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PAPIN: A FORTRAN-IV PROGRAM TO CALCULATE CROSS SECTION PROBABILITY TABLES, BONDARENKO AND TRANSMISSION SELF-SHIELDING FACTORS FOR FERTILE ISOTOPES IN THE UNRESOLVED RESONANCE REGION

J. G. Munoz-Cobos*

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LIST OF LATIN SYMBOLS

a_o	Scattering length
AWRI	Ratio of the mass of the target nucleus to the neutron mass
$\langle D \rangle_{\ell,J}$	Average level spacing in the ℓ,J series
E_f	Upper limit of the sampling energy region
E_L	Lower limit of the sampling energy region
E_{ref}	Reference neutron energy
E_r	Energy of the, r, resonance
$(EU)_{\ell,J}$	Upper limit of the energy in the (ℓ,J) series
$(EL)_{\ell,J}$	Lower limit of the energy in the (ℓ,J) series
$f_{c,i}$	Bondarenko capture factor at group i
$f_{tf,i}$	Bondarenko average weighted flux total cross section at group i
$f_{tc,i}$	Bondarenko average weighted current total cross section at group i
g_J	Spin statistical factor
I	Spin of the target nucleus
J	Spin of the resonance state
K	Wave number
K_o	Reduced wave number
ℓ	Angular momeutum
N	Number of ladders
NR2	Parameter to set the energy limits of the ladder
R	Channel Radius
T	Effective temperature
V_ℓ	Penetration factors
U(x,y)	Voight Profiles function
V(x,y)	Voight Profiles function

LIST OF GREEK SYMBOLS

$\Gamma_{nr}^{(\ell, J)}$	Neutron width of the, r, resonance in the (ℓ,J) series
$\Gamma_{\gamma r}^{(\ell,J)}$	Gamma width of the r resonance in the (ℓ,J) series
$\Gamma_{r}^{(\ell,J)}$	Total width of the r resonance in the (ℓ,J) series
$\Gamma_{nr}^{o(\ell,J)}$	Reduced neutron width of the r resonance in the (ℓ,J) series
$<\Gamma_{n,o}>$	Average neutron width for s-waves
$<\Gamma_{\gamma}>$	Average gamma width for s-waves
$<\Gamma>$	Average total width for s-waves
Δ	Doppler width
ϕ_{ℓ}	Hard sphere phase shift
$\sigma_{n\gamma}^{(\ell)}$	Capture cross section for the ℓ partial wave
$\sigma_{t}^{(\ell)}$	Total cross section for the ℓ partial wave
σ_{o}	Dilution cross section
$\bar{\sigma}_{c,i}(\sigma_{o})$	Bondarenko shielded group capture cross section
$\bar{\sigma}_{ft,i}(\sigma_{o})$	Bondarenko weighted flux shielded group total cross section
$\bar{\sigma}_{ct,i}(\sigma_{o})$	Bondarenko weighted current shielded group total cross section
σ_{pot}	Potential cross section
σ_{min}	Lower limit of the cross section probability table band structure
σ_{max}	Upper limit of the cross section probability table band structure
$<\sigma_{t}>_{i}$	Infinite dilute total cross section at group i
$<\sigma_{c}>_{i}$	Infinite dilute capture cross section at group i
η_{TR}	Transmission self-shielding factor
η_{SIR}	Self-indication self-shielding factor

ABSTRACT

The Fortran IV code PAPIN has been developed to calculate cross section probability tables, Bondarenko self-shielding factors and average self-indication ratios for non-fissile isotopes, below the inelastic threshold, on the basis of the ENDF/B prescriptions for the unresolved resonance region. Monte-Carlo methods are utilized to generate ladders of resonance parameters in the unresolved resonance region, from average resonance parameters and their appropriate distribution functions.

The neutron cross-sections are calculated by the single level Breit-Wigner (SLBW) formalism, with s, p and d-wave contributions. The cross section probability tables are constructed by sampling the Doppler-broadened cross sections.

The various self-shielded factors are computed numerically as Lebesgue integrals over the cross section probability tables.

The program PAPIN has been validated through extensive comparisons with several deterministic codes.

I. INTRODUCTION

PAPIN has been developed as a flexible program to construct cross section probability tables for the calculation of Bondarenko and transmission self-shielding factors for fertile isotopes, in the unresolved resonance region. This report is intended to describe the main features of the program as well as to serve as a user's manual.

II. DESCRIPTION OF THE PROGRAM

In this section we give a brief outline of the program, whose main features are illustrated in the block diagram in Fig. 1. The main program reads the input data and generates resonance ladders, over specified neutron energy regions, by Monte-Carlo methods. This step provides the input for the calculation of the various neutron cross sections, by the subroutines, BREDO, SHIF and VIL. The output cross sections are then Doppler-broadened by the subroutines, SVS, W and QUICKW. On the basis of this information the main program constructs the probability tables, which are utilized by the subroutines BREKO and SHELF to compute Bondarenko factors and transmission self-shielded factors respectively as Lebesgue integrals over the probability tables.[1,2,3]

III. PAPIN MAIN OPERATIONS

Here we describe some of the main operations in PAPIN with detail.

A. Generation of Resonance Ladders

The upper and lower limits E_f and E_i, respectively, of the energy region where the cross section sampling is to be performed, are selected by the expressions,

$$E_f = E_{ref} + TEMP \times D_{min} \qquad (1)$$

$$E_i = E_{ref} - TEMP \times D_{min} \qquad (2)$$

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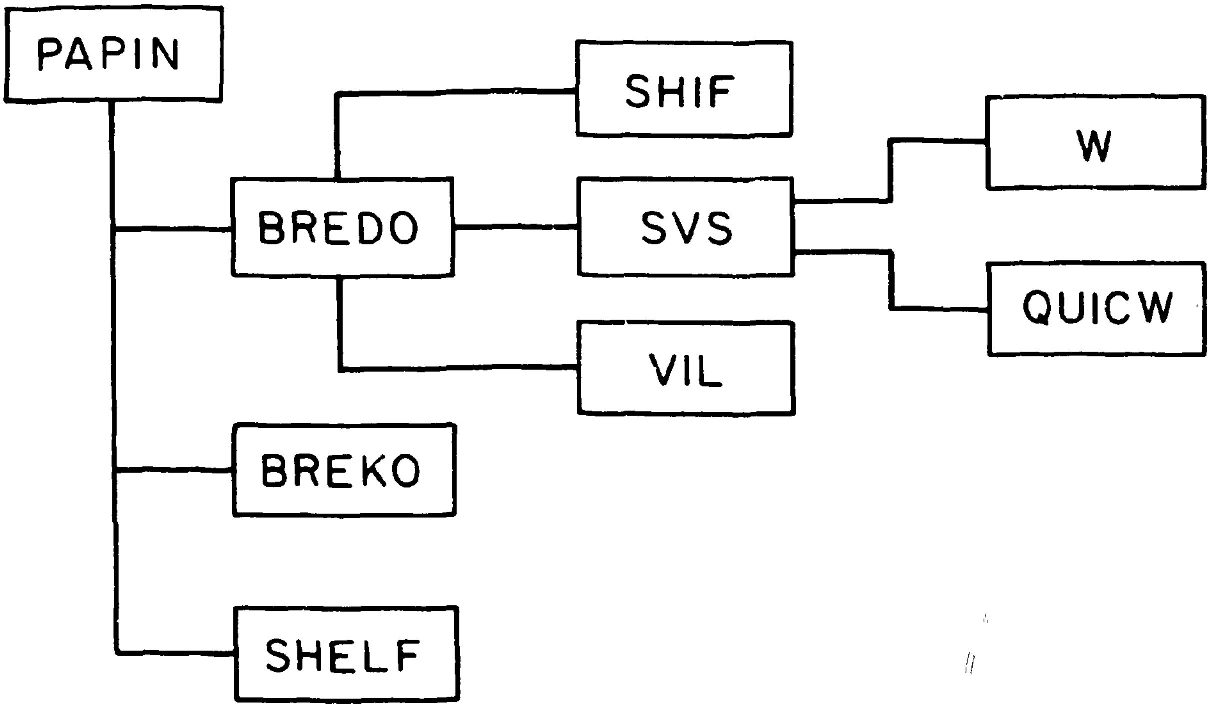

Fig. 1. Block diagram of subroutines in the PAPIN program.

where TEMP = $\frac{NR2}{2} - 5$, E_{ref} and NR2 are input parameters described in section VII, and D_{min} is the smallest value among the quantities $\langle D \rangle_{\ell,J}$ corresponding to E_{ref} in the ENDF/B-V files.

