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LABORATORY RECORDS
1954

RECENT CLASSIFIED NUCLEAR DATA

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PHYSICS DIVISION

RECENT CLASSIFIED NUCLEAR DATA

compiled by

H. Pomerance

Date Issued: NOV 29 1949

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Introduction

The classified nuclear data in this report have been compiled from AEC project reports, and British and Canadian reports reprinted by the AEC, which became available at the Oak Ridge National Laboratory libraries about October, 1947, until October 1, 1949. Previous nuclear data abstracted by the Isotopes Information Committee at this laboratory were reported in the memos CLM-IIC-1 to 10. The neutron cross section data from these memos, together with some information about the radioactive characteristics of the isotopes, were included in report ORNL-86 entitled "Tables of the Neutron Cross Sections for Po-Cm" by G. Haines and K. Way (1948).

Unclassified and declassifiable material does not appear in this report. All such data appearing in the AEC project reports will be used by Dr. K. Way in the table of the isotopes which she is preparing at the Bureau of Standards.

The reports have been abstracted by a group which has included N. M. Dismuke, H. A. Levy, F. K. McGowan, O. E. Myers, R. W. Stoughton, H. Zeldes, with H. Pomerance as Chairman.

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Abbreviations used:

All cross sections are for neutrons unless otherwise stated.

E_n = energy of neutrons

V_n = velocity of neutrons

n = neutron

p = proton

d = deuteron

σ_{ac} = activation cross section

σ_a = absorption cross section

σ_f = fission cross section

σ_s = elastic scattering cross section

σ_{inel} = inelastic scattering cross section

σ_{tr} = transport cross section

$T_{\frac{1}{2}}$ = half life for decay

b = 10^{-24} cm^2

mb = 10^{-27} cm

η = neutrons emitted per neutron absorbed

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SPECIES	INFORMATION	REMARKS
H_2O	$\overline{r^2} = 184.7$ cm^2 $\overline{r^4} = 1.222 \times 10^5$ cm^4 $\overline{r^6} = 2.270 \times 10^8$ cm^6 $\overline{r^8} = 8.642 \times 10^{11}$ cm^8	$\overline{r^n}$ means n-th power slowing down range from a point source using distribution of In resonance neutrons.
	Ref: J. E. Hill, L. D. Roberts and T. E. Fitch, ORNL-181, 1948; ORNL-159, 1948.	
Be	Diffusion length: $L = 20.8 \pm 0.5$ cm	sigma pile 100 cm x 100 cm x 65 cm on a graphite pedestal on a thermal column.
	Age to In: $\tau = 80.2 \pm 2.0$ cm	same pile; ^{235}U fission neutrons.
	$\sigma_s = 1$ b for fasts	from slope of the exponential tail of the age curve.
	$\sigma_a = 10.2 \pm 0.5$ mb thermals	from $L^2 = \frac{1}{3N^2 \overline{\sigma_a} \sigma_{tr}}$ and σ_{tr} from work of Sachs (CP-3801)
	Ref: R. Nobles, J. Wallace, ANL-4076, 1947	
Graphite	Neutron age and moments $\overline{\tau} = 310.6$ cm^2 $\pm$ 1% $\overline{\tau^2} = 11.48 \times 10^4$ cm^4 $\pm$ 3% $\overline{\tau^3} = 5.23 \times 10^7$ cm^6 $\pm$ 6%	Corrected to standard density 1.600 g/cm^3. Transport correction made. Plane source.
	Ref: J. E. Hill, L. D. Roberts and G. McCammon, ORNL-187, 1948.	
Al + H_2O mixture	Mean square slowing down length $\overline{r^2}$ Vol. ratio Al/H_2O $\overline{r^2}$ 1:1 460.7 cm^2 1:2 297.4 (H_2O) 184.7	Al in ¼" plates. from ORNL-181
	Ref: L. D. Roberts, J. E. Hill, T. E. Fitch and J. W. T. Dabbs, Jr., ORNL-294, 1949.	

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SPECIES	INFORMATION	REMARKS
^{135}Xe	Breit-Wigner constants: E_o = 0.0849 ev (0.0863) Γ = 0.114 ev (0.107) σ_o = 3.4 x 10^6 b	Bent crystal spectrometer Least squares fit of 4 sample runs (fit to 6 samples, including above 4).
	Complete curves 0.03 - 0.20 ev are in the full report.	3 more sample runs are mentioned in ORNL-365.
	Ref: S. Bernstein et al, ORNL-325, 1949.	
Th	σ_s(coherent) = 12.9 b, λ_n = 1.06 Å = 12.8 b " = 12.8 b " phase positive.	Crystal diffraction from ThD_2 " " " ThO_2 Transmission of metal.
	Ref: C. G. Shull, E. O. Wollan, R. E. Rundle and W. A. Strauser, ORNL-228, p. 16, 1949.	
Th	$\overline{\sigma}$ = - 170 ± 2 mb $E_n \sim$ 0.5 Mev.	from reactivity change in fast Pu reactor at low power. $\overline{\sigma} = -\sigma_a$ plus effect on reactivity of inelastic scattering.
	Ref: D. B. Hall, J. H. Hall, LAMS-734, 1948.	
^{232}Th	Fission due to ^{235}U fission fragments < .1% of that due to n's.	Upper limit. Source of ^{235}U fission fragments collimated to produce no effect on electrode collecting Th fission fragments.
	Ref: J. L. Fowler, LAMS-648, 1947.	

