On the Decay of Bromine Isotopes $^{86}$Br and $^{87}$Br

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Gamma ray spectra of a mixture of the isotopes $^{86}$Br and $^{87}$Br have been measured by means of a Ge(Li) detector. Both manual and automated techniques were used to separate bromine from other fission products of natural uranium.

A total of 13 gamma rays were observed. The most intense of the $^{86}$Br gamma peaks (1,565 keV) was found to grow in with a half-life of $4.5 \pm 1$ s. This is explained to be due to an isomeric state in $^{86}$Br decaying to the ground state.

1. Introduction

The decay of the isotopes $^{86}$Br(54 s) and $^{87}$Br(55 s) have been previously investigated by Stehney and Steinberg, who discovered the isotope $^{86}$Br through the reaction $^{86}$Kr$(n, p) ^{86}$Br, and by Williams and Coryell, who separated bromine chemically from other fission products of natural uranium and made use of the different half-lives of the selenium precursors to distinguish between these two isotopes. Sass et al. have determined a number of even parity excited states in $^{87}$Kr through the reaction $^{86}$Kr$(d, p) ^{87}$Kr.

Williams and Coryell report 15 gamma rays associated with the decay of $^{86}$Br and 17 gamma rays associated with $^{87}$Br. The beta spectra of these isotopes were also measured and $Q_\beta$ values $7.5 \pm 0.5$ MeV and $6.1 \pm 0.5$ MeV were determined for $^{86}$Br and $^{87}$Br, respectively. A tentative decay scheme for $^{86}$Br was also presented.

In this work, the gamma radiation of these isotopes has been investigated using a Ge(Li) detector and a 4,096 channel pulse height analyser. Two different techniques have been applied in preparing the samples: 1) bromine has been separated from other fission products using normal chemical separation methods and 2) use has been made of the hot-atom reactions of halogens recoiling from the uranium target with methane to produce short-lived radioactive samples.

2. Experimental Techniques

The sources of $^{86, 87}$Br were prepared in two ways:

Procedure 1. Samples of uranyl nitrate were irradiated by means of a pneumatic transport system in the thermal neutron flux of the Triga

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Mk II reactor in Otaniemi. After irradiation the sample was dissolved in 20 ml of hot 8-M HNO₃ solution saturated with KClO₃. KBr and KJ were added as carriers into the solution which was then poured into a separatory funnel containing 10 ml of CCl₄. After extraction of halogen activities in CCl₄ the latter was taken into another separatory funnel containing 20 ml of KNO₂ solution made slightly acid by small amount of HNO₃. Bromine was extracted into the aqueous phase, the organic phase was discarded, and the aqueous phase collected for measurement. The whole separation took about 1.5 minutes.

**Procedure 2.** A gas-sweeping apparatus, which has been constructed for the production of short-lived gaseous fission products, was used to produce the ⁸⁶,⁸⁷Br activities. The principle of operation of this device is the following: UO₂ targets are irradiated by reactor neutrons in a chamber which is filled by methane to a pressure of 2–3 atmospheres. Fission product halogen nuclei that recoil from the target react with methane forming CH₃I and CH₃Br. Besides the halogens only fission product rare gases escape from the target. After irradiation the radioactive mixture of gases contained in the target chamber is swept to the counting position by means of methane flow. Bromine and iodine are collected in a trap containing AgNO₃, which stops the halogens by adsorption but lets the rare gases pass through. Transfer times of about 2 s can be achieved.

The gamma spectra of the bromine fraction (together with iodine in procedure 2) were measured in both cases by means of a 3 cm³ Ge(Li) detector. The energy resolution of the detector-amplifier-biased amplifier system was 6 keV for the 1,332 keV gamma ray in ⁶⁰Co. Energy calibration was done by means of the standard energy lines in ¹³⁷Cs, ⁶⁰Co and ²⁴Na. In addition the double escape peak of the 6,134 keV gamma ray in ¹⁶N was used to calibrate the high energy region of the spectrum.

Pulse-height analysis was performed with a TMC 4,096-channel two-parameter analyser, which was operated either in a 4×1,024 or 8×512 mode. In this way, four or eight successive spectra could be stored automatically in separate parts of the memory, which made it possible to check the half-lives of the observed gamma peaks.

Coincidence spectra were measured by means of the germanium detector and a 3 in × 3 in NaI(Tl) scintillation detector placed in a 90° geometry. Due to the complexity of the spectrum and the poor statistics of the registered coincidence counts no definite conclusions could be drawn from the results.

Energy and intensity determinations of the peaks in the singles spectra were performed by a computer code written by Sarmanto *et al.*

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