To allow for the contribution of resonances outside the sampling region a wider energy region is defined by means of the upper and lower energy limits, $(EU)_{\ell,J}$ and $(EL)_{\ell,J}$, respectively:

$$(EU)_{\ell,J} = E_{ref} + \frac{NR2}{2} \cdot \langle D \rangle_{\ell,J} \qquad (3)$$

$$(EL)_{\ell,J} = E_{ref} - \frac{NR2}{2} \cdot \langle D \rangle_{\ell,J} \qquad (4)$$

The resonance energies are generated from the Wigner Level Space Distribution Function,[3,4] by means of the expression:

$$E_{\ell,J,i+1} = E_{\ell,J,i} + \frac{2}{\sqrt{\pi}} \cdot \langle D \rangle_{\ell,J} \cdot (\ell og R)^{1/2} \qquad (5)$$

where R, is a random number between 0 and 1. The neutron level widths are obtained from Chi-squared distributions with 0 degrees of freedom (ν = 1 or 2), by well known rejection techniques.[3] Finally, the capture level widths are considered constants (equal to their ENDF/B-V prescribed average values).

B. Neutron Cross Section Calculations

For each ladder of resonances, the neutron capture cross section $\sigma_{n\gamma}$, and the total cross section σ_t are computed by the S.L.B.W. formalism in the framework of the ENDF/B prescriptions.[5,6] The Doppler-Broadened cross sections[7,8] are given by the expressions:

$$\sigma_{n\gamma}^{(\ell)} = \frac{2\pi^{3/2}}{K^2} \sum_J g_J \sum_{r=1}^{NR_J} \frac{\Gamma_{nr}^{(\ell,J)} \cdot \Gamma_{\gamma r}^{(\ell,J)}}{\Gamma_r^{(\ell,J)} \cdot \Delta} \cdot U(x,y) \qquad (6)$$

$$\sigma_t^{(\ell)} = \frac{4\pi}{K^2} \cdot (2\ell + 1) \cdot \mathrm{sen}^2\phi_\ell + \frac{2\pi}{K^2}^{3/2} \sum_J g_J \sum_{r=1}^{NR_J} \frac{\Gamma_{nr}^{(\ell,J)}}{\Delta} (U(x,y) \cdot$$

$$\cos(2\phi_\ell) - V(x,y) \sin (2\phi_\ell)) \qquad (7)$$

where,

$$K = \text{wave number} = 2.196771 \frac{AWRI}{AWRI + 1} \cdot 10^{-3} \cdot \sqrt{EREF} \qquad (8)$$

$$\Delta = \text{Doppler width} = 10^{-2} (3.4468 \cdot E_{ref} \cdot T/AWRI)^{1/2} \qquad (9)$$

AWRI = Ratio of the mass of the target nucleus to the neutron mass

$$g_J = \text{spin statistical factor} = \frac{2J + 1}{2 \cdot (2I + 1)} \qquad (10)$$

$$\Gamma_{nr}^{(\ell,J)} = \Gamma_n^{(o)(\ell,J)} \cdot V_\ell (E_{ref}) \cdot (E_{ref})^{1/2} \qquad (11)$$

Where $\Gamma_n^{(o)(\ell,J)}$ are the reduced neutron width and the factors $V_\ell(E_{ref})$ are given by the expressions (for ℓ = 0, 1 and 2).

$$V_0 = 1 \qquad (12)$$

$$V_1 = \frac{\rho^2}{1 + \rho^2} \qquad (13)$$

$$V_2 = \frac{\rho^4}{9 + 3\rho^2 + \rho^4} \qquad (14)$$

with

$$\rho = 0.002196771 \cdot \left(\left(AWRI/(AWRI + 1)\right) \cdot (E_{ref})^{1/2} R\right) \qquad (15)$$

where R is the channel radius in units of 10^{-12} cm. The hard sphere phase shift are computed (for ℓ = 0, 1 and 2) by:

$$\phi\ (\rho_1) = \rho_1 \qquad (16)$$

$$\phi_1(\rho_1) = \rho_1 - \tan^{-1} (\rho_1) \qquad (17)$$

$$\phi_2(\rho_1) = \rho_1 - \tan^{-1} \left(\frac{3\rho_1}{3 - \rho_1^2}\right) \qquad (18)$$

with,

$$\rho_1 = \rho \cdot \frac{a_o}{R} \tag{19}$$

where a_o is the scattering length. The U and V functions are obtained from the expressions:

$$U(x,y) = \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{y \cdot e^{-s^2}}{y^2 + (x-s)^2} \cdot ds \tag{20}$$

$$V(x,y) = \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{(x-s) \cdot e^{-s^2}}{y^2 + (x-s)^2} \cdot ds \tag{21}$$

where

$$x = \frac{Er - E}{\Delta} \tag{22}$$

$$y = \frac{\Gamma_{nr} + \Gamma_\gamma}{2\Delta} \tag{23}$$

The expressions (20) and (21) are computed by the Doppler routine QUICKW. The capture and total cross sections are computed from equations (6) and (7) at one hundred equally spaced energy points. This calculation is then corrected for the contribution of the truncated levels by means of the expression[7,9] (s-waves only):

$$\sigma^\infty = \frac{4\pi}{K_o^2} \cdot So \cdot \frac{<\Gamma>}{4\sqrt{E}} \cdot \left(\frac{EU-EL+ <D>}{(EU-E-0.5 <D>)(E-EL+0.5 <D>)} - K_o\, a_o \ln \left(\frac{E-EL +0.582 <D>}{EU-E+0.582 <D>} \right) \right) \tag{24}$$

where s_o is the s-wave strength function, K_o is the reduced wave number, <D>, the average level spacing for s-wave neutrons, a_o, the scattering length, and EU and EL the upper and lower limits respectively of the resonance ladder. Finally when ENDF/B-V contains a smooth contribution (File 3) to the cross section, this contribution is added to (6) or (7).

C. Construction of the Cross Section Probability Tables

The cross-section band structure is made of 20 bands of width determined by a logarithmic scale,

$$\sigma_n = \sigma_{min} \cdot p^n \tag{25}$$

where

$$p = \exp 0.05 \, \ln \left(\frac{\sigma_{max}}{\sigma_{min}}\right) \tag{26}$$

The lower and upper limits of the band structure σ_{min} and σ_{max} can be defined arbitrarily or calculated by:

$$\sigma_{min} = 0.2 \, \sigma_{pot} \tag{27}$$

$$\sigma_{max} = \sigma_{pot} + \frac{\pi}{K^2} \quad \frac{\langle \Gamma_{n,o} \rangle}{\langle \Gamma^{\ell}_{n,o} \rangle + \langle \Gamma_{\gamma} \rangle} \tag{28}$$

where all the symbols have been defined previously. Two additional cross section bands are included to collect cross sections values below σ_{min} and above σ_{max}.

The total cross section probability table is constructed by sampling the total cross section at the one hundred equidistant points over each ladder of resonances, and determining the fraction belonging to each band in the table. The average value of the total and capture cross sections in each band is also determined (see the work of Levitt,[1] for more details).

IV. CALCULATION OF SHIELDED CROSS SECTIONS

A. Bondarenko Group Cross Sections and Self-Shielding Factors

The Bondarenko shielded group cross sections are defined as ensemble averages over the cross section probability tables,[10] i.e.:

$$\bar{\sigma}_{c,i} \, (\sigma_o) = \frac{1}{\langle \alpha \rangle_i} \left\langle \frac{\sigma_c}{\sigma_t + \sigma_o} \right\rangle_i \tag{29}$$

$$\bar{\sigma}_{tf,i}\ (\sigma_o) = \frac{1}{<\alpha>_i} < \frac{\sigma_t}{\sigma_t + \sigma_o} >_i \tag{30}$$

$$\bar{\sigma}_{tc,i}\ (\sigma_o) = \frac{1}{<\alpha^2>_i} < \frac{1}{\sigma_t + \sigma_o} > - \sigma_o \tag{31}$$

with,

$$\alpha_i = \frac{1}{\sigma_{ti} + \sigma_o} \tag{32}$$

and where $\bar{\sigma}_{ci}$ (σ_o), $\bar{\sigma}_{tf,i}$ (σ_o), $\bar{\sigma}_{tc,i}$ (σ_o) are the capture, flux weighted and current weighted shielded group total cross sections, for the i^{th} neutron energy group and dilution σ_o.

Calling $<\sigma_c>_i$, $<\sigma_t>_i$ the i^{th} group dilute capture and total cross section (i.e. for $\sigma_o \to \infty$), the program PAPIN calculates the self-shielding factors:

$$f_{c,i}\ (\sigma_o) = \bar{\sigma}_{c,i}\ (\sigma_o)/<\sigma_c>_i \tag{33}$$

$$f_{tf,i}\ (\sigma_o) = \bar{\sigma}_{tf,i}\ (\sigma_o)/<\sigma_t>_i \tag{34}$$

$$f_{tc,i}\ (\sigma_o) = \bar{\sigma}_{tc,i}\ (\sigma_o)/<\sigma_t>_i \tag{35}$$

B. Calculation of Transmission and Self-Indication Self-Shielding Factors

The transmission self-shielding factor[11] η_{TR}, and the self-indication self-shielding factor,[11] η_{SIR}, are computed as the following ensemble averages over the cross section probability tables:

$$\eta_{TR} = <\exp\left(-n_1\ (\sigma_t - <\sigma_t>)\right)> \tag{36}$$

$$\eta_{SIR} = <\sigma_\gamma\ \exp\left(-n_1\ (\sigma_t - <\sigma_t>)\right)> \tag{37}$$

where n_1 is the sample thickness in atoms per barn. With these factors, "the program computes the average transmission and the average self-indication ratio."

