observed in these alloys, clouds of greater or lesser than average magnetization. These may be due to some metallurgical process like precipitation[14] or may be due simply to statistical fluctuations.[15] Furthermore, in Ni-Cu "soft," resonant, localized magnon states may be available at very low energies into which the magnons may be easily scattered.[16] All of these factors can reduce the magnon lifetime and thus our upper limit seems reasonable. Unfortunately, existing papers on SWR in these alloys do not report a linewidth.[12]

These are the first observations of magnon thermal conduction in transition metals. At 4 K the magnons contribute only about 3% of the total conductivity, but since our samples are alloys, the change of the electronic and phonon conductivities with magnetic field is much less than that. Thus we have been able to draw several conclusions about the behavior of the magnons in these metals. The results for the Ni-Fe alloys indicate that the magnons are scattered with $\tau_m \propto \omega^{-1/2}$. The only mechanism which gives this frequency dependence and predicts the correct order of magnitude for τ_m is s-d exchange scattering by electrons.

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Reaction Q Values from Near-Threshold Neutron Spectra*

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A thick-target time-of-flight technique has been employed to measure neutron energies for (p,n) resonance levels near threshold in medium-weight nuclei. Combining the results with proton energy measurements of these resonances, the following ground state (p,n) Q values have been deduced: ^{41}K, -1203.8 ± 0.5 keV; ^{45}Sc, -2843.6 ± 4.0 keV; ^{51}V, -1533.7 ± 1.5 keV; and ^{57}Fe, -1618.2 ± 2.0 keV.

Parks et al.[1] have shown by a direct measurement of proton energy, and an indirect measurement of neutron energy, that the first compound nuclear resonance to be reached in the reaction ^{40}Ar$(p,n)^{40}$K lies 3 keV above the true reaction threshold. Johnson, Trail, and Galonsky[2] comment upon this case but point out that there is little other direct evidence for "resonance errors" in Q-value determinations from (p,n) threshold measurements, although the possibility of such errors has long been recognized.[3,4] In fact, Parks et al. state that Johnson, Trail, and Galonsky misinterpreted the Duke results. Thus, even for the reaction ^{40}Ar(p,n) adequate data does not exist for demonstrating a resonance error in Q-value determination from a thick-target threshold measurement. We wish to report a direct measurement of both proton and neutron energies for the reaction ^{41}K$(p,n)^{41}$Ca which shows that for this reaction a sub-

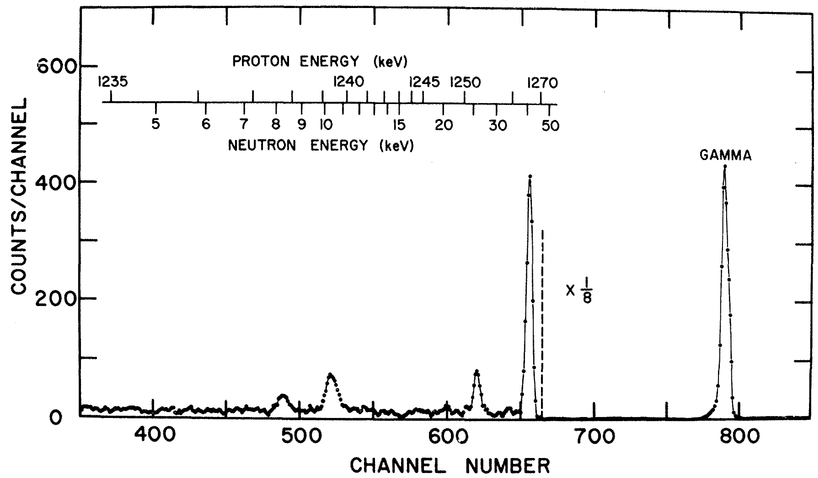

FIG. 1. Neutron time-of-flight spectrum from a thick target of ^{41}K bombarded by protons of energy ≈1280 keV. The ^{41}K+p compound system resonances seen here were excited by protons which had slowed down in the target to the resonance energy. A flat background of 20 counts per channel has been subtracted and the data have been smoothed by a three-channel average.

stantial resonance error is present in the Q value which is obtained from the apparent neutron threshold.

Figure 1 is a neutron time-of-flight spectrum from the reaction ^{41}K(p,n)^{41}Ca. It was obtained by bombarding a thick ^{41}KI target with a pulsed and bunched proton beam whose energy was several tens of keV above threshold. Neutrons were detected with a 2-mm-thick by 7.6-cm-diam ^{6}Li-loaded glass scintillator coupled to an RCA C70133B photomultiplier tube. The flight path was 19 cm and the detector was positioned at 0°. The time resolution of the detector, exclusive of geometrical factors, was 2.5 nsec and its efficiency was about 0.5% for incident 10-keV neutrons. The spectrum of Fig. 1 was accumulated in 10 h with an average beam current of about 2.5 μA. The prominent lines in this spectrum result from narrow resonances in the ^{41}K +p compound system which were excited by protons that had slowed down in the target to the resonance velocities.

