Determination of the Relative Content of U-235 in Enriched Uranium by Alpha-Gamma Coincidence Method Using a Gridded Ionization Chamber

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The alpha-gamma coincidence technique has been often used for the absolute measurement of alpha-activity and the identification of a particular nucleus in the presence of other alpha-active isotopes. For the measurement of weak alpha-source, an alpha-gamma coincidence system composed of a gridded ionization chamber and a NaI scintillation counter is superior to a conventional detector system of two scintillation counters, since the source area and the solid angle for alpha-particle detection in the gridded chamber are larger than those in the scintillation counter. In such a coincidence system, generally, the voltage pulse induced on the collector of the chamber is used for the alpha-gamma coincidence. The resolving time for the fast coincidence between the collector pulse and the gamma-pulse must be kept longer than one micro-second, because the average delay of the start time of the collector pulse relative to the alpha-decay is about one micro-second and furthermore the delay fluctuates over a

few tenth of a micro-second depending on the emission angle of alpha-particle.

Bochagov, Vorob'ev and Komar^{1),2)} found that the height of the voltage pulse induced on the cathode in a gridded chamber depends on the emission angle of alpha-particle in the same formula as that of the collector pulse in a parallel plate chamber³⁾ and suggested a possibility of the measurement of alpha-gamma angular correlation using the cathode pulse. Such a cathode pulse rises up at the same time as the emission of alpha-particle. Accordingly, if the cathode pulse is used in coincidence with the pulse due to gamma-rays, the resolving time for fast coincidence can be easily reduced to the order of 0.1 micro-second. From this view-point, we tried to determine the relative content of U-235 in a slightly enriched uranium using the cathode pulse for alpha-gamma coincidence in the detection system composed of a gridded chamber and a NaI scintillation counter.

Fig. 1 shows a block diagram of the detection

Fig. 1 Schematic diagram of detection system for α - γ coincidence measurement.

system and its electronic circuit. The gridded chamber used in this system has a distance of 30 mm between the cathode and the grid, and 30 mm also between the grid and the collector. The grid is constructed with tungsten wires 0.1 mm in diameter and 1 mm apart, and the shielding inefficiency is estimated to be 0.62%. The stainless source plate of 60 mm in diameter is placed at the center of the cathode. This chamber was filled with a gas mixture of 85% argon and 15% methane and operated at three atm. A NaI crystal of $1\frac{1}{2}$ in. in diameter $\times$ 1 in. in height is placed at the distance of 70 mm below the alpha-source.

For the collector pulse the amplifier with 3 μ sec integrating time constant (τ_i) and 3 μ sec clipping time constant (τ_c), for the cathode pulse the amplifier with $\tau_i=1 \mu$ sec and $\tau_c=3 \mu$ sec, and for the scintillation pulse the amplifier with $\tau_i=1 \mu$ sec and $\tau_c=1 \mu$ sec is used respectively. The resolving times of the fast

Fig. 2 a: Total energy spectrum of the alpha-particles emitted from natural uranium source.

b: Energy spectrum of the alpha-particles from the natural uranium source coincident with the gamma-rays in the energy region of 175 keV to 225 keV.

Fig. 3 a: Total energy spectrum of the alpha-particles emitted from enriched uranium source.

b: Energy spectrum of the alpha-particles from the enriched uranium source coincident with the gamma-rays in the energy region of 175 keV to 225 keV.

c: Estimated energy spectrum of U-238 for the enriched uranium source.

and slow coincidence circuit are designed to be 0.2 μ sec and 5 μ sec, respectively.

The relative content of U-235 in a slightly enriched uranium was determined from the energy spectrum of the alpha-particles coincident with the gamma-rays following alpha-decay of U-235. Two energy regions of the gamma-rays, (i) 125 keV to 175 keV and (ii) 175 keV to 225 keV, were selected for the alpha-gamma coincidence. In both cases, the random coincident counts were less than 2 per cent of the net coincident counts. Figs. 2 and 3 show the energy spectra of the alpha-particles in coincidence with the gamma-rays in the energy interval 175 keV to 225 keV and without coincidence for the natural, and enriched uranium sample, respectively. Assuming that the natural isotope abundance ratio of uranium U-238: U-235: U-234 is 0.9928 : 0.00715 : 0.000058⁴⁾, the

detection efficiencies for alpha-particles emitted from U-235 in the uranium source were estimated to be 2.79×10^{-3} for the case (i) and 5.28×10^{-3} for the case (ii). Using these detection efficiencies, the number of U-235 atoms included in the enriched uranium sample can be easily obtained. Also, the number of U-238 atoms can be estimated from the energy of spectrum of the enriched sample. From the results of these estimates, the ratio of U-235 to U-238 in the enriched uranium was determined to be $(4.42 \pm 0.18) \times 10^{-2}$ from the case (i) and $(4.35 \pm 0.12) \times 10^{-2}$ from the case(ii), respectively. These ratios are in good agreement with the

value $(4.4614 \pm 0.0005) \times 10^{-2}$ determined by a mass-spectrometer.

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