C. Statistical Uncertainties

For a given cross section, σ, the statistical error, $\Delta\sigma$, inherent to the sampling process is given by:[12]

$$\Delta\sigma = \frac{1}{\sqrt{N}} \left(\frac{1}{N} \sum_{j=1}^{N} \sigma_j^2 - \langle\sigma\rangle^2\right)^{1/2} \tag{38}$$

with

$$\sigma_j = \frac{1}{N} \sum_{i=1}^{n} \sigma_{ij} \tag{39}$$

$$\langle\sigma\rangle = \frac{1}{N} \sum_{j=1}^{N} \sigma_j \tag{40}$$

where σ_{ij} is the cross section at the i^{th} sampling energy in the j^{th} ladder; n=100 is the number of sampling points within each ladder; and N the total number of ladders. For ratios of the general type,

$$Y_{AB} = \frac{\langle A\rangle}{\langle B\rangle} \tag{41}$$

the error ΔY_{AB} is computed according to the expression:

$$\Delta Y_{AB} = \left[\left(\frac{\partial Y}{\partial\langle A\rangle}\right)^2 V_{AA} + \left(\frac{\partial Y}{\partial\langle B\rangle}\right)^2 V_{BB} + 2\left(\frac{\partial Y}{\partial\langle A\rangle}\right)\left(\frac{\partial Y}{\partial\langle B\rangle}\right) C_{AB}\right]^{1/2} \tag{42}$$

where we defined the following matrix elements:

$$V_{AA} = \frac{1}{N}\left[\frac{1}{N} \sum_{j=1}^{N} A_j^2 - \langle A\rangle^2\right] \tag{43}$$

with a similar expression for V_{BB}, and

$$C_{AB} = \frac{1}{N^2} \sum_{j=1}^{N} (A_j - \langle A\rangle)(B_j - \langle B\rangle) \tag{44}$$

V. PROGRAM VALIDATION

The program PAPIN has been validated through extensive and detailed comparisons with the deterministic codes, NJOY,[13] UXS,[14] ETOX,[15] and MC^2-2,[16] which are based on analytical averages of the various cross section functionals over the appropriate resonance width and level spacing distributions.

The result of the validation step with 100 ladders, NR2=100 are shown in Table 1 and Table II.

Table I. Values of the Shielded Group Cross Section for the U^{238} at 4000 eV and 300 K (ENDF/B-V)

Dilution σ_o(b)	NJOY (a)	UXS (a)	ETOX (a)	MC^2-2 (a)	PAPIN
	Capture X-Section (b)				
1	0.4769	0.4838	0.4830	0.4833	0.4804 ± 0.0066
10	0.5602	*	*	*	0.5604 ± 0.0078
100	0.7698	0.7698	0.7697	0.7698	0.7688 ± 0.0121
1000	0.8986	*	*	*	0.9021 ± 0.0155
	Flux Weighted Total X-Section (b)				
1	11.94	12.382	12.380	12.382	12.19 ± 0.07
10	12.998	*	*	*	13.19 ± 0.07
100	15.50	15.502	15.502	15.502	15.62 ± 0.13
1000	17.46	*	*	*	17.58 ± 0.21

Table II. Values of the Shielded Group Cross Section for the U^{238} at 9250 eV and 300 K (ENDF/B-V)

Dilution σ_o (b)	NJOY (a)	UXS (a)	ETOX (a)	MC^2-2 (a)	PAPIN
	Capture X-Section (b)				
1	*	0.5365	0.5335	0.5365	0.5380 ± 0.0050
10	0.5794	*	*	*	0.5853 ± 0.0052
100	0.6649	0.6650	0.6649	0.6650	0.6701 ± 0.0059
1000	0.6995	*	*	*	0.7041 ± 0.0063
	Flux Weighted Total X-Section (b)				
1	*	12.681	12.672	12.681	12.596 ± 0.060
10	13.130	*	*	*	13.337 ± 0.061
100	14.766	14.767	14.766	14.767	14.825 ± 0.096
1000	15.596	*	*	*	15.582 ± 0.216

VI. INPUT DATA

A. Structure and Format of Input Cards

1.	Card: FORMAT (1X.I3)	N1
2.	Card: FORMAT (3F12.5)	CSMIN, CSMAX, FIJO
3.	Card: FORMAT (1X, F 12.4, F12.1)	DICRO, DICRI
4.	Card: FORMAT (1X, F5.0)	FOTAS
5.	Data: FORMAT (6F12.4)	EREF, AP, AWRI, R, T, CSDR
6.	DATA: FORMAT (I3, 3F12.4)	NR2, SPI, AN1, CSD3
7.	Number of J sequences for each L value	FORMAT (3I3) NJS(1), NJS(2), NJS(3)
8.	Average resonance parameters in each (I,J) series	FORMAT (5E 12.4) AD(I,J), AGNO(I,J), AMUN(I,J), AGG(I,J), AJ(I,J)

B. Function of Input Data

N1	Number of ladders.
CSMIN	Lower limit of the probability table.
CSMAX	Upper limit of the probability table
FIJO	A flag, if FIJO is equal to 1, the above values of CSMIN and CSMAX are used. If FIJO $\neq$ 1, CSMIN and CSMAX are computed by means of Eq. (26) and (27).
DICRO	Calculates the values of the dilution cross section σ_o, according to the expression, DICRO x 10^J J = 1, 2, 3, 4
DICRI	The infinite dilution parameter (typically $\sigma_o = 10^5$).
FOTAS	A flag, if the value of FOTAS is set equal to 1 the program does not utilize convergence factors for the cross section. If FOTAS is different from 1, PAPIN utilizes a convergence factor at each ladder defined as:

$$\left(\frac{1}{100} \cdot \sum_i \sigma_{tij} + \sigma_3\right)F_j = \sigma_{ref}$$

where σ_{ref} is the reference total cross section, σ_{tij} is the i Doppler Broadened total cross section at energy E_i and ladder j. σ_3 is the smooth cross section due to the difference between the real value of the scattering length and the ENDF/B-V value. F_j is the convergence factor for the j^{th} ladder. (This option was not employed in the results of section 5).

EREF	The reference neutron energy in eV.
AP	The scattering length in units of 10^{-12} cm.
AWRI	The ratio of the mass of a particular isotope to that of the neutron.
R	The channel radius defined as: $R = 0.123\ AWRI^{1/3} + 0.08\ (10^{-12}$ cm)

T	Effective absolute temperature in °K.
CSDR	Reference total cross section in barns.
NR2	Parameter to set the energy limits of the ladder, NR2 ≤ 100. Usually 100 is a convenient value.
SPI	Nuclear spin of the target nucleus.
AN1	Initial thickness of the shielding sample in atom/barn. The program computes the average transmission and the self-shielding factors at several thicknesses as:

$$AN1 + 0.01I \qquad I = 1, 2, \ldots 10$$

CSD3	ENDF/B-V smooth cross section.
NJS(I)	Number of J values for each L value.
AD(I,J)	Average level spacing in the (I,J) series.
AGNO(I,J)	Average reduced neutron width in the (I,J) series.
AMUN(I,J)	Number of degrees of freedom of the neutron width distribution in the (I,J) series.
AGG(I,J)	Average gamma width of the (I,J) series.
AJ(I,J)	The spin of the resonance state.

