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$V^{51}(p,n)Cr^{51}$ Reaction as a 5- to 120-kev Neutron Source

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The $V^{51}(p,n)Cr^{51}$ reaction provides a usable source of monoenergetic neutrons from 5 to 120 kev. The yield indicates resonances in Cr^{52} with an average spacing of less than 2 kev in this evergy range. A preliminary measurement was made of the angular distribution of eleven of the more prominent peaks.

The $V^{51}(p,n)Cr^{51}$ reaction has been recognized as a source of monoenergetic neutrons for many years,[1,2] but has not been extensively used. In connection with a series of experiments on the Oak Ridge National Laboratory 2.5-Mv Van de Graff, we have run a forward yield curve using a 1 kev thick natural vanadium (99.76 percent V^{51}) target. Such targets may be readily prepared by vacuum evaporation from tungsten if care is taken to avoid the tungsten oxide which evaporates at a lower temperature. The neutron yield curve at high energies has been reported.[3]

At proton energies from 1.55 to 1.65 Mev many resonances were observed (Fig. 1), with an average spacing less than 2 kev. The experimental width of the peaks was just that of the target, indicating that the natural widths of the resonances (and the spread of the proton beam) were appreciably less than 1 kev. The threshold was determined as 1.5656±0.0015 Mev by calibration with the $Li(p,n)$ threshold, in agreement with earlier work.[2,4]

The neutron detector used in the measurements was a set of three paraffin-surrounded BF_3 counters grouped in a 45° half-angle forward cone. The response of the counters is expected to vary no more than 20 percent over the 5–120 kev range. The background, as measured below threshold, was negligible (see Fig. 1). Some of the

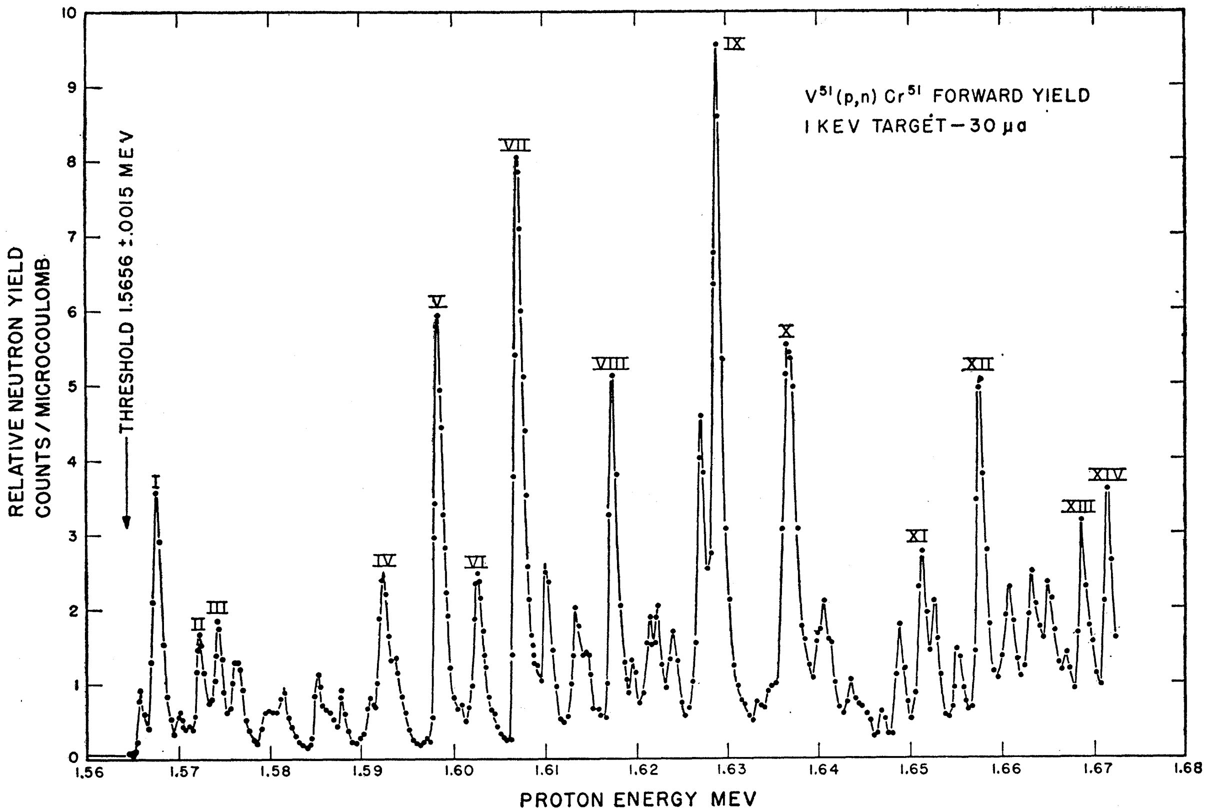

Fig. 1. $V^{51}(p,n)Cr^{51}$ forward neutron yield. Target thickness was 1.0 kev. Proton beam current was about 30 μa.

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[2] Stelson, Preston, and Goodman, Phys. Rev. 80, 287 (1950).
[3] Baker, Howell, Goodman, and Preston, Phys. Rev. 81, 48 (1951).
[4] R. V. Smith and H. T. Richards, Phys. Rev. 74, 1257 (1948).