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SPECIES	INFORMATION	REMARKS
^{232}Th	E_n = 14 Mev $\frac{\sigma_f(^{238}U)}{\sigma_f(^{232}Th)} = 3.50 \pm .07$ $\sigma_f(^{232}Th) = 0.241 \pm 0.020$ b	Neutrons from $^3H(d,n)\,^4He$. Fission pulses counted in flat foil fission chamber. Assuming $\sigma_f(^{238}U) = 0.85$ b (Taschek et al, LAMS-777)
	Ref: G. A. Jarvis, G. Everhart, A. Hemmendinger, F. F. Taschek, LAMS-776, 1948.	
^{230}Th	$\sigma_{ac} = 33 \pm 6$ barns Ref: Earl K. Hyde, ANL-4176, 1948	by activation
^{230}Th	$\sigma_{ac} = 61$ b $\quad v_n = 2200$ m/s	By activation in ANL heavy-water pile. Considerable disagreement with Hyde (28 b) who measured α-activity of Pa^{231} resulting from β^- decay.
	Ref: A. H. Jaffey and E. K. Hyde, ANL-4249, 1949.	
^{232}Th	$\frac{\sigma_f(^{238}U)}{\sigma_f(^{232}Th)} = 3.6 \pm 0.3 \quad E_n = 14$ Mev $\sigma_f(^{232}Th) = 0.24$ b	Neutrons from $^3H(d,n)\,^4He$. Fission tracks counted in photo-plates. Assuming $\sigma_f(^{238}U) = 0.85$ b (Taschek et al, LAMS-777)
	Ref: A. Phillips, L. Rosen, R. F. Taschek et al, LAMS-774, 1948	
^{233}Th	$\sigma_{ac} = 1350 \pm 100$ b $\quad E_n$ thermal	From ^{234}Th activity. Pile irradiation.
	Ref: E. K. Hyde, Richard J. Bruehlman, Winston M. Manning, ANL-4165, 1948.	

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SPECIES	INFORMATION	REMARKS
^{231}Pa	$\sigma_{ac} = 180$ b E_n thermal	β counting of ^{232}Pa (previous reports in CF-3892) irradiated in Argonne CP-3.
	Ref: A. H. Jaffey and I. Van Winkle, ANL-4283, 1949.	
$^{231}Pa(n,2n)^{230}Pa$	$\sigma = 2 \times 10^{-3}$ b	For neutrons inside a uranium slug at Hanford. Measured the ^{230}U formed in beta decay of ^{230}Pa.
	Ref: M. H. Studier and P. A. Sellers, ANL-4286, 1949.	
U	$\overline{\sigma} = +28 \pm 1$ mb $E_n \sim 0.5$ Mev	See Th. $\overline{\sigma}$ positive means the reactivity is increased by processes that produce fissioning neutrons more than it is reduced by capture processes that decrease the neutron number.
	Ref: LAMS-734	
U	$\sigma_{inel}+\sigma_f$ $E_{initial}$ E_{final} 2.50 ± 0.08 b 14 Mev 12 Mev 2.02 ± 0.21 " " 3 Mev $\sigma_{inel} = 1.65$ b	Authors assume difference in measurements with Al detector (3 Mev) and Cu detector (12 Mev) is due to activation of Al foil by ^{238}U fission n's. Corrections for this effect give $\sigma_{inel} + \sigma_f = 2.44$, $\sigma_{inel} = 1.65$ b using $\sigma_f(^{238}U) = 0.85$ b; Taschek et al, LAMS-777. Detectors placed inside U sphere, effect of el cancels out in spherical geom. used. n source probably $^3H(d,n)^4He$.
	Ref: H. H. Barschall, G. G. Everhart, H. T. Gittings, A. Hemmendinger, G. A. Jarvis, R. F. Taschek, LAMS-663 (1947).	