ACKNOWLEGEMENT

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Appendix I. Fortran Listing of PAPIN Program and Subprograms

```
COMPILER OPTIONS - NAME=  MAIN,OPT=02,LINECNT=60,SIZE=0000K,
                  SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      C      THIS PROGRAM COMPUTES A LADDER, FIRST OF ALL IT
      C      COMPUTES THE LIMITS OF THE LADDER, THEN IT GENERATES
      C      THE RESONANCE ENERGIES FOR EACH (L,J) SERIES AND THE
      C      WIDTH, TAKING ACCOUNT THE DEGREES OF FREEDOM.
      C      FIRST WE READ THE AVERAGE RESONANCE PARAMETERS FOR
      C      EACH ENERGY.
      C      EREF = REFERENCE ENERGY IN EV, NJS(I) IS THE NUMBER OF
      C      J STATES FOR A PARTICULAR L STATE.
             DIMENSION SUMCE2(22),VARCE(22),ERRGP(22),ERRTP(22),ERREP(22)
             DIMENSION CSDE1(100),SPCE(100),CSDES(22),CSDEA(100,22),SUMCE(22),
            1CCSVE(22)
             DIMENSION ERPR(22),WIPR(22)
             DIMENSION VARCG(22)
             DIMENSION COBI(100,4)
             DIMENSION SUMG2(22),SPR(22)
             DIMENSION VARPR(22),SUPR2(22),SUCSS(22),VARCS(22),SUMCG(22)
             DIMENSION SUCS2(22)
             DIMENSION AD(3,6),AMUN(3,6),E(100),
            1CSDT1(100),CSPP(30), CSDTS(30), CSDGS(30), COUNT(30), PR(100,22),
            1SPCS(100),F(100),F2(100)
             DIMENSION CSDG1(100),SUPRO(22)
             DIMENSION PR2(100,22),CSDTA(100,22),CSDTB(100,22),CSDGA(100,22)
             COMMON/DSED/ATCS(100),SPCO(100)
             COMMON/DERR/YPT(100,4),YPTG(100,4),YPTT(100,4),YPTC(100,4)
             COMMON/DSELF/CCSV(22), PRT(22), CCSVG(22)
             COMMON/DBRED/ER(3,6,150),GNO(3,6,150),AGG(3,6),NR(3,6),
            1EL(3,6),EU(3,6),NJS(3),AJ(3,6),AGNO(3,6)
             PRINT 20
        20   FORMAT('     PROGRAM PAPIN VERSION FEBRUARY 1981'//)
             READ 50,N1
        50   FORMAT(1X,I3)
             PRINT 55,N1
        55   FORMAT(19H NUMBER OF LACDFRS=,I3)
             READ 40,CSMIN,CSMAX,FIJC
        40   FORMAT(3F12.8)
             READ 51,DICRO,DICRI
             PRINT 51,DICRO,DICRI
        51     FORMAT(1X,F12.4,F12.1)
             READ 52,FOTAS
             PRINT 52 ,FOTAS
        52   FORMAT(1X,F5.0)
             READ 100, EREF, AP, AWRI, R, T, CSDR
       100   FORMAT(6F12.4)
             PRINT 101,EREF,AP,AWRI,R,T,CSDR
       101   FORMAT(16H NEUTRON ENERGY=,F12.2/
            119H SCATTERING LENGTH=,F8.4/
            215H ATOMIC WEIGHT=,F8.3/
            316H CHANNEL RADIUS=,F8.4/
            413H TEMPERATURE=,F8.2/
            531H TOTAL-REFERENCE-CROSS-SECTION=,F10.4)
             READ 110,NR2,SPI,AN1,CSD3
       110   FORMAT(I3,3F12.4)
             PRINT 111,NR2,SPI,AN1,CSD3
       111   FORMAT(5H NR2=,I3/
            114H NUCLEAR SPIN=,F8.4/
            231H INITIAL THICKNES IN ATOM/BARN=,F8.4/
            328H COMPENSATION CROSS SECTION=,F10.4)
             READ 200, (NJS(I), I=1,3)
             PRINT 200,(NJS(I),I=1,3)
       200   FORMAT (3I3)
             PRINT 219
       219   FORMAT('      UNRESOLVED RESONANCE PARAMETERS '/
            1'  L      J                D              AGNO        AMUN       AGG      ')
             DO 230 I=1,3
             NJSI = NJS(I)
             DO 230 J=1, NJSI
             READ 220, AD(I,J), AGNO(I,J), AMUN(I,J), AGG(I,J), AJ(I,J)
       220   FORMAT(5E12.4)
       230   PRINT 221,I,AJ(I,J),AD(I,J),AGNO(I,J),AMUN(I,J),AGG(I,J)
       221   FORMAT(1X,I2,3E12.4,F6.1,E12.4)
             DICR2=DICRO
      C      COMPUTES THE SMALLER OF THE AD(I,J)
             ADMIN = AD(1,1)
             DO 250 I=1,3
             NJSI = NJS(I)
             DO 250 J=1, NJSI
             IF (AD(I,J).LE.ADMIN) ADMIN = AD(I,J)
       250   CONTINUE
      C      COMPUTES THE LIMITS EINIT AND ENF OF THE LADDER
             TEMP=PLOAT(NR2)/2.-5.
             EINIT = EREF-TEMP*ADMIN
             EFIN = EREF+TEMP*ADMIN
      C      COMPUTES THE LOWEST VALUE OF THE ENERGY EL(I,J) IN EACH
      C      (I,J) SERIES.
```

```
      TEMP=TEMP*5.
      DO 260 I=1,3
      NJSI = NJS(I)
      DO 260 J=1,NJSI
      EL (I,J) = EREF-TEMP*AD(I,J)
  260 EU(I,J)=EREF+TEMP*AD(I,J)
C     GENERATION OF RESONANCE PARAMETERS.
C     GENERATION OF RESONANCE ENERGIES ER(I,J,K)
      NR2=125
      DO 500 L=1,N1
  261 DO 270 I=1,3
      NJSI=NJS(I)
      DO 270 J=1,NJSI
      ER(I,J,1)=EL(I,J)
      DO 270 K=2,NR2
 270  ER(I,J,K)=ER(I,J,K-1)+1.128379*AD(I,J)*SQRT(-ALOG(RANF(0)))
