PHYSICAL REVIEW C VOLUME 24, NUMBER 4 OCTOBER 1981

Masses of ^{78}Ge and ^{78}As

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(Received 9 February 1981)

Precise measurements of ground-state Q values for ^{76}Ge$(t,p)^{78}$Ge(6310±5 keV) and ^{80}Se$(d,\alpha)^{78}$As(5755±12 keV) result in mass excesses of −71 861±6 keV for ^{78}Ge and −72 805±13 keV for ^{78}As, both of which are much more precise than previous values.

[NUCLEAR REACTIONS ^{76,nat}Ge(t,p), ^{80}Se(d,α) measured Q values, deduced mass excesses. Enriched targets.]

Several recent experiments have provided measurements of the ground-state (g.s.) Q values of the reactions ^{76}Ge$(t,p)^{78}$Ge and ^{80}Se$(d,\alpha)^{78}$As. Beams of tritons and deuterons were provided by the University of Pennsylvania Tandem Van de Graaff accelerator and the resultant protons and alpha particles were momentum analyzed in a multiangle spectrograph. These measurements, along with the compiled mass excesses of the other reaction components, yield mass excesses for ^{78}Ge and ^{78}As that are significantly more precise than previous values.

The ^{80}Se$(d,\alpha)^{78}$As reaction has been described elsewhere.[1] In that paper, a g.s. Q value of 5755±12 keV was quoted. Not mentioned was the resulting mass excess of −72 805±13 keV for ^{78}As. This is in agreement with, but significantly more precise than, the recent compilation which lists −72 740±70 keV.[2] The latter value was derived from the mass of stable ^{78}Se and the β-decay endpoint energy of the ^{78}As to ^{78}Se transition.

The ^{76}Ge$(t,p)^{78}$Ge g.s. Q value was found using a series of (t,p) reactions on various Ge targets. These experiments have also been described previously.[3–6] The isotope ^{76}Ge appears as a weak (0.1%→0.9%) impurity in the other enriched Ge targets and as a 7.8% component of the natural Ge target. The relatively large forward angle cross section leading to the g.s. in the ^{76}Ge$(t,p)^{78}$Ge reaction (~3.5 mb/sr) compensates for the weak concentration so that a peak due to the g.s. of ^{78}Ge appears clearly. Figure 1 shows a sample spectrum for each of the reactions used in this analysis. Because the g.s. Q values of the (t,p) reaction on the other Ge isotopes and the excitation energies of several low-lying states are accurately known, the ^{78}Ge g.s. peak is surrounded by peaks of known Q value. These other peaks were used to fine tune the spectrograph energy calibration. The ^{76}Ge$(t,p)^{78}$Ge reaction performed with an enriched ^{76}Ge target was not used because it did not contain such calibration peaks.

The Q values of reference peaks were calculated using tabulated masses[2] and known excitation energies of low-lying states in the residual nuclei. The three-parameter fit involved first varying the beam energy so as to give a best fit to the calibration peaks. All fits used linear least-squares methods. This procedure was performed separately for each angle of a particular experiment, but an average of these values was used as the beam energy in all further calculations. The second stage of the fit involved linearly varying the radius of curvature of the protons in the spectrograph so that $\rho' = \alpha\rho + \beta$. Different values of α and β were used for each an-

TABLE I. Separate results for the ^{76}Ge$(t,p)^{78}$Ge g.s. Q value (keV).

Main target isotope	θ_{lab}	^{76}Ge$(t,p)^{78}$Ge g.s. Q value
^{nat}Ge	3.75	6321.6
^{nat}Ge	11.25	6312.3
^{72}Ge	3.75	6305.8
^{72}Ge	11.25	6319.5
^{74}Ge	3.75	6309.5
^{74}Ge	11.25	6306.2
^{74}Ge	33.75	6309.6
Weighted average = 6310 ± 5		

