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NEUTRON ACTIVATION CROSS SECTIONS IN THE FAST REACTOR

Work done by:

A. H. Spano

D. B. Hall

J. H. Hall

Report written by:

A. H. Spano

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ABSTRACT

Cross sections for the observed (n, γ), (n, p) and (n, α) activations of fifteen isotopes, all of them 100% abundant with the exception of the 95% abundant S^{32}, have been measured using fission neutrons in the Los Alamos plutonium reactor. The measurements were based on the known thermal cross sections for each of the isotopes in the manner of Hughes, and on $\sigma(n,\gamma) = 0.13$ barns for Au for an effective neutron energy of 1.1 Mev. (n,2n) activations were not observed because of the high threshold energies necessary.

NEUTRON ACTIVATION CROSS SECTIONS IN THE FAST REACTOR

In conjunction with other work, measurements have been made of some activation cross sections of a number of isotopes (F^{19}, Na^{23}, Al^{27}, S^{32}, Sc^{45}, V^{51}, Mn^{55}, As^{75}, Y^{89}, Cb^{93}, I^{127}, La^{139}, Pr^{141}, Ta^{181}, Bi^{209}) for neutrons of approximately 1 Mev effective energy in the Los Alamos fast plutonium reactor. The method used made the fast activation cross section, σ_f, independent of any actual determination of counter efficiency, e. This was done in the manner of Hughes[1] by comparing the activation by fast neutrons with that by thermal neutrons and utilizing the known thermal cross section, σ_{th}. In this way, a foil of the isotope to be used was first activated in the thermal column of the Los Alamos water moderated pile, and from the induced beta activity and known half life, a saturation activity, (As)th, could be calculated.

$$(As)_{th} = (nv)_{th} \times \sigma_{th} \times N_{th} \times e \qquad (1)$$

where $(nv)_{th}$ is the flux in the thermal column and N_{th}, the number of atoms of the foil. The efficiency factor, e, is a product of the counter geometry factor and of the self-absorption factor, the latter a function of the beta energy. Because the same beta activity was induced by fast neutrons, e, as found by the thermal activation, could then be used for the fast activation if the counter geometry and foil

1 D. J. Hughes, MDDC-27

thickness in mg/cm^2 were kept the same. This would give the formula

$$\sigma_f = \frac{(nv)_{th}}{(nv)_f} \times \frac{N_{th}}{N_f} \times \frac{(As)_f}{(As)_{th}} \times \sigma_{th} \qquad (2)$$

In the case of the (n,p) and (n,α) reactions for an isotope Z^A, in order to obtain the same beta activity efficiency factor, isotopes $(Z-1)^{A-1}$ and $(Z-2)^{A-4}$ respectively were irradiated by thermal neutrons to give the same active isotopes, i.e.,

for (n,p) $\quad Z^A\ (n,p)\ (Z-1)^A$

$(Z-1)^{A-1}\ (n,\gamma)\ (Z-1)^A$

for (n,α) $\quad Z^A\ (n,\alpha)\ (Z-2)^{A-3}$

$(Z-2)^{A-4}\ (n,\gamma)\ (Z-2)^{A-3}$

The only exceptions to this were in the cases of F^{19} (n,p) and F^{19} (n,α) reactions

$$F^{19}\ (n,p)\ O^{19} \xrightarrow[29.5\ sec]{4.1\ Mev}$$

$$F^{19}\ (n,\alpha)\ N^{16} \xrightarrow[7.4\ sec]{4.4\ Mev}$$

Here, the thermal activation of O^{18} and N^{15} would have been very difficult due to the rarity of O^{18} (0.2% abundant) and of N^{15} (0.38% abundant) and also because of their gaseous form. In these two cases the efficiency factor used was the same as for the (n,γ) reaction. This was justified for the

reasons that the same foil was used for all three simultaneous activations, and that the maximum beta energies from F^{20}, O^{19}, and N^{16} are nearly the same, specifically 5 Mev, 4.1 Mev, and 4.4 Mev respectively, so that for a thin sample the correction will be small. The half lives for these fluorine reactions were all short: 12 sec, 29.5 sec, and 7.4 sec, and a Brush oscillograph was used to record the pulses from a scale of 64 circuit for these short lived activities.

