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Mass of ^{57}Ni*

H. Nann, E. Kashy, D. Mueller and A. Saha

Cyclotron Laboratory, Michigan State University
East Lansing, Michigan 48824

and

S. Raman

Physics Division, Oak Ridge National Laboratory,
Oak Ridge, Tennessee 37830

ABSTRACT

A measurement of the Q-values of the $^{59}Ni(p,t)^{57}Ni$ and the $^{58}Ni(^{3}He,\alpha)^{57}Ni$ reactions shows a significant discrepancy with the current tabulated mass values. We find -12738.2 ± 3.3 keV and +8360.3 ± 4.0 keV, respectively, leading to a new improved mass excess for ^{57}Ni of -56078.4 ± 3.0 keV.

NUCLEAR REACTIONS $^{59}Ni(p,t)$; $^{58}Ni(^{3}He,\alpha)$; measured Q-values, deduced mass excess for ^{57}Ni.

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Since the 1971 Wapstra-Gove Mass Tables[1] were published, several reaction Q-values have been found[2-4] which disagree from the tables by several standard deviations. In this note, we report new results for the mass for ^{57}Ni found during the course of studying the $^{59}Ni(p,t)^{57}Ni$ and $^{58}Ni(^{3}He,\alpha)^{57}Ni$ reactions. The ^{57}Ni mass excess of -56104 ± 7 keV reported in the 1971 Mass Table is based on the end point energy for the ^{57}Ni - ^{57}Co decay[5]. A previously measured Q-value of +8400 ± 50 keV for the $^{58}Ni(^{3}He,\alpha)^{57}Ni$ reaction[6] was not used to determine the mass excess of ^{57}Ni.

In the $^{59}Ni(p,t)^{57}Ni$ experiment, we used a 40 MeV proton beam from the Michigan State University cyclotron. The reactor produced ^{59}Ni target (37.4% ^{58}Ni, 43.0% ^{59}Ni, 15.2% ^{60}Ni, 1.0% ^{61}Ni, 2.1% ^{62}Ni, and 1.2% ^{64}Ni) was a rolled foil of about 230 $\mu g/cm^2$ thickness. The reaction products were detected in the focal plane of an Enge split-pole spectrograph by a position sensitive proportional counter. The resolution obtained was about 15 keV full width at half maximum (FWHM). Figure 1 shows an example of the spectra obtained. As one can see, the ground and 0.769 MeV state transitions of the $^{59}Ni(p,t)^{57}Ni$ reaction fall in the same region as the ground and 1.454 MeV state transitions of the $^{60}Ni(p,t)^{58}Ni$ reaction and the ground state transition of the $^{58}Ni(p,t)^{56}Ni$ reaction. These three transitions thus serve as calibration lines for the $^{59}Ni(p,t)$ Q-value determination. The spectrograph calibration method and fitting procedure is described extensively elsewhere[7]. Since the present measurement involves only the position of the tritons from the different Ni-isotopes in the target, the uncertainties attributed to the beam energy and the scattering angle and due to target thickness effects are negligible. The main source of errors are the Q-values of the calibration reactions and local non-linearities in the position-sensitive detector. The uncertainties of both sources are estimated to be $\leq$ 3 keV. Using the most recent mass excess values of Jolivette et al.[4] for the calibration Q-values we obtain -12738.2 ± 3.3 keV for the Q-value of the $^{59}Ni(p,t)^{57}Ni$ ground state transition. This value is 18.4 keV more negative than the -12719.8 ± 7.6 keV result calculated from the 1971 Mass Table.