      DO 263 I=1,3
      NJSI=NJS(I)
      DO 263 J=1,NJSI
      M=1
      IF (ER(I,J,NR2).GT.EU(I,J)) GO TO 262
      NR(I,J)=NR2
      GO TO 263
  265 M=M+1
  262 NR3=NR2-M
      IF (ER(I,J,NR3).LT.EU(I,J)) GO TO 264
      IF (ER(I,J,NR3).GT.EU(I,J)) GO TO 265
      NR(I,J)=NR2-M
      GO TO 263
  264 NR(I,J)=NR2-M+1
  263 CONTINUE
C     GENERATION OF THE WIDTH
      DO 280 I=1,3
      NJSI=NJS(I)
      DO 280 J=1,NJSI
      IF (AMUN(I,J).GT.1.) GO TO 281
      NR4=NR(I,J)
      DO 283 K=1,NR4
C     CHI-SQUARED ONE DEGREE OF FREEDOM
  282 R1=-ALOG(RANF(0))
      R2=-ALOG(RANF(0))
      IF ((R1-1.0)**2.GT.2.0*R2) GO TO 282
  283 GNO(I,J,K)=AGNO(I,J)*R1**2
      GO TO 280
C     CHI-SQUARED TWO DEGREES OF FREEDOM
  281 NR4=NR(I,J)
      DO 285 K=1,NR4
  285 GNO(I,J,K)=-AGNO(I,J)*ALOG(RANF(0))
 280  CONTINUE
C     MAKES THE ENERGY GRID
      DELE=(EFIN-EINIT)/99.
      E(1)=EINIT
      DO 290 I=1,99
  290 E(I+1)=EINIT+FLOAT(I)*DELE
C     COMPUTES THE CROSS-SECTIONS IN EACH PIONT OF THE GRID.
      DO 291 I=1,100
      EI=E(I)
      CALL PREDC(EI,EREF,AD,A,RI,R,I,SPI,CSDG,CSDT,CSP,CSDE)
      CSDE1(I)=CSDE
      CSDG1(I)=CSDG
      CSDT1(I)=CSDT+CSD3
  291 CONTINUE
      SPCE(L)=0.0
      SPCG(L)=0.0
      SPCS(L)=0.0
      DO 292 I=1,100
      SPCE(L)=SPCE(L)+CSDE1(I)
      SPCG(L)=SPCG(L)+CSDG1(I)
 292  SPCS(L)=SPCS(L)+CSDT1(I)
      ATCS(L)=SPCS(L)/100.
      F(L)=CSDR/ATCS(L)
      F2(L)=F(L)*F(L)
      IF(FOTAS.EQ.1.) F(L)=1.
      DO 293 I=1,100
      CSDG1(I)=F(L)*CSDG1(I)
 293  CSDT1(I)=F(L)*CSDT1(I)
      DO 295 J=1,4
      YPT(L,J)=0.0
      YPTT(L,J)=0.0
      YPTC(L,J)=0.0
      YPTG(L,J)=0.0
      DO 296 I=1,100
      COBI(L,J)=CSDT1(I)+DICR2*10.**J
      YPT(L,J)=YPT(L,J)+(1./COBI(L,J))
      YPTT(L,J)=YPTT(L,J)+(CSDT1(I)/COBI(L,J))
      YPTC(L,J)=YPTC(L,J)+(1./(COBI(L,J)*COBI(L,J)))
 296  YPTG(L,J)=YPTG(L,J)+(CSDG1(I)/COBI(L,J))
      YPTC(L,J)=YPTC(L,J)/100.
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      YPT(L,J)=YPT(L,J)/100.
      YPTT(L,J)=YPTT(L,J)/100.
      YPTG(L,J)=YPTG(L,J)/100.
  295 CONTINUE
      IF(FIJO.EQ.1.)GO TO 294
      SIGOR=(6.51*10.**5/EREF)*((AWRI+1.)/AWRI)**2
      AGNR=SQRT(EREF)*AGNO(1,1)
      AGGR=AGG(1,1)
      CSMIN=0.2*CSP
      CSMAX=CSP+1.0*SIGOR*AGNR/(AGNR+AGGR)
  294 CONTINUE
      TK=EXP(0.05*ALOG(CSMAX/CSMIN))
      CSPP(1)=CSMIN
      DO 300 K=2,20
  300 CSPP(K)=CSPP(1)*TK**(K-1)
      CSPP(21)=CSMAX
C     CONSTRUCT THE PROBABILITY TABLE OF THE LADDER
      DO 306 K=1,22
      CSDES(K)=0.0
      CSDTS(K)=0.0
      COUNT (K)=0.0
  306 CSDGS(K)=0.0
      DO 301 I=1,100
      IF(CSDT1(I).LE.0.0) GO TO 307
      C7=ALOG(CSDT1(I)/CSPP(1))
      C9=ALOG(TK)
      C3=C7/C9
      IF(C3.LT.0.0) GO TO 307
      IF(C3.GT.20.)GO TO 308
      C8=INT(C3)
      K1=IFIX(C8+2.)
      COUNT(K1)=COUNT(K1)+1.
      CSDTS(K1)=CSDTS(K1)+CSDT1(I)
      CSDES(K1)=CSDES(K1)+CSDE1(I)
      CSDGS(K1)=CSDGS(K1)+CSDG1(I)
      GO TO 301
  307  COUNT(1)=COUNT(1)+1.
      CSDES(1)=CSDES(1)+CSDE1(I)
      CSDTS(1)=CSDTS(1)+CSDT1(I)
      CSDGS(1)=CSDGS(1)+CSDG1(I)
       GO TO 301
  308 COUNT(22)=COUNT(22)+1.
      CSDES(22)=CSDES(22)+CSDE1(I)
      CSDTS(22)=CSDTS(22)+CSDT1(I)
      CSDGS(22)=CSDGS(22)+CSDG1(I)
  301 CONTINUE
C     CSDTA(L,K), SAMPLING CROSS-SECTION
      DO 310 K=1,22
      PR(L,K)=COUNT(K)/100.
      PR2(L,K)=(PR(L,K))**2
      IF(COUNT(K).EQ.0.0) GO TO 311
      CSDTA(L,K)=CSDTS(K)/COUNT(K)
      CSDTB(L,K)=CSDTA(L,K)*CSDTA(L,K)
      CSDGA(L,K)=CSDGS(K)/COUNT(K)
      CSDEA(L,K)=CSDES(K)/COUNT(K)
      GO TO 310
  311 CSDTA(L,K)=0.0
      CSDTB(L,K)=0.0
      CSDGA(L,K)=0.0
      CSDEA(L,K)=0.0
  310  CONTINUE
C      COMPUTE THE FACTOR OF FITING
  500 CONTINUE
      IF(FOTAS.EQ.1.) GO TO 551
      SUMF=0.0
      SUMF2=0.0
      DO 540 L=1,N1
      SUMF=SUMF+F(L)
  540 SUMF2=SUMF2+F2(L)
C     COMPUTES THE VARIANCE OF F, VARF
      VARF=(SUMF2/FLOAT(N1))-(SUMF/FLOAT(N1))**2
      AVF=SUMF/FLOAT(N1)
      PRINT 550,VARF
  550 FORMAT(15H VARIANCE OF F=,F12.5)
  551 CONTINUE
C     COMPUTES THE VARIANCE OF THE PROBABLITIES VARPR(K)
C     AND THE PROBABILITY TABLE
      DO 560 K=1,22
      SUPRO(K)=0.0
  560 SUPR2(K)=0.0
      DO 570 K=1,22
      DO 575 L=1,N1
      SUPRO(K)=SUPRO(K)+PR(L,K)
  575 SUPR2(K)=SUPR2(K)+PR2(L,K)
      PRT(K)=SUPRO(K)/FLOAT(N1)
      VARPR(K)=(SUPR2(K)/FLOAT(N1))-(SUPRO(K)/FLOAT(N1))**2
      WIPR(K)=SQRT(VARPR(K))
      ERPR(K)=WIPR(K)/SQRT(FLOAT(N1))
```