Since for a given incident proton energy the lines in the thick-target neutron spectrum give no indication of the resonant proton energies (in the absence of a Q value), this spectrum was combined with proton energies obtained from a conventional thin-target yield curve as measured at the Australian National University with a long counter[5,6] (Fig. 2). Proton energies for that measurement were calibrated with ^{27}Al(p,γ)^{28}Si resonances at 1213.0 ± 0.3 and 1262.2 ± 0.3 keV.[7] The apparent thick-target threshold from those measurements (1237.25 ± 0.5 keV) agrees well with that of Johnson, Trail, and Galonsky[2] (1239.5 ± 1.5 keV). Table I lists the proton energies and laboratory neutron energies at 0° for four ^{41}K(p,n)^{41}Ca resonances. A weighted average yields a Q value of −1203.8 ± 0.5 keV and a corresponding ^{41}K-^{41}Ca mass difference of 421.4 ± 0.5 keV. This Q value is 5.9 keV lower than that deduced from the apparent reaction threshold, but is 9 keV above the Q value calculated from the 1964 mass table.[8]

Table I includes results for single resonances in the reactions ^{45}Sc(p,n)^{45}Ti, ^{51}V(p,n)^{51}Cr, and ^{57}Fe(p,n)^{57}Co. The tabulated ^{51}V(p,n)^{51}Cr resonance is the peak labeled I in the thick-target neutron time-of-flight spectrum presented in

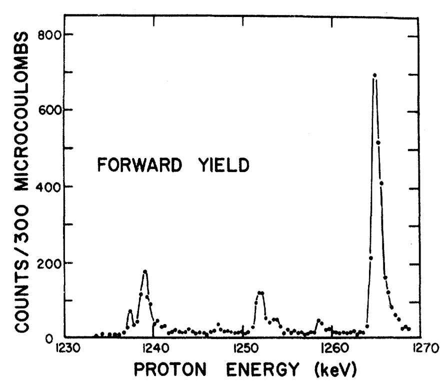

FIG. 2. Thin-target neutron yield curve from the reaction ^{41}K(p,n)^{41}Ca as measured with a long counter. A more accurate measurement of resonance proton energies (Ref. 6) showed that proton energies in the figure should be increased be 0.35 keV.

Table I. Proton and neutron energies of several compound system resonances and the resultant ground-state reaction Q values. Quoted errors associated with this work are probable errors for the $^{41}K(p,n)^{41}Ca$ results and standard errors for the other neutron energy measurements and Q values.

Reaction	Lab. Proton Energy (keV)	0° Lab. Neutron Energy (keV)	$Q_{\text{this work}}$ (keV)	$Q_{\text{mass table}}$ (a) (keV)	$Q_{\text{threshold meas.}}$ [negl. resonance errors] (keV)
$^{41}K(p,n)^{41}Ca$	1237.85 ± 0.5	8.32 ± 0.14	-1203.9 ± 0.5		
	1239.45 ± 0.5	10.5 ± 0.2	-1203.8 ± 0.5		
	1252.85 ± 1.	26.0 ± 0.7	-1204.3 ± 1.1		
	1265.75 ± 0.5	41.9 ± 1.3	-1203.0 ± 1.3		
	Q value weighted average:		-1203.8 ± 0.5	-1195 ± 8	-1209.7 ± 1.5 (b)
$^{45}Sc(p,n)^{45}Ti$	2910.3 ± 4. (c)	8.14 ± 0.08	-2843.6 ± 4.	-2841.0 ± 3.7	-2843.2 ± 4. (c)
$^{51}V(p,n)^{51}Cr$	1567.3 ± 1.5 (d)	6.49 ± 0.04	-1533.7 ± 1.5	-1534.1 ± 1.1	-1533.7 ± 1.8 (b)
$^{57}Fe(p,n)^{57}Co$	1649 ± 2. (e)	4.55 ± 0.1	-1618.2 ± 2.	-1619.0 ± 2.5	-1619 ± 2. (b)

[a] J. H. E. Mattauch, W. Thiele, and A. H. Wapstra, Nucl. Phys. 67, 32 (1965).

[b] Johnson, Trail, and Galonsky, Ref. 2.

[c] Brugger, Bonner, and Marion, Ref. 11, their values adjusted to $^7Li(p,n)^7Be$ threshold of Ref. 10; the tabulated resonance proton energy was obtained from their threshold measurement, interpreted, and adjusted as explained in text.

[d] Gibbons, Macklin, and Schmitt, Ref. 9, peak I, adjusted to $^7Li(p,n)^7Be$ threshold of Ref. 10.

[e] Johnson, Trail, and Galonsky, Ref. 2 threshold, interpreted and adjusted as explained in text.