The $^{58}Ni(^{3}He,\alpha)^{57}Ni$ experiment was performed with a 70 MeV ^{3}He beam using a similar setup as described before. The target was prepared by vacuum evaporation of ^{58}Ni (isotopically enriched to 99.9%) onto a carbon backing and had a thickness of about 90 $\mu g/cm^2$. In this experiment, the magnetic rigidities of the alpha particles from the $^{58}Ni(^{3}He,\alpha)^{57}Ni$ reaction were compared to those from the calibration reaction $^{52}Cr(^{3}He,\alpha)^{51}Cr$. The magnetic field of the spectrograph was adjusted to put the alpha particles from both ground state transitions on the same location of the focal plane. This method, described in detail previously[8], does not rely on the linearity of the detector. The dependence of the Q-value determination on the beam energy and scattering angle was minimized by choosing the calibration reaction with a very similar Q-value and by measuring at very forward angles ($\theta_{lab} < 10°$). The main sources of error, here, were the uncertainties in the energy loss corrections resulting from target thickness uncertainties and the uncertainty in the Q-value of the

calibration reaction $^{52}Cr(^{3}He,\alpha)^{51}Cr$, again taken from Jolivette et al.[4] The Q-value thus obtained for the $^{58}Ni(^{3}He,\alpha)^{57}Ni$ reaction is +8360 ± 4.0 keV, 16 keV less positive than the published value of +8376 ± 8 keV.

The results of both measurements together with the values used for calibration are collected in Table I. From the two Q-values a mass excess for ^{57}Ni of -56078.4 ± 3.0 keV was extracted. This value is 25.6 keV more positive than the value -56104 ± 7 keV reported in the 1971 Mass Table. The apparent discrepancy between this 25.6 keV and the average deviation of 17.1 keV in the Q-values measured is the result of the change in the measured masses of the $^{58,59,60}Ni$ isotopes since 1971.

Table I.--Q-value measurements for the determination of the mass excess of ^{57}Ni. The mass excesses of Ref.4 have been used throughout this work.

Reaction	Q-value (keV)	Mass excess of final nucleus (keV)
$^{52}Cr(^{3}He,\alpha)^{51}Cr$	+ 8537.8 ± 2.2	
$^{58}Ni(^{3}He,\alpha)^{57}Ni$	+ 8360.3 ± 4.0	-56080.4 ± 4.6
$^{60}Ni(p,t)^{58}Ni$	-11904.5 ± 2.8	
$^{58}Ni(p,t)^{56}Ni$	-13979.0 ± 3.0	
$^{59}Ni(p,t)^{57}Ni$	-12738.2 ± 3.3	-56075.2 ± 3.9

Weighted average of the mass excess for ^{57}Ni: -56078.4 ± 3.0 keV.

References

1) A.H. Wapstra and N.B. Gove, Nucl. Data A9(1971); N.B. Gove and A.H. Wapstra, ibid. A11(1972).

2) J.D. Goss, C.P. Browne, and A.A. Rollefson, Phys. Rev. Lett. 30, 1255(1971).

3) A. Moalem and B.H. Wildenthal, Phys. Rev. C8, 1961(1973).

4) P.L. Jolivette, J.D. Goss, G.L. Marolt, A.A. Rollefson, and C.P. Browne, Phys. Rev. C10, 2449(1974).

5) E.W.A. Lingeman, J. Konijn, F. Diederix and B.J. Meijer, Nucl. Phys. A100, 136(1967).

