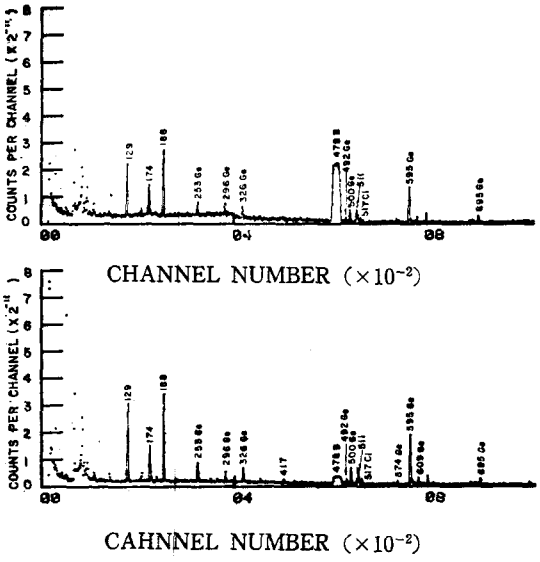

Fig. 2. Capture Gamma-ray Spectrums of the Preconcentrated Boron from 29g Aluminum (upper part) and from 200g Uranium Dioxide (lower part) after Background Subtraction.
(The numbers in spectrum are gamma-ray energies in keV)

those of the previous papers. The peak of boron is, therefore, appeared as relatively high one.

If the minimum detection limit of boron defined by Currie[8] is calculated again for the present work, this is further lowered to 1989 counts with 10% uncertainty.It means 0.30ppm, 0.18ppm. 0.045ppm and 0.090ppm for 30g of aluminm, 50g of steel, 200g of uranium dioxide and 100g of graphite, respectively.

The alternate counting technique, as discribed in section 2-2, is also used in order to neglect the error caused by the variation of neutron flux during the measurement, which was shown as 0.3% in previous papers. This kind of error can be neglected by using this technique although the variation of flux is large, unless the flux is suddenly risen or fallen. It will be more effective if high enriched lithium-6 plate is used instead of natural lithiun brick but this plate can be hardly obtained.

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