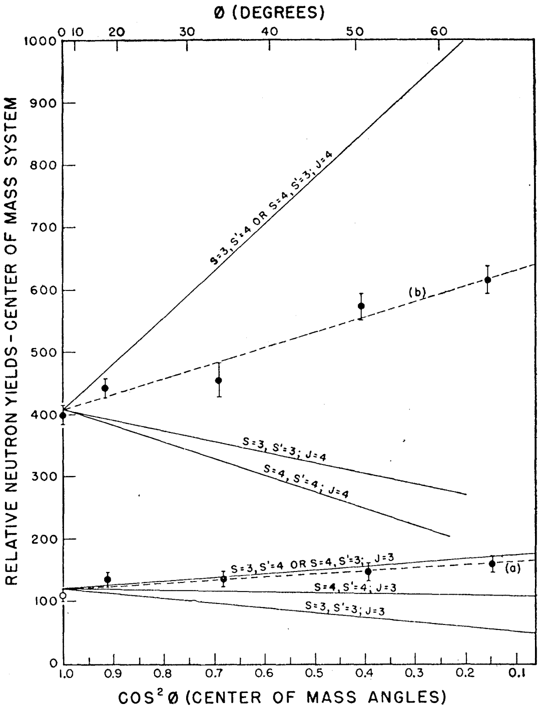

FIG. 2. Selected neutron angular distributions. Curve (a) corresponds to peak IV, Curve (b) to peak V. Points for curve (a) were taken with a detector half-angle of 22°. Points for curve (b) are a combination of two runs, one with a detector half-angle of 9°, the other, 22°. The two runs gave identical results within probable error. The solid lines are calculated (Channel Spin formalism) and correspond to $l=1$ protons and neutrons.

more intense $V(p,n)$ peaks together with the corresponding 0° neutron energies are listed in Table I.

A rough determination of the angular distribution of neutrons from eleven of the more prominent peaks has been made. The runs were made with a small paraffin-surrounded $B^{10}F_3$ detector subtending either a 9° or a 22° half-angle cone, depending upon the yield available. The region from 0° to 60° was covered at 15° intervals with about 10 percent counting statistics (standard deviation) after subtracting a 20–30 percent background as determined with a shadow cone. Departures from isotropy were found in two cases (Peaks IV and V), the intensity increasing with the angle to the proton direction in each case (see Fig. 2). The coefficient of the P_2 term in a Legendre polynominal expansion fitting the data $W(\phi)\sim 1+AP_2(\cos\phi)$ is given in Table I, together with an estimate of the uncertainty in its determination.

The two anisotropic peak angular distributions, if considered as dominated by single resonances, can be fitted with reasonable channel spin mixtures,[5] assuming the initial and final nuclei have spins of 7/2 and the same parity, as predicted by the shell model. Peak IV can be fitted for p wave protons and neutrons assuming spin $J=3$ or 4 for the compound nucleus, while Peak V is well fitted only for $J=4$. The channel spin pairs are shown unmixed in Fig. 2. No reasonable fits were found for either angular distribution using the j-j coupling model.[6]

The absolute yield of Peak VII (1-kev target) was estimated, using a McKibben long counter standardized with a Po-B neutron source of given yield, to be 380 (±10 percent) neutrons per steradian per microcoulomb near 0°. Another estimate was obtained from an activation experiment in which the 25-minute beta activity of I^{128}, induced by neutron bombardment of NaI(Tl) crystals, was measured. Published iodine cross sections,[7] also based on a long counter calibration, were used to compute the absolute yield and a value twenty percent lower than the above was obtained.

TABLE I. $V^{51}(p,n)Cr^{51}$ neutrons: Selected peaks. The figures in the last column represent the coefficient A, of the angular distribution $W(\phi)\sim 1+AP_2(\cos\phi)$.

Peak	E_p(Mev)	0°E_n(kev)	A
I	1.568	4.8	0±0.13
II	1.573	11.3	0±0.13
III	1.575	13.6	...
IV	1.592	34	−0.21±0.07
V	1.598	40	−0.30±0.05
VI	1.603	45	0±0.13
VII	1.607	50	0±0.13
VIII	1.617	61	0±0.13
IX	1.629	74	0±0.13
X	1.637	82	0±0.13
XI	1.651	97	...
XII	1.658	104	0±0.13
XIII	1.669	116	−0.11±0.13
XIV	1.672	119	...

Useful yields of monoenergetic neutrons can be obtained from the $V(p,n)$ reaction at 15 or more reasonably discrete energies from 5 kev to 120 kev, above which the more prolific $Li(p,n)$ reaction gives monoenergetic neutrons at the forward angles.

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[5] J. M. Blatt and L. C. Biedenharn, Revs. Modern Phys. 24, 258 (1952).

[6] G. R. Satchler, Proc. Phys. Soc. (London) A66, 1081 (1953).

[7] *Neutron Cross Sections*, Atomic Energy Commission Report AECU-2040 Supplement No. 2 (Office of Technical Services, Department of Commerce, Washington, D. C., 1953).