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DATE: *January 21, 1957*

SUBJECT: *Cross Section Program at ORNL*

TO: *Members of the Nuclear Cross Section
Advisory Group*

FROM: *J. A. Harvey and J. L. Fowler*

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Oak Ridge National Laboratory
Oak Ridge, Tennessee

Jan. 21, 1957

To: Members of the Nuclear Cross Section
Advisory Group

From: J. A. Harvey and J. L. Fowler

Subject: Cross Section Program at ORNL

I. High Voltage Group

Differential Neutron Cross Section of C^{12} -- H. B. Willard, J. K. Bair, and
H. O. Cohn

The absolute differential cross section for neutron scattering from C^{12} has been remeasured as a function of angle at the following neutron energies: 1.45, 2.00, 2.25, 2.50, 2.75, 2.95, 3.05, 3.25, 3.50, and 3.75. Within the statistics of the measurements, the order of 5%, the results are in agreement with ORNL data reported previously.¹

¹ J. E. Wills, Bull. A. P. S. Series L1, Vol. No. 4, F3, p. 175 (1956).

Elastic Neutron Scattering Angular Distribution for Oxygen and Beryllium -- J. L. Fowler and H. O. Cohn

The differential elastic scattering cross section measurements for oxygen and beryllium have been continued with curves being obtained at 0.73, and 2.15 1.00, 1.50, and 1.75/Mev neutron energies. An abstract on the results has been submitted for presentation at the American Physical Society meeting at New York, 1957, as follows:

"The non-resonant neutron differential elastic scattering cross sections for oxygen and beryllium have been measured as a function of angle at several

energies by the technique of detecting scattered neutrons with a shielded recoil counter. For oxygen the data together with other measurements reported in the literature allow one to estimate the scattering phase shifts in the $0-2\frac{\text{Mev}}{\text{energy}}$ range. In this range the s-wave potential scattering phase shifts vary smoothly with energy and can be calculated from a static potential well. If one also requires that the energy position of the $J = 1/2^+$ bound state of O^{17} be correctly given by the well, the parameters are determined for any given shape. Analysis of the literature scattering data for C^{12} and use of the bound s-level in C^{13} in the same manner, gives a similar potential well for a neutron due to the C^{12} core. In order to make the effective radius of the potentials change in the expected way in going from C to O, one must introduce a diffuse boundary to the well. The elastic neutron scattering from He^4 has been calculated¹ with the same type wells."

¹ E. Van der Spuy, Nuclear Physics 1, 381 (1956).

$Be^9(n,\alpha)$ --- E. C. Campbell and P. H. Stelson.

An abstract entitled "Measurements of the Cross Section of $Be^9(n,\alpha)He^6$ Reaction" has been submitted for presentation at the American Physical Society meeting at New York, 1957:

"The cross section for the reaction $Be^9(n,\alpha)He^6$ (0.8 sec) was measured by detecting the β -decay of He^6 for neutron energies up to 4.4 Mev. Square-wave modulation of the (p,n) neutron source together with synchronous gating of the anthracene β -detector eliminated counts due to fast neutrons. The cross section exhibits a smooth rise from less than 10 microbarns at the expected threshold of $0.7 \pm .05$ Mev to a peak of 100 ± 10 millibarns at 3.0 Mev,

followed by a decrease to 60 millibarns at 4.4 Mev. The absolute neutron flux was determined with a U^{238} fission chamber to an accuracy of $\pm 6\%$. The β -counting efficiency is known to $\pm 5\%$."

Coulomb Excitation -- P. H. Stelson and F. K. McGowan.

The coulomb excitation of the 2^+ states in even-even isotopes of tin and zirconium have been observed by bombarding normal elements with 9.0 and 10.0 Mev α -particles. Results are summarized in an abstract to be presented at the 1957 New York meeting of the American Physical Society entitled "Coulomb Excitation of 2^+ States in even-even Isotopes of Tin and Zirconium."

(p, γ) Reaction -- H. B. Willard, J. K. Bair, and H. O. Cohn.

The zero-degree yields of gamma rays from the reactions $P^{31}(p,p'\gamma_{1.26 \text{ Mev}})P^{31*}$ and $P^{31}(p,\alpha,\gamma_{1.78 \text{ Mev}})Si^{21*}$ have been measured from 3 to 4 Mev bombarding proton energies. Over 26 narrow resonances were observed in this interval. In addition, a spectrum at 3.72 Mev revealed the presence of a 2.24-Mev gamma ray from the second excited state of P^{31} .