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SPECIES	INFORMATION	REMARKS
U	$\overline{\sigma_a} = .84$ b $\int_{.5\ ev}^{2\ Mev} \sigma_a \frac{dE}{E} = \overline{\sigma_a} \int_{.5}^{2} \frac{dE}{E}$ Ref: V. H. Rumsey, CRP-360, 1947.	From swing measurements in a Cd tube placed along axis of low power heavy water pile.
^{233}U	$\eta = 2.38 \pm .08$ thermal Ref: A. J. Cruikshank, D. J. Littler, A. G. Ward, CRP-378, 1948.	Experiment measures $p\eta = 2.15 \pm .03$ where p is the resonance escape probability. Large part of the error arises from uncertainty in the value of p.
^{234}U	$\frac{\overline{\sigma_f}\ (^{234}U)}{\overline{\sigma_f}\ (U)} = 0.174 \pm 0.038$ b (a) $\frac{\overline{\sigma_f}\ (^{234}U)}{\overline{\sigma_f}\ (^{233}U)} = (1.27 \pm 0.12) \times 10^{-3}$ b (b) Ref: M. M. Shapiro and J. R. Barnes, ORNL-51, 1948.	Photographic emulsion method. Assuming $\sigma_f(^{234}U) \propto \frac{1}{v_n}$ gives $\sigma_f(^{234}U) = 0.69 \pm 0.15$ from (a) $= 0.64 \pm 0.06$ from (b) for $v_n = 2200$ m/sec. Weighted mean = 0.65 ± 0.06. This value might be at most 10% low.
^{235}U	$\frac{\sigma_f\ (^{238}U)}{\sigma_f(^{235}U)} = 0.520 \pm 0.005$ $E_n = 14$ Mev $\sigma_f(^{235}U) = 1.63 \pm 0.12$ b Ref: G. A. Jarvis, G. Everhart, A. Hemmendinger, G. A. Jarvis, F. F. Taschek, LAMS-776, 1948.	Neutrons from $^3H(d,n)\ ^4He$. Fission pulses counted in flat foil fission chamber. Background correction (obtained with ^3H of target replaced by ^1H) made. Assuming $\sigma_f(^{238}U) = 0.85$ b (Taschek et al, LAMS-777).

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SPECIES	INFORMATION	REMARKS
^{235}U	$\frac{\sigma_f(^{238}U)}{\sigma_f(^{235}U)} = 0.63 \pm 0.07$ $E_n = 14$ Mev	Neutrons from $^{3}H(d,n)\,^{4}He$. Fission tracks in photo-plates.
	$\sigma_f = 1.34$ b	Assuming $\sigma_f = 0.85$ b for ^{238}U (Taschek et al, LAMS-777).
	Ref: A. Phillips, L. Rosen, R. F. Taschek et al, LAMS-774, 1948.	
^{235}U fission	Fission neutron spectrum.	Proton recoil counter with Al absorbers.
	E — N(E)	
	3.30 Mev — 114.3 ± 1.5 10^4 neutrons/Mev kw. sec.	
	4.46 — 54.0 ± .8	
	5.68 — 23.0 ± .3	
	6.86 — 9.26 ± .2	Curves are given to show fit of data to 3 theories of prompt neutron emission.
	7.86 — 4.18 ± .2	
	8.97 — 2.1 ± .1	
	10.04 — 0.75 ± .05	
	11.04 — 0.40 ± .02	
	12.16 — 0.18 ± .02	
	13.17 — 0.094 ± .02	
	14.29 — 0.027 ± .01	
	15.00 — 0.014 ± .003	
	16.05 — 0.015 ± .003	
	17.22 — 0.001 ± .003	
	Ref: B. E. Watt, LA-718, 1949	
^{235}U fission	Relative no. of prompt neutrons per 100 kev interval, for thermal neutrons on ^{235}U foil.	2800 tracks. Recoil protons in cloud chamber.
	50-99 kev — 34.2 ± 5.0	Data fit Watt's empirical curve, and also evaporation theory of La-1010 vol. 3.
	100-199 — 40.3 4.1	
	200-299 — 50.6 5.3	
	300-399 — 55.3 6.5	
	400-499 — 58.6 7.2	
	500-699 — 68.0 6.5	
	$\frac{\text{proton recoils 50-600 kev}}{\text{" " 600 - } \infty} = .54 \pm 0.05$	Watt's formula gives .52. Evaporation model gives .42.
	Ref: T. W. Bonner, R. A. Ferrell, M. C. Rinehart, LA-715, 1949	