Fig. 3. The numeral labeling of resonances in this spectrum corresponds to that in the $^{51}V(p,n)^{51}Cr$ thin-target yield curve of Gibbons, Macklin, and Schmitt[9]; the proton energy of peak I was taken from their paper, adjusted to a $^7Li(p,n)^7Be$ threshold of 1880.6 keV.[10] The $^{45}Sc(p,n)^{45}Ti$ and $^{57}Fe(p,n)^{57}Co$ resonances listed in Table I are responsible for the respective experimental thresholds. The proton energy for the ^{57}Fe resonance was obtained from the threshold measurement of Johnson, Trail, and Galonsky[2] by assuming they quoted the low-energy edge of this resonance and that their energy resolution was about 1 keV. Similarly, the proton energy for the quoted ^{45}Sc resonance was obtained from the threshold measurement of Brugger,

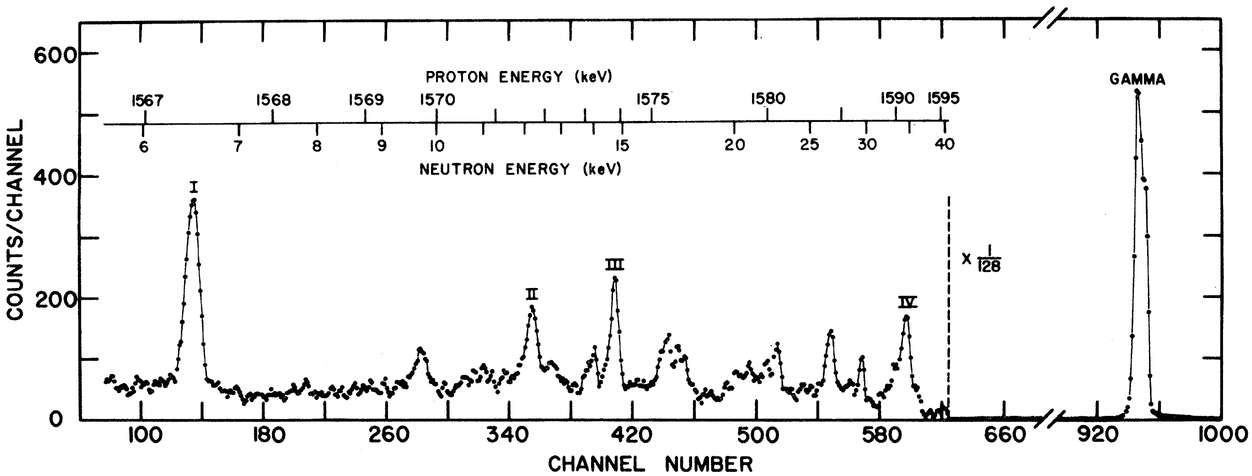

FIG. 3. Neutron time-of-flight spectrum from a thick ^{51}V target bombarded by ≈1595-keV protons. The flight path was 40 cm, a flat background of 150 counts per channel has been subtracted, and the data have been smoothed by a three-channel average.

Bonner, and Marion[11] using an estimated energy resolution of 3 keV [from their ^{45}Sc(p,n)^{45}Ti neutron forward yield curve], and adjusting the result to the 1880.6 keV ^{7}Li(p,n)^{7}Be threshold value.[10]

The existence of several significant differences between the method reported here and that of the Duke group[1] warrants some discussion. While the establishment of (p,n) reaction Q values does require the precise measurement of both proton and neutron energies, the direct measurement of neutron energies alone allows access to spectroscopic information thus far unobtainable, for several practical reasons, from the Duke high-resolution proton techniques. The Duke requirements of an extremely thin, uniform target and a highly monoenergetic proton beam, coupled with a proton-energy–associated Doppler resolution limit caused by thermal motion of target atoms, restrict this technique to gaseous, cooled targets and an energy resolution of about 0.2 keV. The thick-target method, on the other hand, allows neutron measurements from anything of known and uniform composition[12] and replaces the requirement of a highly monoenergetic proton beam with that of an intense nanosecond pulsed beam. The neutron-energy resolution limit associated with thermal motion of target nuclei depends on the neutron velocity rather than proton velocity when neutron energies are measured. This Doppler limit favors neutron resolution for reactions with negative Q values by a factor of order 10 for the reactions reported above. Besides the great relaxation of target requirements and the much more favorable Doppler limit there is also a kinematic advantage in neutron measurements. Near reaction threshold, center-of-mass motion causes the neutron energy to increase more rapidly than the proton energy does. The kinematic improvement in resolution for peak I in Fig. 3, for example, is $dE_n/dE_p|_\mathrm{I} = 1.38$ and is larger at lower energies.

The low neutron detection efficiency associated with a thin ^{6}Li-loaded glass scintillator, whose solid angle is made small by the requirement of a relatively long neutron flight path, is largely compensated for by the use of a thick target. Since protons slow down in the target through all energy levels, data associated with all neutron energies are accumulated simultaneously. Low yields from the reactions described above, however, have forced us to work with a resolution determined by detector geometry (time spreads caused by scintillator thickness and the use of a flat scintillator). We can nevertheless state that the neutron laboratory resonance width (full width at half-maximum) of the ^{51}V(p,n)^{51}Cr resonance referred to above is 170 eV or less, which corresponds to a proton laboratory resonance-width upper limit of 123 eV. The corresponding peak cross section is 0.6 mb/sr or more.

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