Energy Levels of C^{13} -- A. Galonsky, C. D. Moak, R. I. Traughber, and C. M. Jones.

Ten energy levels in C^{13} including the new levels at 5.49 and 6.09 Mev have been observed by detecting the protons produced in the $B^{11}(He^3,p)C^{13}$ reaction. An abstract on the work is to be presented at the 1957 New York meeting of the American Physical Society.

Millimicrosecond Time-of-Flight Spectrometry -- W. M. Good, J. H. Neiler, and J. H. Gibbons.

The cross sections of Y, Ti, and Pb have been studied at selected energies in the energy range 2.8 to 34 kev. Some of the observed levels were analyzed and these are listed below with the corresponding nuclear parameters.

Table

Element	E_0 (kev)	Γ	J	$\sigma \sqrt{t^2}$	Probable J	Remarks
Yttrium	8.5	60 ev 100 ev	1 0	8×10^5	0	Spin state assignment probable but not certain.
	11.2	50 ev 80 ev	1 0	4.5×10^5	0	
Titanium		Assuming				Isotopic assignment uncertain but both are probably due to Ti^{48}
	3.0	Ti^{46} 100 ev	Ti^{48} 20 ev (1/2)	--	(1/2)	
	3.7	150 ev	<u>30 ev</u> (1/2)	--	(1/2)	
	17.5	---	7 kev (1/2)	$\Gamma^0 = 52$ ev	(1/2)	
						S. P. width: $\Gamma^0 = 4800$ ev

The total cross section of natural lead between 20 and 34 kev departs from a straight line behavior, but not sufficiently so to justify any discussion at this time. Further investigation with separated isotopes is anticipated.

The ion source and the analyzer both are presenting problems which are more formidable than anticipated. The ion source under its operating conditions of high current output when it is being pulsed deteriorates for some as yet unknown

reason. The analyzer difficulty is that the 20 channel analyzer has been slightly changed to put more channels across a resonance with the consequence that channel instabilities range up to 4%.

Neutron Activation Cross Sections with Sb-Be Neutrons -- N. H. Lazar, W. S. Lyons, and R. L. Macklin.

An abstract on neutron activation cross sections with Sb-Be neutrons has been submitted for presentation at the 1957 New York meeting of the American Physical Society as follows:

"Neutron activation cross sections for Sb-Be neutrons (~ 25 kev) have been measured by gamma ray scintillation spectrometry. General agreement with theoretical predictions of absorption cross section vs atomic weight is found. Magic shell effects are quite evident and correspond with singularly low observed cross sections. Agreement with earlier published results¹ is generally within a factor of two. The activity determination through the measurement of the gamma ray intensity rather than the beta rays permits thick samples to be used and thereby a large increase in sensitivity and precision is obtained in favorable cases; e.g. a cross-section of 1.02 ± 0.2 mb was found for Na²³. Values of 1.08 ± 0.10 b for Au¹⁹⁷ and 0.80 ± 0.08 b for In¹¹⁵ (54 min) have been measured. Results on other nuclides are being checked. This work is based on an absolute measurement of the iodine activation cross section reported earlier.^{2"}

1 V. Hummel and B. Hammermesh, Phys. Rev. 82, 67 (1951).

2 R. L. Macklin, Bull. Am. Phys. Soc., Series II, 1, 264 (1956).

The latest results are summarized below:

Sb - Be Activation Cross Sections
Based on 820 ± 60 mb for I-127

Target Isotope	E_γ (Mev)	γ 's/decay	σ^* (mb)	Target Isotope	E_γ (Mev)	γ 's/decay	σ^* (mb)
Na 23	1.38	1.00	$1.0 \pm .2$	Ag 107	.61	.0225*	930 ± 180
Mg 26	.83	.70	< 20	In 115	1.28	.848	805 ± 80
Al 27	1.78	1.00	$1.4 \pm .2$	Sb 121	.57	.664	950 ± 100
Cl 37	2.1	.47	$1.1 \pm .2$	Sb 123	.603	1.00	456 ± 46
K 41	1.52	.20	< 20	[I 127	.455	.172	$820 \pm 60]$
Ti 50	.32	.95	5 ± 3	Ba 138	.165	.23*	11.4 ± 1.1
V 51	1.45	1.00	50 ± 5	La 139	1.60	.882*	50 ± 7
Mn 55	.82	1.00	55 ± 6	Ce 140	.145	.615	21 ± 2
Cu 63	.511	.38	116 ± 12	Ce 142	.29	.426*	425 ± 43
Cu 65	1.04	.10	46 ± 5	Pr 141	1.59	.041*	547 ± 55
Ga 71				Sm 152	.105	.357	860 ± 130
Ge 74	.274	.112	54 ± 8	Sm 154	.25	.043	465 ± 70
As 75	.55	.446*	740 ± 70	Gd 158	.364	.123*	710 ± 71
Br 81	1.03	.255*	550 ± 55	Er 170	.308 + .295	1.00 (?)	(272 ± 27)
Rb 85	1.08	.15	181 ± 35	Hf 180	.482	.85	441 ± 66
Rb 87	(1.85)	(.23)	75 ± 15	W 186	.686	.288*	296 ± 44
Zr 94	.745	.97	243 ± 36	Re 185			
Zr 96	.660 (Tc 97)	1.00	$22 \pm 4 (?)$	Re 187	.155	.162*	1490 ± 230
Mo 98	.14 + .18	.72*	209 ± 21	Os 190	.129	.224	886 ± 130
Mo 100	.192	1.00	38 ± 8	Ir 193			
	.30 (Tc 100)	1.00	45 ± 9	Au 197	.411	.95	1120 ± 110
Ru 96	.216	.92	321 ± 60	Hg 202	.279	.828	64 ± 13
Ru 102	.498	.90	386 ± 39	Th 232	.310(Pa 233)		500 ± 100
Ru 104	.73	1.00	211 ± 21	U 238			
Pd 108	.088	.0357*	700 ± 70				

*Own Measurement

II. Fast Chopper Time-of-Flight Spectrometer -- J. A. Harvey, R. C. Block and G. G. Slaughter.

The 256 channel magnetic core time analyzer with a 1/4 second Brown recorder output is now in operation at the LITR. Channel widths from 0.5 to 8 μ sec are available. A teletype punch will be added soon in order to feed the data directly into the ORACLE.

Transmission measurements on Eu^{151} and Eu^{153} are being repeated using the new time analyzer. Measurements have been made on enriched Sm^{147} and Sm^{149} so that the measurements on fission product Sm can be analyzed to get parameters for resonances in Sm^{151} .

A program has been started to determine the absorption cross section from total cross section measurements of several nuclides in the thermal energy range. The total cross section of U^{234} has been measured and a sample of Pu^{240} is now being prepared. After the TNCC meeting at ORNL in October 1956 an agreement was made with Egelstaff that the thermal cross sections of several of the available samples of fission products would be measured at ORNL. Measurements on these are in progress.

III. Electronuclear Research Division

23 Mev Proton Induced Inelastic Scattering and (p,d) Reactions on Heavy Elements -- B. L. Cohen

The study of anomalous inelastic scattering was extended to include heavy elements, higher excitation energies of the final nucleus, and deuterons from (p,d) reactions. The energy distributions of protons inelastically scattered from each of the principle Pb isotopes and from Be are very similar, consisting of seven relatively well defined groups with the same energy, cross section, and angular distribution. All elements studied with atomic number above 40 have prominent groups with $E_p - E_p' \simeq 2.5$ Mev. The deuteron energy distributions from

(p,d) reactions in Bi and the Pb isotopes are very similar (five prominent groups with the same energy and similar cross sections) in spite of differing Q-values. There are also strong similarities in the deuteron spectra from Au and Pt, and Pd and Ag.

Fission Fragment Spectrograph -- B. L. Cohen

The long range particles from fission were definitely identified as alphas, and their energy distribution was measured. Agreement with Allen and Dewan is excellent; no fine structure is present above 8 Mev.

The pulse-height vs energy for fission fragments in CsI(Tl) was determined. The relationship is approximately linear over much of the range; light output continues to increase with ionization density even at very high values of the latter.

Electromagnetic Separations -- J. A. Martin

A separation of highly-irradiated plutonium containing 30% Pu²⁴⁰ gave the following estimated results:

	Purity (%)	Weight (gm Pu)
Pu ²⁴⁰ product	85-93	3.1
Pu ²⁴¹ product	65-75	0.45
Pu ²⁴² product	40-60	0.08

The ratio of well focused Pu⁺ ions to plutonium vaporized as PuCl₃ was approximately 6%. Purification and assay of the products should be completed by February 15, 1957.

A sample holder for the MTR fast chopper has been filled with 0.3984 gms of PuO₂ (80% Pu²⁴⁰) by J. H. Cooper, Chemistry Division.

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