Systematics of Photoneutron Reactions*

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USING the method of direct neutron detection previously reported,[1] we have measured the photoneutron yields from 13 singly isotopic elements when irradiated with betatron *bremsstrahlung* at energies from threshold to 24 Mev. Four enriched BF_3 proportional counters were symmetrically placed 13.5 cm from the target in the paraffin house of reference 1 to increase the sensitivity of the apparatus. Neutron yields were taken at 0.5-Mev intervals to a statistical accuracy of better than 1 percent, except for the first two points near threshold, where the statistical inaccuracy never exceeded 3 percent. The energy of the betatron was stable to better than 0.1 Mev, as evidenced by repeated daily checks of the bismuth (γ,n) threshold during the course of the experiment.

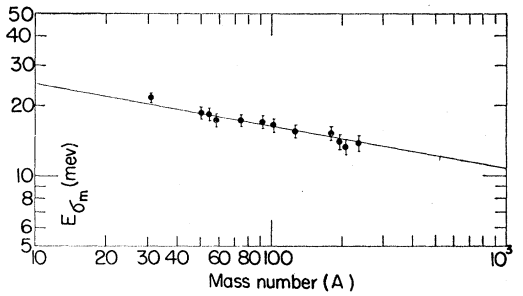

FIG. 1. Log-log plot of $E\sigma_m$ *versus* mass number.

Excitation functions constructed from the total neutron yield data by the usual method of successive subtractions[2] show the characteristic large dipole resonance behavior for all the elements investigated. The data are summarized in Table I, where the significant parameters for the resonances are given. Here σ_m represents the maximum value of the cross section, $E\sigma_m$ the energy at which this maximum occurs, Γ the width of the resonance at half maximum, and $\int\sigma dE$ the integrated cross section to 25 Mev. Also tabulated is the neutron yield at 22-Mev betatron energy for comparison with the measurements of Price and Kerst.[3]

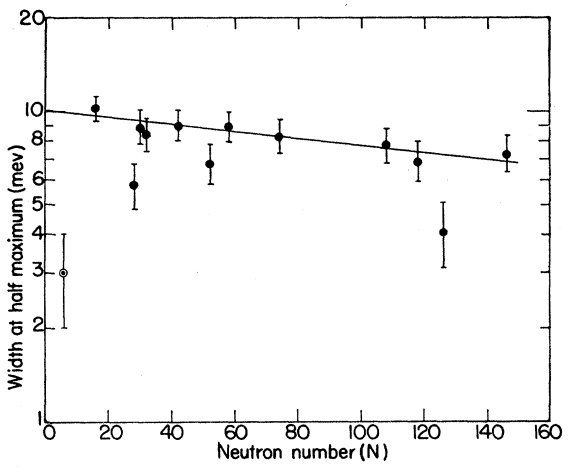

FIG. 2. Width at half-maximum of neutron emission resonance *versus* neutron number.

The log-log plot of $E\sigma_m$ against mass number is shown in Fig. 1. The least-squares straight line through the experimental points yields $E\sigma_m = 38.5A^{-0.19}$, in close agreement with the results of Cameron[4] from other data and in striking agreement with the predictions of Goldhaber and Teller.[5]

A plot of the dipole resonance half-widths against neutron number (Fig. 2) shows a slow decrease in half-width as N increases, with the exception of four elements having unusually narrow resonances. The correlation of these elements, C^{12} $(N=6)$, V^{51} $(N=28)$, Cb^{93} $(N=52)$, and Bi^{209} $(N=126)$, with the shell model is unusual for phenomena concerned with such high excitation energies.

Further details of this study will appear later.

TABLE I. Summary of data.

Isotope	Target thickness (g/cm²)	Thresholds (Mev) (γ,n)	Thresholds (Mev) $(\gamma,2n)$	$E_{\sigma m}$ (Mev)	Γ Half-width (Mev)	σ_m $\left(\frac{10^{-26}}{\text{cm}^2}\right)$	$\int\sigma dE$ (Mev-barns)	22-Mev yield/mole-r $\times10^{-6}$ (this paper)	22-Mev yield/mole-r $\times10^{-6}$ (Price & Kerst)
$_6C^{12}$	12.8	18.7	32.6	22.0	3.0	0.93	0.030	0.026	
$_{15}P^{31}$	4.31	12.05	24.50	21.5	10.2	1.77	0.178	0.35	0.33
$_{23}V^{51}$	2.68	11.15	19.88	18.7	5.8	9.8	0.625	2.05	1.6
$_{25}Mn^{55}$	1.57	10.00	19.40	18.4	8.8	10.7	0.974	2.86	1.9
$_{27}Co^{59}$	2.59	10.25	19.67	17.3	8.4	8.1	0.697	2.28	2.3
$_{33}As^{75}$	1.34	10.10	17.42[a]	17.3	9.0	10.1	0.888	3.39	3.9
$_{41}Cb^{93}$	1.36	8.70	17.88[a]	17.0	6.8	21.3	1.62	6.05	5.8
$_{45}Rh^{103}$	1.81	9.35	17.47[a]	16.5	8.9	22.8	2.16	8.18	
$_{53}I^{127}$	1.23	9.10	16.72	15.5	8.3	26.7	2.27	10.2	11.0
$_{73}Ta^{181}$	0.468	7.55	13.84[a]	15.1	7.9	36.8	3.17	10.4	19.0
$_{79}Au^{197}$	0.455	7.90	13.71[a]	13.9	6.9	49.2	3.54	20.4	19.0
$_{83}Bi^{209}$	0.434	7.40	13.30[a]	13.2	4.1	45.0	2.92	17.9	25.0
$_{92}U^{238}$	0.548	5.97	12.18[a]	13.8	6.6	109.0	7.94	52.3	51.0

[a] Computed from mass formula.

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Low-Lying Many-Particle Levels in Odd Mass Nuclides with 21, 23, 25, or 27 Protons or Neutrons

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LOW-LYING excited levels in odd-mass nuclei with 21, 23, 25, or 27 protons or neutrons are to be expected because of the coupling of nucleons in the $f_{7/2}$ state.[1,2]

We were able to confirm their occurrence in some hitherto uninvestigated cases with 23 and 25 identical nucleons. Our results, which will be discussed below, are given in Table I, together with other data.[3–9]

V^{49}:—The positron decay of Cr^{49} was investigated both with a Geiger counter $\beta\gamma$-coincidence apparatus and with a NaI-scintillation spectrometer. The maximum energy of the beta spectrum is 1.47 ± 0.04 Mev by Al absorption, while roughly half of the positrons go to the ground-state of V^{49}. Gamma lines of 0.060 (5 percent), 0.091 (18 percent), 0.151 (12 percent), and 1.57 (5 percent) Mev were found (intensities relative to the total number of positrons). The 0.151-Mev line is presumably the crossover. The 1.57-Mev line is also found by O'Connor *et al.*[10] There is no indication of their 0.19-Mev line. Experiments are in progress to determine the multipolarity of the low-energy lines.

V^{51}:—The 0.325-Mev gamma line has been reported by several workers,[4] both in the electron-capture decay of Cr^{51} and in the β^- decay of Ti^{51}. From $V(p,p')$ reactions Hausman *et al.*[5] reported a second low-lying level at 0.48 Mev. We could not find a corresponding gamma line in the scintillation spectrum, either from the