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  570 CONTINUE
C      COMPUTES THE VARIANCE OF SAMPLING CORRECTED CROSS-SECTIONS VARCS
C      AND THE CORRECTED CROSS-SECTION VALUES CCSV
      DO 600 K=1,22
      SUMCE(K)=0.0
      SUMCE2(K)=0.0
      SPR(K)=0.0
      SUCSS(K)=0.0
      SUCS2(K)=0.0
      SUMCG(K)=0.0
  600 SUMG2(K)=0.0
      DO 610 K=1,22
      DO 611 L=1,N1
      SUMCE(K)=SUMCE(K)+PR(L,K)*CSDEA(L,K)
      SUMCE2(K)=SUMCE2(K)+PR(L,K)*CSDEA(L,K)*CSDEA(L,K)
      SUCSS(K)=SUCSS(K)+PR(L,K)*CSDTA(L,K)
      SUCS2(K)=SUCS2(K)+PR(L,K)*CSDTB(L,K)
      SUMCG(K)=SUMCG(K)+PR(L,K)*CSDGA(L,K)
      SUMG2(K)=SUMG2(K)+PR(L,K)*CSDGA(L,K)**2
  611 SPR(K)=SPR(K)+PR(L,K)
      IF(SPR(K).EQ.0.0) GO TO 612
      CCSVE(K)=SUMCE(K)/SPR(K)
      CCSV(K)=SUCSS(K)/SPR(K)
      CCSVG(K)=SUMCG(K)/SPR(K)
      VARCE(K)=SUMCE2(K)/SPR(K)-(SUMCE(K)/SPR(K))**2
      VARCS(K)=(SUCS2(K)/SPR(K))-(SUCSS(K)/SPR(K))**2
      VARCG(K)=SUMG2(K)/SPR(K)-(SUMCG(K)/SPR(K))**2
      GO TO 610
  612 CCSV(K)=0.0
      CCSVE(K)=0.0
      CCSVG(K)=0.0
      VARCS(K)=0.0
      VARCG(K)=0.0
  610   CONTINUE
      DO 635 K=1,22
      ERRGP(K)=SQRT(ABS(VARCG(K)))/SQRT(FLOAT(N1))
      ERRTP(K)=SQRT(ABS(VARCS(K)))/SQRT(FLOAT(N1))
  635 ERREP(K)=SQRT(ABS(VARCE(K)))/SQRT(FLOAT(N1))
      PRINT 629
  629 FORMAT(9X,'PROBABILITY TABLE'/
     11X,'UPPER LIMIT',1X,'PROBABILITY',1X,'   ERROR   ',1X,' TOTAL-X-S'
     12X,'  ERROR   ',1X,'CAPTURE X-S',1X,'  ERROR   ')
      CSPP(22)=10000.
      DO 631 K=1,22
  631 PRINT 630,CSPP(K),PRT(K),ERPR(K),CCSV(K),ERRTP(K),CCSVG(K),ERRGP(K
     1)
  630 FORMAT(1X,F11.5,1X,E11.4,1X,E11.4,1X,E11.4,1X,E11.4,1X,E11.4,1X,E1
     11.4)
      AFGC2=0.0
      AFTC2=0.0
      AFTCS=0.0
      AFGCS=0.0
      AFECS=0.0
      DO 653 K=1,22
      AFTCS=AFTCS+PRT(K)*CCSV(K)
      AFECS=AFECS+PRT(K)*CCSVE(K)
      AFGCS=AFGCS+PRT(K)*CCSVG(K)
      AFTC2=AFTC2+PRT(K)*CCSV(K)**2
  653 AFGC2=AFGC2+PRT(K)*CCSVG(K)**2
      VFT=AFTC2-AFTCS**2
      VFG=AFGC2-AFGCS**2
      WFT=SQRT(VFT)
      WFG=SQRT(VFG)
      XPCG=0.0
      XPCG2=0.0
      XPCT=0.0
      XPCT2=0.0
      DO 700 L=1,N1
      XPCG=XPCG+SPCG(L)/100.
      XPCG2=XPCG2+(SPCG(L)/100.)**2
      XPCT=XPCT+SPCS(L)/100.
  700 XPCT2=XPCT2+(SPCS(L)/100.)**2
      DIN=SQRT(FLOAT(N1))
      EFT=SQRT(XPCT2/FLOAT(N1)-(XPCT/FLOAT(N1))**2)/DIN
      EFG=SQRT(XPCG2/FLOAT(N1)-(XPCG/FLOAT(N1))**2)/DIN
      PRINT 654,AFTCS,EFT,AFGCS,EFG
  654 FORMAT(16H AVERAGE-TOT-CS=,F12.4,6H ERROR,F12.4,18H AVERAGE-GAMMA-
     1CS=,F12.4,6H ERROR,F12.4)
      CALL BREKO(DICRO,DICRI,N1,EFT,EFG)
      CALL SHELF(CSDR,AN1,N1,EFG)
      STOP
      END
```

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      SUBROUTINE BREKO(DICRO,DICRI,N1,EFT,EFG)
      DIMENSION AGDCS(4),ATDCS(4),BFG(4),BFT(4),EBFG(4),EBFT(4),EDTCS(4)
     1,EDGCS(4)
      DIMENSION VAYPTG(4),VAYPTT(4),COVG(4),COVT(4)
      DIMENSION SYPT(4),SYPT2(4),SYPTG(4),SYPTG2(4),SYPTT(4),SYPTT2(4)
      DIMENSION ASYPT(4),ASYPTG(4),ASYPTT(4),VAYPT(4)
      DIMENSION DENOM(22),DENOI(22)
      DIMENSION AFDCS(4),BFF(4),SYPTC(4),SYPTC2(4),ASYPTC(4),COVTC(4),
     1EDCCS(4),VAYPTC(4),EBFF(4)
      COMMON/DERR/YPT(100,4),YPTG(100,4),YPTT(100,4),YPTC(100,4)
      COMMON/DSELF/CCSV(22),PRT(22),CCSVG(22)
C COMPUTE THE GROUP CROOSS SECTIONS WITH DILLTE X-SECTION,AGDCS,ATDCS
      DICR1=DICRO
      DO 50 J=1,4
      DICRO=DICRI*10**J
      SAVIF=0.0
      SAVI1=0.0
       SAVIG=0.0
      SAVIT=0.0
      DO 10 K=1,22
      DENOM(K)=CCSV(K)+DICRO
      SAVI1=SAVI1+PRT(K)/DENOM(K)
      SAVIG=SAVIG+PRT(K)*CCSVG(K)/DENOM(K)
      SAVIF=SAVIF+PRT(K)*CCSV(K)/DENOM(K)
 10   SAVIT=SAVIT+PRT(K)*(1./(DENOM(K)*DENOM(K)))
      ATDCS(J)=(SAVI1/SAVIT)-DICRO
      AGDCS(J)=SAVIG/SAVI1
      AFDCS(J)=SAVIF/SAVI1
C COMPUTE THE INFINITE DILUTE CROSS-SECTION IDCSG,IDCST
      SAID1=0.0
      SAIDG=0.0
      SAIDF=0.0
       SAIDT=0.0
       DO 20 K=1,22
      DENOI(K)=CCSV(K)+DICRI
      SAID1=SAID1+PRT(K)/DENOI(K;
      SAIDG=SAIDG+PRT(K)*CCSVG(K)/DENOI(K)
      SAIDF=SAIDF+PRT(K)*CCSV(K)/DENOI(K)
 20   SAIDT=SAIDT+PRT(K)*(1./(DENOI(K)*DENOI(K)))
      DICSG=SAIDG/SAID1
      DICST=SAID1/SAIDT-DICRI
      DICSF=SAIDF/SAID1
C   COMPUTE TBE BOUDARENKO FACTORS BFG, BFT
      BFG(J)=(1./DICSG)*AGDCS(J)
      BFT(J)=(1./DICST)*ATDCS(J)
      BFF(J)=(1./DICSF)*AFDCS(J)
 50   CONTINUE
      DO 60 J=1,4
      SYPT(J)=0.0
      SYPTC(J)=0.0
      SYPTC2(J)=0.0
      SYPT2(J)=0.0
      SYPTT(J)=0.0
      SYPTT2(J)=0.0
      SYPTG(J)=0.0
      SYPTG2(J)=0.0
      DO 70 L=1,N1
      SYPT(J)=SYPT(J)+YPT(L,J)
      SYPT2(J)=SYPT2(J)+YPT(L,J)*YPT(L,J)
      SYPTG(J)=SYPTG(J)+YPTG(L,J)
      SYPTG2(J)=SYPTG2(J)+YPTG(L,J)*YPTG(L,J)
      SYPTC(J)=SYPTC(J)+YPTC(L,J)
      SYPTC2(J)=SYPTC2(J)+YPTC(L,J)*YPTC(L,J)
      SYPTT(J)=SYPTT(J)+YPTT(L,J)
 70   SYPTT2(J)=SYPTT2(J)+YPTT(L,J)*YPTT(L,J)
      ASYPTT(J)=SYPTT(J)/FLOAT(N1)
      ASYPTC(J)=SYPTC(J)/FLOAT(N1)
      ASYPT(J)=SYPT(J)/FLOAT(N1)
      ASYPTG(J)=SYPTG(J)/FLOAT(N1)
      COVG(J)=0.0
      COVT(J)=0.0
      COVTC(J)=0.0
      DO 71 L=1,N1
      COVG(J)=COVG(J)+(1./FLOAT(N1))*(1./FLOAT(N1))*(YPT(L,J)-ASYPT(J))*
     1(YPTG(L,J)-ASYPTG(J))
      COVTC(J)=COVTC(J)+(1./FLOAT(N1))*(1./FLOAT(N1))*(YPTC(L,J)-ASYPTC(
     1J))*(YPT(L,J)-ASYPT(J))
 71   COVT(J)=COVT(J)+(1./FLOAT(N1))*(1./FLOAT(N1))*(YPTT(L,J)-ASYPTT(J)
     1)*(YPT(L,J)-ASYPT(J))
      VAYPT(J)=(1./FLOAT(N1))*(SYPT2(J)/FLOAT(N1)-ASYPT(J)**2)
      VAYPTG(J)=(1./FLOAT(N1))*(SYPTG2(J)/FLCAT(N1)-ASYPTG(J)**2)
      VAYPTT(J)=(1./FLOAT(N1))*(SYPTT2(J)/FLCAT(N1)-ASYPTT(J)**2)
      VAYPTC(J)=(1./FLOAT(N1))*(SYPTC2(J)/FLCAT(N1)-ASYPTC(J)**2)
