Mass and excited states of ^{100}Nb

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The ^{100}Mo(t,^{3}He)^{100}Nb reaction has been used to determine the mass and the energy levels of ^{100}Nb. A mass excess of -79480 ± 30 keV is obtained for ^{100}Nb, in substantial disagreement with β-decay results. Twenty-two excited states of ^{100}Nb with $E_x < 1.3$ MeV have been observed.

[NUCLEAR REACTION ^{100}Mo(t, ^{3}He), E = 23.0 MeV; measured $\sigma(E_{^3\mathrm{He}}, \theta)$. ^{100}Nb deduced levels. New mass of ^{100}Nb.]

^{100}Nb has previously[1] been observed in studies of the ^{100}Mo(n, p) ^{100}Nb reaction, in the β^- decay of ^{100}Zr and as a fission by-product. Two isomers of ^{100}Nb have been identified: Their half-lives[2] are 1.5 ± 0.2 s and 3.1 ± 0.3 s. Studies[2-4] of the γ rays in ^{100}Mo, formed in the β^- decay of these two isomers, show that the 1.5-s isomer should have a low spin since it decays to 0^+ and 2^+ states of ^{100}Mo. This is confirmed by the fact that it is the only one of the two isomeric states populated in the decay of ^{100}Zr($J^\pi = 0^+$). The decay of the 3.5-s isomeric state is poorly known but its population in fission, the fact that it is not populated in the ^{100}Zr β^- decay, and its probable[2] β^- decay to a 4^+ state in ^{100}Mo at 1135 keV suggest a large spin. $Q_{\beta^-} = 6240 \pm 100$ keV from the decay[3] of the 1.5-s isomeric state. Wapstra and Bos[5] adopt 6230 ± 130 keV. It is not known which of the two isomeric states is the ground state or what their separation is. No other states of ^{100}Nb have previously been observed.

The masses and the low-lying states of ^{100}Nb have been studied by the (t, ^{3}He) reaction on ^{100}Mo. A 23-MeV triton beam from the LASL three-stage Van de Graaff facility and a magnetic spectrometer of the quadrupole-dipole-dipole-dipole (Q3D) type which has a focal plane detector consisting of a 1-m long helix detector with 0.8-mm spatial resolution[6] were used.

A self-supporting target[7] of molybdenum enriched[8] to 95.9% ^{100}Mo (also containing 1.7% ^{98}Mo) was oriented at 20° to the incident triton beam. The target was 338 μg/cm^2 thick. Data were taken with the ^{100}Mo target at $\theta = 25°$, 30°, and 35° and total integrated beam currents of 3.16 to 4.32 mC. Runs were also made with an enriched ^{24}Mg target under identical conditions preceding and following each run to calibrate[9] the channel number versus the energy of the outgoing ^{3}He ions.

Figure 1 shows spectra obtained at $\theta_{\mathrm{lab}} = 25°$ and 35°, and a partial spectrum of the results at 30°. The numbered groups correspond to states in ^{100}Nb: See Table I. The resolution of single groups (full width at half maximum $\simeq$ 25 keV) observed under similar conditions in other experiments[9,10] is clearly not sufficient to resolve the many states of ^{100}Nb with $E_x < 1.4$ MeV. The 23 groups displayed in Table I are a lower limit to the states of ^{100}Nb in that range. States $\lesssim$ 20 keV apart would not be resolved, nor could we resolve

