Multiple Coulomb Excitation of $^{198}$Hg and $^{200}$Hg

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Multiple Coulomb excitation measurements on $^{198,200}$Hg have been performed with 5 MeV/amu $^{208}$Pb projectiles and $B(E2)$-values are determined for transitions between states up to spin $8^+$. In $^{198}$Hg a reduction of the $B(E2)$-value for the yrast transition $8^+ \rightarrow 6^+$ by a factor of 3 as compared to the rigid rotor prediction is observed, which supports the earlier proposed idea that the ground state band is crossed between the $6^+$ and $8^+$ state by a weakly interacting $vi_{13/2}$ rotation aligned band. In each of the two nuclei, $^{198}$Hg and $^{200}$Hg, a state with a possible $I^*=8^+$ assignment is observed, which is tentatively interpreted as the $8^+$ member of the ground state band.

1. Introduction

The positive parity yrast bands in the even-even nuclei $^{190-198}$Hg show marked anomalies at low spin values: The bands have a regular behaviour only up to the $6^+$ state, while the energies of the higher spin states are compressed; the $8^+$, $10^+$, and $12^+$ states are almost degenerate ($\Delta E \leq 100$ keV), and the spacing between the $12^+$ and $14^+$ states is roughly equal to the $2^+$ energy [1-6]. This behaviour has led to the interpretation that the yrast states with spin $I^* \geq 8^+$ are members of a rotation aligned two-quasiparticle band built on the neutron $i_{13/2}$ configuration. The work presented here, multiple Coulomb excitation of $^{198,200}$Hg with Pb projectiles, has been carried out to investigate two consequences of this interpretation:

1. In a schematic description of the $vi_{13/2}$ rotation alignment in $^{198}$Hg the ground state band and the $vi_{13/2}^2$ rotation aligned band intersect between $I^*=6^+$ and $8^+$. Judged from the abruptness of the slope change of the yrast line at the crossing point the interaction between the two bands should be very weak. Consequently one expects a reduction of the $B(E2, 8^+ \rightarrow 6^+)$ value as compared to the rotational prediction, whereas all other $B(E2)$ values in the yrast sequence should have rotational values. Experimentally the $B(E2)$-values are known for the $2^+ \rightarrow 0^+$ and $4^+ \rightarrow 2^+$ transitions from Coulomb excitation measurements [7, 8] and for the $10^+ \rightarrow 8^+$ and $12^+ \rightarrow 10^+$ transitions from delayed coincidence experiments [3]. These values follow indeed the rotational prediction. Multiple Coulomb excitation should allow to determine the $B(E2, 6^+ \rightarrow 4^+)$ and the crucial $B(E2, 8^+ \rightarrow 6^+)$-value and should thus complete the systematic of the yrast band $B(E2)$s in $^{198}$Hg up to $I^*=12^+$; moreover, the weakness of the interaction between the two crossing bands should

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lead to an observable population of the $8^+$-member of the ground state band.

(2) In $^{200}$Hg the positive parity yrast sequence is known only up to $I^* = 6^+$. In the ($\alpha$, $2n$) reaction no higher spin members of this sequence have been observed, although states with spins up to 13 were populated [3]. This indicates that the $I^* = 8^+$ and $10^+$ yrast states lie high above the negative parity yrast line. A possible explanation could be that the rotation alignment of the $\nu_{1/2}^3$ configuration is blocked by the large energy gap above $N=120$ in the Nilsson scheme, and will occur at a higher rotational frequency [3]. In this case the positive parity yrast sequence will be identical to the ground state band up to higher spins than in $^{198}$Hg; a VMI extrapolation leads to $E(8^+) = 2560$ keV and $E(10^+) = 3510$ keV as compared to the observed $E(11^-) = 2642$ keV. With multiple Coulomb excitation one should be able to observe the $8^+$ member of the ground state band.

2. Experimental Methods and Analysis

The experiments were performed at the UNILAC of the Gesellschaft für Schwerionenforschung at Darmstadt with 5 MeV/amu $^{208}$Pb ions and beam currents of about 0.5 particle-nA. The targets consisted of $\approx 1$ mg/cm$^2$ HgS, enriched in $^{198}$Hg and $^{200}$Hg to 96.4% and 95.7%, respectively, which was sandwiched between 20 $\mu$g/cm$^2$ carbon foils. They were prepared as described by Esat et al. [10] with one modification: In order to get a reproducible deposition of the HgS on the C-backing a $\approx 5$ $\mu$g/cm$^2$ thick layer of Al was evaporated on the C-backing before evaporating the HgS. A particle-gamma coincidence arrangement consisting of three Ge(Li)-detectors and two position-sensitive parallel plate avalanche detectors was used [11]. The particle detectors covered an angular range of $15^\circ \leq \theta_{lab} \leq 60^\circ$, $-28^\circ \leq \phi_{lab} \leq +28^\circ$ (detector I), and $15^\circ \leq \theta_{lab} \leq 60^\circ$, $150^\circ \leq \phi_{lab} \leq 210^\circ$ (detector II), while the three $\gamma$-detectors were located at $\theta_{\gamma} = 30^\circ$, $\phi_{\gamma} = 0^\circ$ (detector 1), $\theta_{\gamma} = 30^\circ$, $\phi_{\gamma} = 180^\circ$ (detector 2) and $\theta_{\gamma} = 150^\circ$, $\phi_{\gamma} = 0^\circ$ (detector 3). Because of the small mass difference between projectile and target, no attempt was made in the present case to identify the recorded particle by kinematic coincidences; the de-excitation $\gamma$-rays were thus detected in coincidence with either the recoiling Hg-ions (Hg-event) or the scattered Pb-projectiles (Pb-events). The Dopplershift correction of the observed $\gamma$-ray energy was performed for the coincidence combinations (I,1), (I,3) and (II,2) assuming the detected particle to be the Hg-recoil nucleus. As a result, the “corrected” $\gamma$-spectra display two kinds of peaks: Narrow, duly corrected lines (resolution $\leq 4$ keV at 500 keV) for Hg-events and rather broad bumps for Pb-events as the latter are corrected in the wrong way. The narrow lines appear at energies $E_{\gamma 0}$ corresponding to the emission of $\gamma$-rays in the rest system of the excited Hg-nuclei, while the bumps show up either below or above $E_{\gamma 0}$ depending on whether the $\gamma$-rays are observed in or opposite to the direction of the detected Pb-ion. Thus it is still possible to identify even weak transitions and to extract the $\gamma$-intensities for the two event-types.

In addition to the Doppler shift correction the detector arrangement allows to measure the $\gamma$-intensities as function of the angle between beam and recoil ion. The $\gamma$-particle angular correlations are sensitive to the number of Coulomb excitation steps, thereby providing information on the spins of the excited levels, and allow to determine individual $B(E2)$-values.

Figure 1 shows examples for the Dopplershift corrected $\gamma$-ray spectra obtained for $^{198}$Hg and $^{200}$Hg. A summary of the energies of the observed $\gamma$-lines and their angle integrated yields is given in Table 1. To extract the $\gamma$-particle angular correlations for the more intense lines, the angular region covered by the particle detectors was divided into five bins; the normalized angular correlations for Hg-events, which were averaged over the three coincidence combinations, are shown in Fig. 2 as a function of the corresponding mean c.m. scattering angles $\langle \theta_{cm} \rangle$ of the Pb projectile.