      EDGCS(J)=SQRT((1./ASYPT(J)**2)*VAYPTG(J)+(ASYPTG(J)/ASYPT(J)**2)**
     12*VAYPT(J)-2.*(ASYPTG(J)/ASYPT(J)**3)*COVG(J))
      EDTCS(J)=SQRT((1./ASYPT(J)**2)*VAYPTT(J)+(ASYPTT(J)/ASYPT(J)**2)**
     12*VAYPT(J)-2.*(ASYPTT(J)/ASYPT(J)**3)*COVT(J))
      EDCCS(J)=SQRT((1./ASYPTC(J)**2)*VAYPT(J)+(ASYPT(J)/ASYPTC(J)**2)**
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     12*VAYPTC(J)-2.*(ASYPT(J)/ASYPTC(J)**3)*COVTC(J))
      EBFG(J)=SQRT((1./(DICSG*DICSG))*EDGCS(J)**2+(AGDCS(J)/DICSG**2)**2
     1*EFG**2)
      EBFF(J)=SQRT((1./(DICSF*DICSF))*EDTCS(J)**2+(AFDCS(J)/DICSF**2)**2
     1*EFT**2)
60    EBFT(J)=SQRT((1./(DICST*DICST))*EDCCS(J)**2+(ATDCS(J)/DICST**2)**2
     1*EFT**2)
      PRINT 57
57    FORMAT('        BONDARENKO GROUP CROSS SECTIONS    '//)
      PRINT 55
55    FORMAT('  AWFT AVERAGE WEIGHTED FLUX TOTAL X-SECTION,AWCT AVERAGE
     1WEIGHTED CURRENT TOTAL X-SECTION     '/)
      PRINT 59
59    FORMAT('        DILUTION    CAPTURE X-SECTION    ERROR      AWFT X-SECT
     1ION   ERROR    AWCT-X-SECTION    ERROR')
      DO 62 J=1,4
      DICRO=DICRI*10.**J
62    PRINT 63,DICRO,AGDCS(J),EDGCS(J),AFDCS(J),EDTCS(J),ATDCS(J),EDCCS(
     1J)
63    FORMAT(6X,F7.1,6X,F12.4,5X,F7.4,5X,F12.4,3X,F7.4,3X,F12.4,3X,F7.4)
      PRINT 58
58    FORMAT('         BONDARENKO SELF-SHIELDING FACTORS   '//)
      PRINT 69
69    FORMAT('     BFT BONDARENKO WEIGHTED FLUX SELF SHIELDING FACTOR'/
     1'    BFC BONDARENKO WEIGHTED CURRENT SELF SHIELDING FACTOR'/)
      PRINT 68
68    FORMAT('         DILUTION  CAPTURE FACTOR    ERROR      BFC   FACTOR
     1     ERROR      BFF FACTOR    ERROR')
      DO 66 J=1,4
      DICRO=DICRI*10.**J
66    PRINT 67,DICRO,BFG(J),EBFG(J),BFT(J),EBFT(J),BFF(J),EBFF(J)
67    FORMAT(6X,F7.1,6X,F8.5,5X,F8.5,6X,F8.5,6X,F8.5,3X,F8.5,5X,F8.5)
        RETURN
       END


      SUBROUTINE BREDO(E,EREF,AP,AWRI,R,T,SPI,CSDG,CSDT,CSP,CSDE)
C     THIS SUBROUTINE COMPUTES THE DOPPLER BROADENED TOTAL CROSS SECTION
C     AND GAMMA CROSS SECTION, CSDT AND CSDG.
      DIMENSION CSP1(3),G(3,6),GN(3,6,150),CSDG3(3,6,150),CSDG1(3,6),
     1CSDG2(3),CSDT3(3,6),CSDT4(3,6,150),CSDT5(3)
      COMMON/UBRED/ER(3,6,150),GNO(3,6,150),AGG(3,6),NR(3,6),
     1EL(3,6),EU(3,6),NJS(3),AJ(3,6),AGNO(3,6)
      COMMON/DSIF/FI(3)
      COMMON/DVIL/V(3)
      DATA INDICE/0/
      SE=SQRT(E)
      IF(INDICE.EQ.1) GO TO 10
      INDICE=1
      SEF=SQRT(EREF)
      SAF=2.196771*(AWRI/(AWRI+1.))*SEF/1000.
      SIGO=(6.51*10.**5/EREF)*((AWRI+1.)/AWRI)**2
      RO3=SAF*R
      RO=SAF*AP
      DELTA=SQRT(3.446R*EREF*T/AWRI)/100.
       CALL VIL(RO3)
      CALL SHIF(RO)
      DO 40 I=1,3
40    CSP1(I)=4.*(2.*(FLOAT(I)-1.)+1.)*SIGO*(SIN(FI(I)))**2
      CSP=CSP1(1)+CSP1(2)+CSP1(3)
      DO 50 I=1,3
      NJSI= NJS(I)
      DO 50 J=1,NJSI
   50 G(I,J)=(2.*AJ(I,J)+1.)/(4.*SPI+2.)
 10   CONTINUE
      FA=((AGNO(1,1)*SE+AGG(1,1))/(4.*SE))
      FB=(EU(1,1)-EL(1,1)+20.)/((EU(1,1)-E+10.)*(E-EL(1,1)+10.))
      FC=2.1875*AP*ALOG((E-EL(1,1)+11.84)/(EU(1,1)-E+11.84))/1000.
      FVS=1.313*10.**5*AGNO(1,1)*(FA*FB-FC)
C     COMPUTE DOPPLER BROADENED GAMMA CROSS-SECTIONS, CSDG.
C     COMPUTE DOPPLER BROADENED TOTAL CROSS-SECTION.
      DO 100 I=1,3
      NJSI=NJS(I)
      DO 100 J=1,NJSI
      NRI=NR(I,J)
      DO 100 K=1,NRI
      GN(I,J,K)=GNO(I,J,K)*V(I)*SEF
      AD3=3.544907*SIGO*G(I,J)
      BD=GN(I,J,K)*AGG(I,J)/((GN(I,J,K)+AGG(I,J))*DELTA)
      BD1=GN(I,J,K)/DELTA
      X=(ER(I,J,K)-E)/DELTA
      Y=(GN(I,J,K)+AGG(I,J))/(2.*DELTA)
      CALL SVS(X,Y,U,V1)
      CSDG3(I,J,K)=AD3*BD*U
      CSDT1=AD3*BD1*COS(2.*FI(I))*U
      CSDT2=AD3*BD1*SIN(2.*FI(I))*V1
```

```
100   CSDT4(I,J,K)=CSDT1-CSDT2
      DO 300 I=1,3
      NJSI=NJS(I)
      DO 300 J=1,NJSI
      CSDT3(I,J)=0.0
      CSDG1(I,J)=0.0
      NRI=NR(I,J)
      DO 300 K=1,NRI
      CSDG1(I,J)=CSDG1(I,J)+CSDG3(I,J,K)
300   CSDT3(I,J)=CSDT3(I,J)+CSDT4(I,J,K)
      DO 301 I=1,3
      CSDT5(I)=0.0
      CSDG2(I)=0.0
      NJSI=NJS(I)
      DO 301 J=1,NJSI
      CSDG2(I)=CSDG2(I)+CSDG1(I,J)
301   CSDT5(I)=CSDT5(I)+CSDT3(I,J)
      CSDG=CSDG2(1)+CSDG2(2)+CSDG2(3)
      CSDT=CSDT5(1)+CSDT5(2)+CSDT5(3)+CSP
      CSDT=CSDT+FVS
      CSDE=CSDT-CSDG
      RETURN
      END


      SUBROUTINE SHELF(CSDR,AN1,N1,EFG)
      COMMON/DSED/ATCS(100),SPCG(100)
C     COMPUTES: AVERAGE TRANSMISSION, AVERAGE SELF-INDICATION RATIO,
C     TRANSMISSION SELF-SHIELDING FACTOR, SELF INDICATION RATIO-
C     SELF-SHIELDING FACTOR.
      DIMENSION EXFLUM(100),EXFLU2(100),EXFLUT(100),EXFLT2(100),EXSIR(10
     10),EXSIR2(100),EXASI1(100),EXASI2(100)
      DIMENSION EFLUC(22), EFLUD(22)
      COMMON/DSELF/CCSV(22),PRT(22),CCSVG(22)
C     COMPUTES THE TRANSMISSION SELF-SHIELDING FACTOR, TSSF
      DIN2=FLOAT(N1)
      DIN=SQRT(FLOAT(N1))
      PRINT 5
5     FORMAT('     AVERAGE TRASMISSION ATR,TRASMISSION SELF SHIELDING FAC
     1TOR  TSSF'/
     2'     AVERAGE SELF INDICATION RATIO SIR AND SELF INDICATION SELF SH
     3IELDING FACTOR SIRSS'//)
      PRINT 6
6     FORMAT(' ATOM/BARN    AT       ERROR      TSSF      ERROR      SIR       ER
     1ROR       SIRSS   ERROR'/)
      DO 40 J=1,10
      TSSF=0.0
      TSSF2=0.0
      AN1=AN1+0.01
      DO 10 K=1,22
       EFLUC(K)=EXP(-AN1*(CCSV(K)-CSDR))
      TSSF2=TSSF2+PRT(K)*(EFLUC(K))**2
10    TSSF=TSSF+PRT(K)*EFLUC(K)
C     COMPUTES THE AVERAGE TRANSMISSION, ATR
      ATR=TSSF*EXP(-AN1*CSDR)
C     COMPUTES THE SELF-INDICATION-RATIO-SELF-SHIELDING-FACTOR, SIRSS
      SIRSS=0.0
      DO 20 K=1,22
      EFLUD(K)=CCSVG(K)*EFLUC(K)
20    SIRSS=SIRSS+PRT(K)*EFLUD(K)
C     COMPUTES THE AVERAGE SELF-INDICATION RATIO, ASIR
      SUMG2=0.0
      DO 30 K=1,22
30    SUMG2=SUMG2+PRT(K)*CCSVG(K)