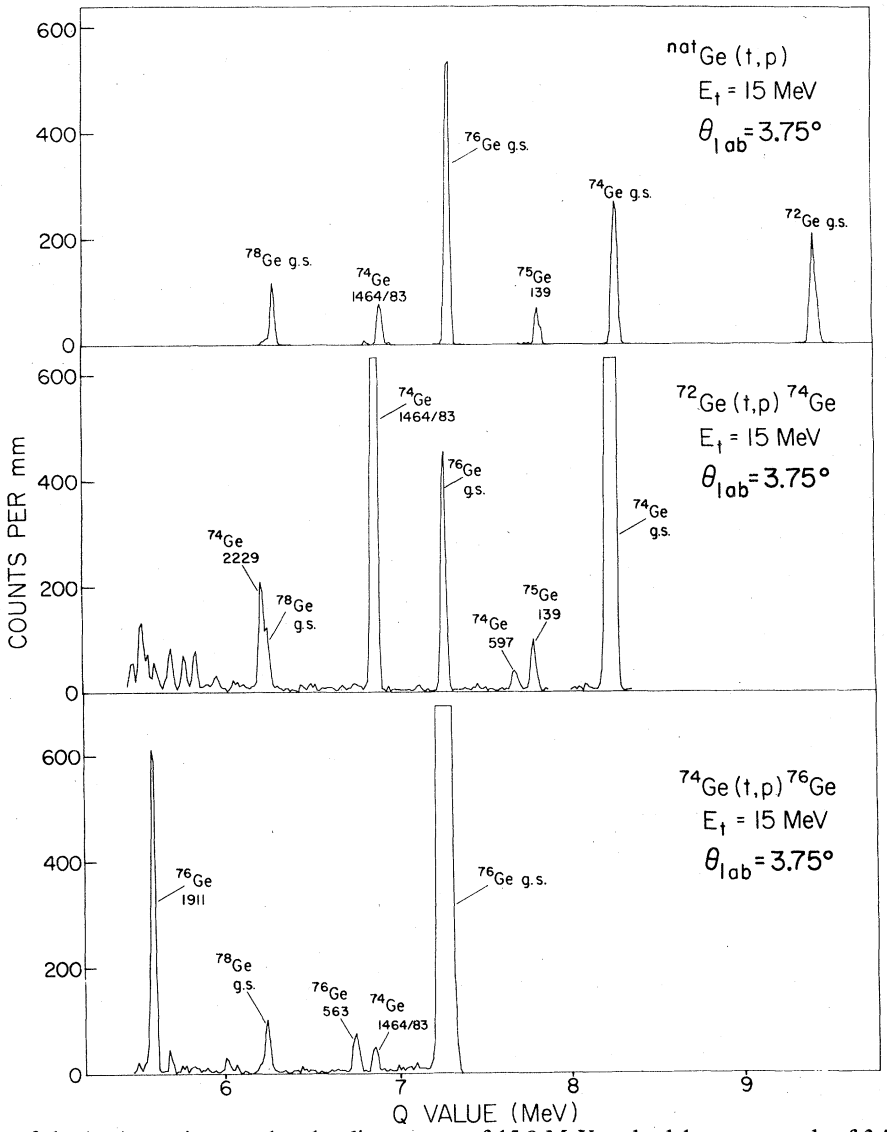

FIG. 1. Spectra of the (t,p) reaction at a bombarding energy of 15.0 MeV and a laboratory angle of 3.75°, obtained with a natural Ge target (top) and with enriched targets of ^{72}Ge (middle) and ^{74}Ge (bottom). The g.s. peak from the reaction ^{76}Ge$(t,p)^{78}$Ge is visible near $Q=6.3$ MeV in all three spectra.

gle. Typical parameter values were a beam energy shift of 50 keV (out of 15 MeV), $\alpha=1.003$, and $\beta=0.2$ cm (where ρ was about 65 cm for most peaks). Chi squared per degree of freedom for all fits was less than 1.10. This procedure eliminates all significant systematic errors such as small uncertainties in the beam energy and slight irregularities in the spectrograph calibration. While our value does depend on the other Ge(t,p) Q values (all of which are known to better than 3 keV), it would be significantly affected only if all other values were wrong in the same direction, i.e., all too small or all too large. The separate results are listed by target and angle in Table I. The weighted average Q value is 6310 ± 5 keV. The resulting mass excess of ^{78}Ge is $-71\,861\pm6$ keV. This is roughly 1.5 standard deviations away from the previous value of $-71\,760\pm70$ keV,[2] which was derived from β-decay energies.

For the ^{80}Se$(d,\alpha)^{78}$As, only a few reference peaks due to ^{12}C and ^{16}O impurities were available. As a result, only a beam energy fit was performed, which explains the larger uncertainty (±12 keV) in the quoted Q values. If all of the oxygen were on

TABLE II. Comparison of present results with published values.

	Present work (keV)	Previous work (keV)
^{78}As Mass excess	$-72\,805 \pm 13$	$-72\,740 \pm 70$[a]
^{78}Ge Mass excess	$-71\,861 \pm 6$	$-71\,760 \pm 70$[a]
^{78}Ge $\rightarrow$ ^{78}As β-decay end point	944 ± 14[c]	980 ± 20[b]
^{78}As $\rightarrow$ ^{78}Se β-decay end point	4227 ± 13[c]	4310 ± 70[b]

[a]Reference 2.
[b]Experimental measurement. Reference 7.
[c]Calculated from masses.

the surface, our value would be in error by 5 keV due to energy loss in the target.

Our new mass values can be used to calculate β-decay endpoint energies to compare with the experimental values. The results are 944 ± 14 and 4227 ± 13 keV for the ^{78}Ge to ^{78}As decay and the ^{78}As to ^{78}Se decay, respectively. The most recent experimental values are 980 ± 20 and 4310 ± 70 keV, respectively.[7] Both sets are approximately one standard deviation apart. Table II summarized the present results and recent compilations. The new mass values are significantly more precise than previous ones. They also permit an independent check of the β-decay endpoint energies which was not previously possible.

We acknowledge financial aid and support from the National Science Foundation.

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