The fast reactor flux, $(nv)_f$, equal to 0.85×10^9 neutrons per square cm per sec, was determined by the activation of gold foils using $\sigma_{th} = 100$ barns and $\sigma_f = 0.13$ barns; thus, all fast cross sections given below are based on these gold cross sections for radiative capture. The value of 0.13 barns was calculated by integrating the published σ_c values[2] over the measured spectrum of the fast reactor. The flux in the thermal column was measured using standard In foils and found to agree with earlier independent measurements. The neutrons in the column were well thermalized, the Cd ratio being about 20,000 at a point 3 feet from the Cd curtain. In the fast reactor the number of cadmium neutrons in the center was negligible, to the extent that a correction for thermal activation was unnecessary.

The counter used, of 0.004" aluminum wall thickness was periodically checked with a U glass standard to measure any aging effect. A 5% difference was noted over a period

2 K. I. Greisen MDDC 286

of several months. The counter resolution time was measured, from which was derived a calibration curve of counting losses as a function of counting rate.

The error assigned to the thermal flux, (nv)th, was 5%; this included the error in the power determination, which is less than one percent, and the error in the placing of the sample in the thermal column, estimated at several percent. The error in weighing samples on a chemical balance was less than one percent. The calculated saturated activity gave generally a maximum deviation from the mean of some six points of about 7%, this combined with a 2% error in irradiation time gave about an 8% error in As. The flux in the fast reactor, $(nv)_f$, is based on a 10% error in the values of the thermal (n,γ) cross section for Au of 100 barns and of σ_f of 0.13 barns. The error placed on $(mv)_f$ is 15%. For σ_{th}, the values given by Seren[3] have generally been used, to which he assigns a 20% error. Wherever possible the same foil was used for both the thermal and fast activations, however, where two different foils were used the error introduced because of different thickness did not exceed 5%. All of these errors combine to give a total maximum error of about 30% for each value of σ_f given in Table I.

The NaF, S, Sc_2O_3, V, As, Y_2O_3 samples were made by Mr. W. Wellborn and Mr. W. Smith of CMR-6. These samples were made from loose crystals pressed in a die in the shape

3 Seren, Values of σ_{th}, MON P 405

TABLE I

Isotope	PUBLISHED VALUE OF σ_f FOR FISSION NEUTRONS			σ_f FAST REACTOR			σ_f BASED ON A VALUE OF σ_{th} OF		
	n,γ	n,p	n,α	n,γ	n,p	n,α	n,γ	n,p	n,α
F^{19}		0.6 mb	4.5 mb	1.0 mb	0.28 mb	2.0 mb	9.4 mb	9.4 mb	9.4 mb
Na^{23}	0.29 mb			1.2 mb			630 mb		
Al^{27}	0.4 mb	2.8 mb	0.6 mb	0.28 mb	2.2 mb	0.56 mb	200 mb	48 mb	630 mb
S^{32}		12 mb			50 mb			0.23 b	
Sc^{45}				32 mb			22 b		
V^{51}	2.2 mb			2.0 mb	0.20 mb		4.5 b	141 mb	
Mn^{55}	3.5 mb			2.5 mb		0.43 mb	10.7 b		4.5 b
As^{75}				50 mb			4.2 b		
Y^{89}				8.2 mb			1.24 b		
Cb^{93}	52 mb			41 mb			1.4 b		
I^{127}				120 mb			6.25 b		
La^{139}				6.6 mb			8.4 b		
Pr^{141}				34 mb			10 b		
Ta^{181}				160 mb			21 b		
Bi^{209}	3.8 mb			2.6 mb			55 mb		

of discs, one half inch in diameter and about 50 mils thick. For the Cb, I, and Pr isotopes, loose crystals were used, while for Al, Mn, Ta and Au, thin metal foils were activated.

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