Studies on Low Spin Yrast States in $^{212m}$Po

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Level energies of low-spin yrast states up to spin $8^+$ are firmly established on the basis of $\alpha-\gamma$-spectroscopy. Six new $\alpha$-lines associated with the decay from $^{212}$Po suggest additional levels populated in the $\beta$-decay of $^{212}$Bi.

1. Introduction

This report contains the results of $\alpha-\gamma$ measurements associated with the $^{212}$Po level scheme. Reaction products, which decay to $^{212}$Po, were formed from the $^{208}$Pb $\rightarrow$ $^{210}$U reaction in deep-inelastic collisions during a search for superheavy elements with the gas jet transport system [1, 2] at the UNILAC heavy ion accelerator in Darmstadt. Until the publication of two recent studies [3, 4] indicating low-spin yrast levels in $^{212}$Po, scant experimental data associated with the $^{212}$Po scheme have appeared in the literature since Perlman et al. [5] reported the discovery of a high-spin isomer in $^{212}$Po with a 45.1 s half-life.

Auerbach and Talmi [6] have suggested spin $16^+$ for this isomer on the basis of a shell-model calculation which assumes orbitals described by the $(\hbar_{9/2})_n^2 \cdot (\gamma_{1/2})_n^2 \cdot 16^+$ configuration. Their results also predict a second isomer with spin $I=8-10$, and show that the lowest $I^+=0^+, 2^+, 4^+, 6^+, 8^+$ yrast states appear at decreasing energy intervals for increasing excitation energies. This outcome is a consequence of configurations which couple two $h_{9/2}$ protons to $I^+$ and two $g_{9/2}$ neutrons to $0^+$ (and vice versa). In a similar shell-model calculation for the neutron-magic $^{210}$Po Kim and Rasmussen [7] found that the low-spin yrast states are dominated by the $(h_{9/2})_n^2$ proton orbitals, thus lending credence to the contention that only small amounts of other proton orbitals are mixed. This theoretical interpretation seems to be supported by the recent discovery of Lieder et al. [4] of a second isomer in $^{212}$Po with a 14.2 ns half-life. This isomer, which lies just above the $6^+$ state and was deduced from a single $\alpha$-line ($l,0180\pm30$ keV), was tentatively assigned $8^+$ in that investigation. Lieder et al. did not, however, report the $8^+ \rightarrow 6^+$ transition, and the order of the $6^+ \rightarrow 4^+$ and $4^+ \rightarrow 2$ transitions had to be inferred from level systematics of even $^{202-210}$Po isotopes [8-10]. Baisden et al. [3] performed investigations of isomeric states in $^{212}$Bi produced by heavy ion reactions. They reported three “long-range” alphas emitted from excited states in $^{212}$Bi following $\beta^-$ decay from the 25 min $(9^-$) isomer in $^{212}$Bi. No $\gamma$-rays were measured in that work. The results of the current measurement, in which $\alpha-\gamma$ coincidences were recorded, indicate that features of both previous spectroscopy studies [3, 4] have merit and that the discrepancies can be reconciled.

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In the current measurement the energy of the $8^+$ isomer is established to within $\pm 5$ keV, the $8^+\rightarrow 6^+$ transition is reported, and the positions of the $4^+$ and $6^+$ states are unambiguously determined. In addition six new weak $\alpha$-lines are given, which are associated with the decay from excited states of $^{212}$Po.

2. Experimental Set Up

Reaction products decaying to $^{212}$Po were produced by bombarding a 6.3 mg/cm$^2$ thick natural uranium target with a $^{208}$Pb beam from the UNILAC accelerator with energies from 7.0 MeV/u down to the reaction barrier. The target was located inside the gas chamber of the gas jet system (see [2] for details). The thermalized products were subsequently swept out of the chamber with the aerosol-loaded Ar transport gas, through a 1 mm diameter capillary, and deposited on a 100 $\mu$g/cm$^2$ aluminum collector foil of the $\alpha$-recoil time-of-flight (TOF) mass spectrometer [11]. A 200 $\mu$m thick Si surface-barrier detector, located 1 cm behind the collector foil, was the $\alpha$-start detector. The stop signal was provided by $\alpha$-recoils which were detected by a scintillator. In addition to the start detector a Ge(Li) detector was placed 2 cm behind the collector foil. A 4-parameter experiment was performed with this detector arrangement. Data were collected for the alpha energy $E_\alpha$, the gamma energy $E_\gamma$, the time of flight of the recoils, and the time correlation between an $\alpha$-particle and a $\gamma$-ray. The masses of the reaction products were determined on the basis of the TOF measurement [12]. The half-lives were determined with the “mother-daughter”

3. Results

An alpha singles spectrum is shown in Fig. 1 with details of the 10 MeV $\alpha$-group given in the upper right corner. The spectrum is taken at the planar detector of the $\alpha$-wheel [13] and contains the sum of several 1 h counting intervals with the first 10 min omitted to remove the 45 s component of the 11.650 MeV activity. Our experimental half-lives are 7 ±1 min for the 11.650 MeV $\alpha$-line and 28 ± 1 min for the 10 MeV $\alpha$-group. The mass of the 11.6 MeV activity was determined to be (212.3 ± 1.7) u. Despite the fact that only about 10% of the activity belongs to the 7 min half-life this provides experimental confirmation of the interpretation of Baisden et al. for that $\alpha$-activity. The mass of the 10 MeV$^2$ group is (216 ± 6) u.

The $^{212}$Po levels proposed in the present work are based on $E_\alpha$, $E_\gamma$ and $\alpha-\gamma$ coincidence measurements. Measured $\alpha$- and $\gamma$-energies associated with $^{212}$Po are presented in Table 1. There is very good agreement in terms of energy and intensity between the three strongest alpha lines from this work and those reported by Baisden et al. [3]. Six new weak $\alpha$-lines are also listed in Table 1 from the current investigation. They are likewise interpreted as representing $\alpha$-decays from excited states of $^{212}$Po to the $^{208}$Pb ground state. All gamma rays listed in Table 1 are seen in the coincidence spectrum of the 8.78 MeV $\alpha$-gate, which represents the $\alpha$-decay of the $^{212}$Po ground state. The energies correspond to those measured by Lieder et