$B(E2;0_g^+ \rightarrow I^\pi K=2^+0)$ of the 1276.7 keV transition in ^{178}Hf

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A reanalysis of the (α,α') data for extracting the reduced excitation probability $B(E2;0_g^+ \rightarrow I^\pi K=2^+0)$ of the 1276.7 keV transition in ^{178}Hf indicates an error in the earlier published value. The new value of $B(E2)$ from the (α,α') data is 0.022(5) e^2 b^2 and is consistent with a recent measurement. The extracted total mean lifetime of the 1276.7 keV level is $\tau = 0.70^{+0.22}_{-0.14}$ ps.

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Recently, Aprahamian *et al.* [1] measured the mean lifetimes of some of the levels in ^{178}Hf [1] by using the gamma-ray induced Doppler broadening (GRID) technique [2]. Two of the three $B(E2)$ values in ^{178}Hf extracted from the lifetimes [1] agree with the values measured by Ronningen *et al.* [3]. However, there is a sharp disagreement between the values of $B(E2)$ of the 1276.7 keV transition. The reported $B(E2)$ value [3] of the 1276.7 keV transition is five times smaller than that extracted from the recent lifetime measurements [1]. In addition, the value of the mean lifetime extracted from $B(E2)$ measured by Ronningen *et al.* [3], as given in the Nuclear Data Sheets [4], i.e., 8.8±3.5 ps, adds to the confusion of the degree of this state's collectivity, as discussed below.

The mean lifetime of the 1276.7 keV level is important because Aprahamian *et al.* [1] find a collective band built on this state, which can be interpreted as a two-phonon excitation. Thus, it is important to resolve the discrepancy between the two measurements. The 1276.7 keV 2^+ state decays to the 0^+, 2^+, and 4^+ members of the ground band. The relative branching ratios to these three states are 18.8, 100, and 29.2, respectively. The 1276.7 keV level decays predominantly to the 93.2 keV 2_g^+ state via a 1183.5 keV transition with an admixture of 85.6%$M1$+14.4%$E2$ [5,6]. Table I shows a comparison of the $B(E2)$ values and extracted mean lifetimes between the two measurements [1,3].

The mean lifetime of the 1276.7 keV state, extracted from Ref. [3], as reported in Nuclear Data Sheets [4] (converting their $T_{1/2}$ to τ), is τ=8.8±3.5 ps. This value is within about two standard deviations (2σ) of the value from the new measurement [1]. However, in extracting the uncertainties on the mean lifetime [4], an assumption was made that a 40% uncertainty in $B(E2)$ would yield a 40% uncertainty in the mean lifetime τ. Since τ depends inversely on $B(E2)$, one can use the same percentage uncertainty in both cases only when the uncertainty is small. In this case with a large uncertainty of approximately 40% in $B(E2)$, to obtain one and two standard deviations on τ, one must calculate the mean lifetimes from the upper and lower limits of the $B(E2)$ value. The new limiting values of τ for 1σ are 6.2 and 14.4 ps, and for 2σ are 4.9 and 39.6 ps.

Thus, even for 2σ, the lower limit on τ of 4.9 ps is well outside the range of the new measurements. One has a clear discrepancy for this level's mean lifetime but good agreement for the other levels, where in each case the three states were measured at the same time.

We reanalyzed the earlier (α,α') data [3] and γ-ray [6] Coulomb excitation data to seek a resolution for the discrepancy. In the original paper [3], the ^{178}Hf (α,α') spectrum was

TABLE I. $B(E2)$ of the transitions and the mean lives of the states in ^{178}Hf. Note that the $B(E2)$ value reported for the 1276.7 keV transition is also consistent with the value reported by Varnell *et al.* [7].

Transition energy (keV)	$B(E2;0^+ \rightarrow 2^+)$ in WU (Ref. [3])	$B(E2;0^+ \rightarrow 2^+)$ in WU (Ref. [1])	Mean life in ps extracted from Refs. [3] in [4]	Mean life in ps (Ref. [1])
1174.6	3.9(1)	>2.73 <12.78	0.90(3)	>0.27 <1.27
1496.4	0.44(7)	>0.58 <20.86	1.30(30)	>0.03 <1.09
1276.7	0.07(3)	>0.33 <1.45	8.8(3.5)	>0.35 <1.52

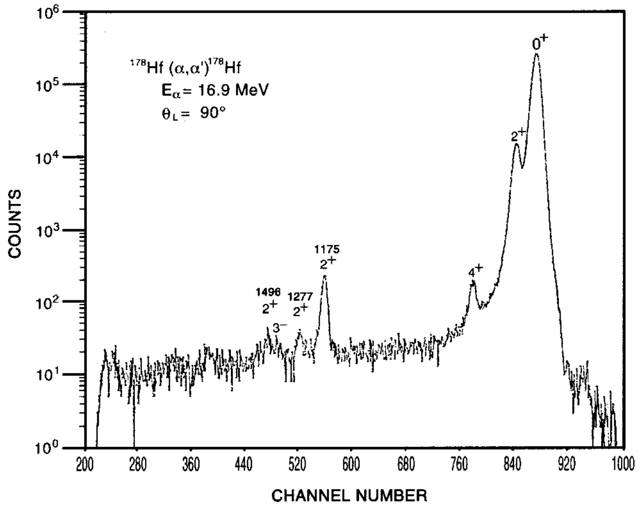

FIG. 1. Spectrum of α particles scattered from ^{178}Hf target.

not published. In Fig. 1, the original α,α' spectrum is shown. It is clear from Fig. 1 that the peak for the excitation of the 1276.7 keV level is not 1%–2% of the 1174.6 keV peak, so its $B(E2)$ cannot be 1%–2% of the 1174 keV transition strength as reported earlier [3]. One can see from Fig. 1 that the intensity of the 1496 keV peak is of the same order as the 1276.7 keV one or even weaker. The $B(E2)$ value for the 1496 keV transition was reported as 12% of the 1174.6 keV transition [3]. The relative intensities of the 1276.7 and 1496 keV peaks relative to the 1174.6 keV one are the order of 10:1, respectively, but not 100:1 as reported earlier for the former case. We went back to the original analysis and found that an error was made in transposing the numbers and consequently in determining the $B(E2)$ of the 1276.7 keV transition. The correct value of $B(E2;0_g^+\rightarrow I^\pi K=2^+0)$ is 0.022(5) e^2 b^2.

A reanalysis of the earlier γ-ray data [6] was also made, taking into account the background over a larger energy range to avoid possible uncertainties in background determination under the weak 1183 keV peak that falls between the stronger 1175 and 1190 keV peaks in the γ-ray spectrum. This gives an upper limit for $B(E2)$ now in this range also.

This new $B(E2)$ value along with the γ-ray branching ratio of 12.7% for the 1276.7 keV transition and 85.6% $M1$ nature of the 1183.5 keV $2^+\rightarrow 2^+$ transition from this level leads to a lifetime for the 1276.7 keV level of $\tau = 0.70^{+0.22}_{-0.14}$ ps. This is in agreement with the measurement [1] of $0.35<\tau(\mathrm{ps})<1.52$. The value of $B(E2)$ for the 1276.7 keV transition is still only (20±5%) of that for the 1174.6 keV transition. Hence, the 1276.7 keV level is still significantly less collective than the 1174.6 keV level, which is believed to have a γ-vibrational character.

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