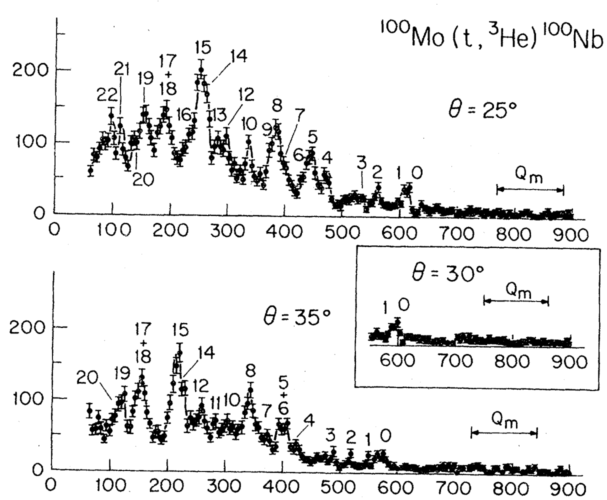

FIG. 1. Spectra of the ^{3}He ions from the ^{100}Mo(t, ^{3}He) ^{100}Nb reaction at E_t = 23.0 MeV, $\theta_{\mathrm{lab}} = 25°$ and 35°, B = 5.4532 kG. The ordinate shows the total number of counts recorded in a 5-channel bin. The abscissa shows the channel number. The inset shows the region corresponding to $-6.0 < E_x < -6.8$ MeV at 30°. For a discussion of the regions labeled Q_m see the text. The numbered groups are due to states in ^{100}Nb: See Table I.

TABLE I. Energy levels of ^{100}Nb.

Group No. [a]	E_x in ^{100}Nb (keV)	$d\sigma/d\Omega$ [b] (μb/sr)
0	0 [c]	0.090
1	25±10	0.093
2	131±10	0.080
3	(210±15) [d]	
4	348±15	0.19
5	410±15	
6	450±20 [e]	
7	520±20 [e]	
8	565±10	
9	(595±20) [e]	
10	680±20	0.28
11	(720±20) [f]	
12	784±20	
13	820±20 [f]	
14	865±20 [e]	
15	893±20	
16	945±20 [e]	
17	1040±20 [e]	
18	1075±20 [e]	
19	1136±20 [f]	
20	1180±25 [f]	
21	1260±30 [g]	
22	1300±30 [g]	

[a] See Fig. 1.
[b] $\theta_{lab}=25°$; ±40%.
[c] Q_0 measured in this experiment is −6.690±0.030 MeV.
[d] Observed at only one angle. There is weak structure at all three angles suggesting unresolved states with 200 $< E_x <$ 300 keV.
[e] Not resolved.
[f] Resolved at one angle.
[g] Kinematically observable at only one angle.

states which are weakly populated if in close proximity to strong groups.

The mass of the ground state of ^{100}Nb derived from our results is 99.914 675 (32) u, using Q_0 = −6690 ± 30 keV as measured from our data, the masses of ^{100}Mo, t and ^{3}He from Wapstra and Bos[5] as well as the conversion factor 931.5016 (26) MeV/u used by them. The atomic mass excess of ^{100}Nb is then −794 80 (30) keV, yielding Q_{β^-}(max) = 6709 ± 30 keV. This is puzzling in view of the fact that Stippler *et al.*[3] found Q_{β^-} for the 1.5-s, low spin isomeric state of ^{100}Nb to be 6240 ± 100 keV. We show in Fig. 1 the region at all three angles where a group corresponding to Q_{β^-} = 6230 ± 130 keV (the Wapstra-Bos value[5]) should be observed. No structure is evident at any of these angles, which is particularly surprising in view of the fact that the 1.5-s isomer is a low spin state. The relatively constant background for the channels above group 0 can be easily understood in several ways and may be in part due to the presence of counts from the ^{98}Mo(t, ^{3}He)^{98}Nb reaction (^{98}Mo was a 1.7% contaminant) whose ground state Q value is[5] −4.566 MeV. However, the more likely explanation is leak-through of α particles into the ^{3}He spectrum since the (t, α) reaction is three orders of magnitude more prolific than is the (t, ^{3}He) reaction. These counts, from ^{100}Mo(t, α)^{99}Nb, would appear as a continuum due to the high excitation energy in the residual nucleus ^{99}Nb. It would be interesting to see if additional β^- decay studies would confirm Q_{β^-}. Studies of the branching ratios of the decay of both isomeric states would permit limits to be placed on the J^π of the two isomers, and might suggest their ordering in ^{100}Nb in conjunction with the results presented here.

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