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SPECIES	INFORMATION	REMARKS
^{236}U	Spontaneous fission rate 40 ± 24 f/g/hr 10 ± 8 Ref: A. H. Jaffey and A. Hirsch, ANL-4326, 1949.	sample I enriched ^{236}U sample II " "
^{238}U	σ_f = 1.13 ± .03 b for E_n = 14 Mev Ref: Warren Nyer, LA-719, 1949.	Shallow ionization chamber.
^{238}U	σ_f / E_n 0.80 b / 13.5 mev 0.85 / 14 0.88 / 15 0.89 / 15.1 0.74 / 16 0.74 / 16.6 0.72 / 17 0.65 / 18 Ref: G. Everhart, H. T. Gittings, A. Hemmendinger, R. F. Taschek, LAMS-777, 1948.	Neutrons from $^{3}H(d,n)\,^{4}He$. Fissions from thin ^{238}U foil counted in single foil flat fission chamber. Flux monitored by counting α's from reaction at same angle. Bretcher and French (LAMS-396) have found σ_f = 2 b, E_n = 14 Mev; however large statistical error.
^{240}U	formed by $^{239}U(n,\gamma)$ $T_{\frac{1}{2}}$ = 14 ± 2 hrs β^- Ref: E. K. Hyde and M. H. Studier, ANL-4143, 1948 and ANL-4182, 1948.	A second order neutron capture reaction on ^{238}U.
^{234}Np (4.4 d, K)	σ_f = 600 - 1200 b thermal neutrons Ref: E. K. Hyde, W. C. Bentley, French Hagemann, ANL-4152, 1948.	High σ_f is the evidence for correct mass assignment, rather than other possibility ^{233}Np.

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SPECIES	INFORMATION	REMARKS
^{240}Np	$T_{\frac{1}{2}} = 7.3 \pm .3$ m $\quad \beta^-$ Ref: ANL-4182.	Produced in beta decay of ^{240}U. See ^{240}U.
^{238}Pu	$\sigma_a = 455 \pm 50$ b (pile neutrons) Ref: R. J. Bruehlmann, W. C. Bentley and E. K. Hyde, ANL-4215, 1948.	Estimated from the growth of a fission cross section. (formation of ^{239}Pu; σ(fission) = 18.2 b).
^{238}Pu	Spontaneous fission rate: $4.0 \pm .34 \times 10^6$ f/g/hr Ref: A. H. Jaffey and A. Hirsch, ANL-4286, 1949.	By counting and based on $T_{\frac{1}{2}} = 92$ yrs. for ^{238}Pu.
^{239}Pu	$\frac{Y_F}{Y_{TH}} = 0.93 \pm 0.07$ where Y is the yield of delayed neutrons in fast fission (Y_F) and thermal fission (Y_{TH}). Ref: J. Wallace, ANL-4174, 1948.	Method is described in ANL-4010. Yield = $\frac{\text{delayed neutrons}}{\text{delayed + instantaneous}}$
^{239}Pu fission	Fission spectrum for $E_n = 1 - 8.5$ Mev " " " $E_n = 0.2 - 1.5$ Mev Results indicate: (a) max. between $E_n = 1 - 2$ Mev (b) $\sim$ 17% of n's have $E_n > 4$ Mev (c) $\overline{E_n} = 2.6$ Mev. Ref: H. T. Richards and L. Speck, LA-556, 1946.	Photo plate, 1000 tracks. Recoils measured out to 15°. Hemispherical shell of ^{239}Pu + ~ 70 kev n's from Li + 10 kev p's. H filled + alcohol-water vapor cloud chamber, 500 tracks. Recoils meas. out to 15°. Disk of ^{239}Pu + ~70 kev n's from Li + 10 kev p's. Primary n's used to calibrate chamber.

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SPECIES	INFORMATION	REMARKS
^{239}Pu	Capture to fission ratio. $\alpha = 0.44$ no cutoff $\alpha = 0.64$ "5 ev" cutoff $\alpha = 0.84$ "30 ev" cutoff for dE/E spectrum relative error 10% absolute error 30% Interpretation: $\alpha = 0.28$ below 30 ev $\alpha = 1.05$ above 30 ev Ref: W. R. Kanne et al, KAPL-183, 1949.	This is an interim report. Method and equations are in KAPL-64. The ^{240}Pu is counted by its spontaneous fission. Using equations of KAPL-64.
^{241}Am	$\sigma_{ac} \sim 400$ b E_n thermal Ref: J. M. Grunland and L. Yaffe, CR-PRG-51, 1949.	Compared Po α's and Am α's, assuming $\sigma_{ac}(Bi) = .015$ b.
^{241}Am	$\sigma_{ac} \approx 400$ b pile neutrons Ref: I. Perlman (reported by), UCRL-71, 1948.	Forms long lived ^{242}Am.
$^{243?}Am$	Found a new α-activity. Produced by 2nd order thermal neutron capture. Ref: K. Street and G. T. Seaborg, UCRL-311, 1949.	15 month bombardment of ^{241}Am. Identified by milking the Am of the ^{239}Np(2.25 d) decay product.
$\geq {}^{243}Cm$	$T_{\frac{1}{2}}$ (spontaneous f) < a few million years. Ref: I. Perlman, BC-80, 1947.	Produced by irradiation of ^{241}Am in Hanford Pile for 15 months.

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