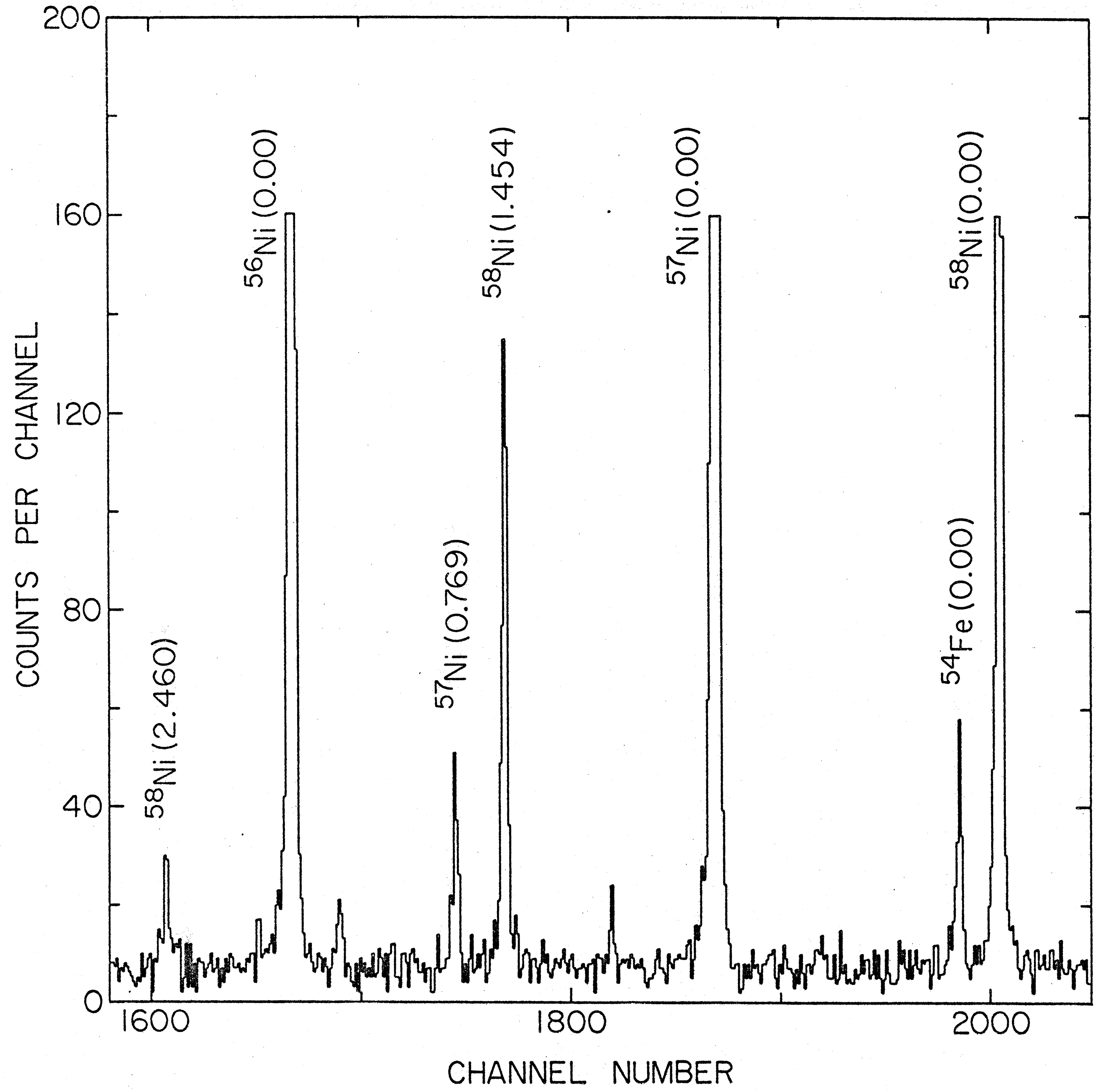
6) C.M. Fou and R.W. Zurmühle, Phys. Rev. 140, B1283(1965).

7) J.A. Nolen, Jr., G. Hamilton, E. Kashy and I.D. Proctor, Nucl. Instr. Methods 115, 189(1974).

8) W. Benenson, E. Kashy, I.D. Proctor, and B.M. Preedom, Phys. Lett. 43B, 117(1973); E. Kashy, W. Benenson, I.D. Proctor, P. Hauge, and G. Bertsch, Phys. Rev. C7, 2251(1973).

Figure Caption

Fig. 1. Triton spectrum of the $^{58,59,60}Ni(p,t)^{56,57,58}Ni$ reactions. The peaks are labelled by the final nucleus and its excitation energy,



200
160
120
80
40
0
COUNTS PER CHANNEL
1600
1800
2000
CHANNEL NUMBER
58Ni (2.460)
56Ni (0.00)
57Ni (0.769)
58Ni (1.454)
57Ni (0.00)
54Fe (0.00)
58Ni (0.00)