      ASIR=SIRSS*EXP(-AN1*CSDR)/SUMG2
      DO 41 L=1,N1
      EXFLUM(L)=EXP(-AN1*(ATCS(L)-CSDR))
      EXFLU2(L)=EXFLUM(L)*EXFLUM(L)
      EXFLUT(L)=EXP(-AN1*ATCS(L))
      EXFLT2(L)=EXFLUT(L)*EXFLUT(L)
      EXSIR(L)=(SPCG(L)/100.)*EXFLUM(L)
      EXSIR2(L)=EXSIR(L)*EXSIR(L)
      EXASI1(L)=(SPCG(L)/100.)*EXFLUT(L)
41    EXASI2(L)=EXASI1(L)*EXASI1(L)
      SEFLUM=0.0
      SEFLU2=0.0
      SEFLUT=0.0
      SEFLT2=0.0
      SESIR=0.0
      SESIR2=0.0
      SEASI1=0.0
```

```
      SEASI2=0.0
      DO 50 L=1,N1
      SEFLUM=SEFLUM+EXFLUM(L)
      SEFLU2=SEFLU2+EXFLU2(L)
      SEFLUT=SEFLUT+EXFLUT(L)
      SEFLT2=SEFLT2+EXFLT2(L)
      SESIR=SESIR+EXSIR(L)
      SESIR2=SESIR2+EXSIR2(L)
      SEASI1=SEASI1+EXASI1(L)
 50   SEASI2=SEASI2+EXASI2(L)
      ERTSF=SQRT(SEFLU2/DIN2-(SEFLUM/DIN2)**2)/DIN
      ERAT=SQRT(SEFLT2/DIN2-(SEFLUT/DIN2)**2)/DIN
      ERSIRF=SQRT(SESIR2/DIN2-(SESIR/DIN2)**2)/DIN
      ERSIR1=SQRT(SEASI2/DIN2-(SEASI1/DIN2)**2)/DIN
      ESIR=SQRT((1./SUMG2**2)*ERSIR1**2+(SIRSS*EXP(-AN1*CSDR)/SUMG2**2)*
     1*2*EFG**2)
      PRINT 60,AN1,ATR,ERAT,TSSF,ERTSF,ASIR,ESIR,SIRSS,ERSIRF
 60   FORMAT(1X,F8.4,2X,F7.5,2X,F7.4,2X,F8.4,2X,F7.4,2X,F7.4,2X,F7.4,2X,
     1F7.4,2X,F7.4)
 40     CONTINUE
      RETURN
      END


      SUBROUTINE SHIF(RO)
      COMMON/DSIF/FI(3)
      FI(1)=RO
      FI(2)=RO-ATAN(RO)
      FI(3)=RO-ATAN(3.*RO/(3.-RO*RO))
      RETURN
      END


      SUBROUTINE VIL(RO1)
      COMMON/DVIL/V(3)
      V(1)=1.
      V(2)=RO1*RO1/(1.+RO1*RO1)
      V(3)=RO1**4/(9.+3.*RO1*RO1+RO1**4)
      RETURN
      END


      SUBROUTINE SVS(A,B,C,D)
      COMMON/TRTI/TR(62,62),TI(62,62),AIMW,AX,KI,REW,Y1
      DATA K/0/
      IF(K.EQ.1)   GO TO 3
      K=1
      KI=1
      X=-.1
      DO 2 I=1,62
      Y=-.1
      DO 1 J=1,62
      CALL W(X,Y,TR(I,J),TI(I,J))
    1 Y=Y+.1
    2 X=X+.1
    3 CONTINUE
      AX=A
      Y1=B
      CALL QUICKW
      C=REW
      D=AIMW
      RETURN
      END                                                          OK  0090
                                                                   OK  0100
```

```
      SUBROUTINEW(REZ,AIM1,REW,AIMW)
      REW=0.
      AIMW=0.
      AIMZ=ABS (AIM1)
      IF(REZ)27,2001,27
 2001 IF(AIM1)27,2002,27
 2002 REW=1.
      RETURN
   27 R2=REZ*REZ
      AI2=AIMZ*AIMZ
      ABREZ=ABS (REZ)
      IF(ABREZ+1.25*AIMZ-5.0)102,102,100
  100 IF(ABREZ+1.1*AIMZ-6.6)117,117,116
  101 IF(ABREZ+1.43333*AIMZ-4.3)119,119,118
  102 IF(ABREZ+1.863636*AIMZ-4.1)111,111,104
  103 IF(AIMZ-1.5)110,120,120
  104 IF(AIMZ-1.4)115,115,101
  105 IF(ABREZ+1.07317*AIMZ-4.4)119,119,118
  106 IF(ABREZ-2.7)127,128,128
  107 IF(ABREZ-3.1)106,108,108
  108 IF(ABREZ-3.4)129,130,130
  109 IF(R2+1.18*AI2-5.76)103,107,107
  110 IF(R2+1.7227*AI2-4.41)125,126,126
  111 IF(R2+1.71*AI2-2.89)113,109,109
  112 IF(R2+1.69*AI2-1.69)123,124,124
  113 IF(R2+2.0408*AI2-1.0)114,112,112
  114 IF(R2+1.5625*AI2-.25)121,122,122
  115 IF(ABREZ+1.43333*AIMZ-4.3)120,120,105
  116 NMAX=1
      GO TO 15
  117 NMAX=2
      GO TO 15
  118 NMAX=3
      GO TO 15
  119 NMAX=4
      GO TO 15
  120 NMAX=6
      GO TO 15
  121 NMAX=2
      GO TO 20
  122 NMAX=3
      GO TO 20
  123 NMAX=4
      GO TO 20
  124 NMAX=5
      GO TO 20
  125 NMAX=6
      GO TO 20
  126 NMAX=7
      GO TO 20
  127 NMAX=8
      GO TO 20
  128 NMAX=9
      GO TO 20
  129 NMAX=10
      GO TO 20
  130 NMAX=11
   20 KW=2
      AIMZ=AIM1
      GO TO 200
   15 KW=1
      IF(AIM1)2000,150,150
 2000 KW=2
      AIMZ=AIM1
      GO TO 200
C WA IS OBTAINED FROM ASYMTOTIC SERIES
  150 RV=2.*(R2-AI2)
      AK=4.*REZ*AIMZ
      EL=AK
      H=0.
      B=0.
      A=0.
      TEMPH=0.
      TEMEL=0.
      G=1.
      C=-1.1283792*AIMZ
      D=1.1283792*REZ
      AM=RV-1.
      AAK=1.
      K=0
   11 AJTEMP=2.*AAK
      TEMP4=(1.-AJTEMP)*AJTEMP
      AJP=RV-(4.*AAK+1.)
      GO TO 40
```

```
   41 AAK=AAK+1.
      K=K+1
      PR=REW
      PI=AIMW
   12 AMAGN=TEMPM**2+TEMEL**2
      REW=(TEMPC*TEMPM+TEMPD*TEMEL)/AMAGN
      AIMW=(TEMPM*TEMPD-TEMEL*TEMPC)/AMAGN
      IF(ABS (REW-PR)-1.E-6)665,11,11
  665 IF(ABS (AIMW-PI)-1.E-6)65,11,11
   65 RETURN
C WT IS OBTAINED FROM TAYLOR SERIES
  200 TEMP1=R2+AI2
      TEMP2=2.*TEMP1*TEMP1
      AJ=-(R2-AI2)/TEMP2
      AK=2.*REZ*AIMZ/TEMP2
      C=0.
      B=0.
      AJSIG=0.
      D=0.
      JSIG=0
      G=0.
      H=0.
      EL=0.
      A=1.
      AM=1.
      SIGP=1.5
      EXPON=EXP (TEMP2*AJ)
      EXPC=EXPON*COS (TEMP2*AK)
      EXPS=-EXPON*SIN (TEMP2*AK)
      SIG2P=2.*SIGP
    4 AJ4SIG=4.*AJSIG
      AJ4SM1=AJ4SIG-1.
      TEMP3=1./(AJ4SM1*(AJ4SIG+3.))
      TT4=SIG2P*(2.*AJSIG-1.)
      TEMP4=TT4/(AJ4SM1*(AJ4SIG+1.)*(AJ4SIG-3.)*AJ4SM1)
      AJP=AJ+TEMP3
      GO TO 40
   42 AJSIG=AJSIG+1.
      JSIG=JSIG+1
    6 TEMP7=(AM*AM+EL*EL)*1.7724539
      REF=(AIMZ*(C*AM+D*EL)-REZ*(AM*D-C*EL))/
     1TEMP7/TEMP1
      AIMP=(AIMZ*(AM*D-C*EL)+REZ*(C*AM    +D*EL))/TEMP7/TEMP1
      PR=REW
      PI=AIMW
      REW=EXPC-REF
      AIMW=EXPS-AIMP
      IF(ABS (REW-PR)-1.E-6)664,7,7
  664 IF(ABS (AIMW-PI)-1.E-6)64,7,7
   64 RETURN
    7 SIG2P=2.*AJSIG
      GO TO 6
   40 TEMPC=AJP*C+TEMP4*A-AK*D
      TEMPD=AJP*D+TEMP4*B+AK*C
      TEMEL=AJP*EL+TEMP4*H+AK*AM
      TEMPM=AJP*AM+TEMP4*G-AK*EL
      A=C
      B=D
      G=AM
      H=EL
      C=TEMPC
      D=TEMPD
      AM=TEMPM
      EL=TEMEL
      IF(ABS (TEMPM)+ABS (TEMEL)-1.0E15)49,43,43
   43 C=1.0E-15*C
      D=1.0E-15*D
      AM=1.0E-15*AM
      EL=1.0E-15*EL
      TEMPC=1.0E-15*TEMPC
      TEMPD=1.0E-15*TEMPD
      TEMPM=1.0E-15*TEMPM
      TEMEL=1.0E-15*TEMEL
      GO TO 50
   49 IF(ABS (TEMPM)+ABS (TEMEL)-1.0E-15)44,44,50
   44 C=1.0E15*C
      D=1.0E15*D
      AM=1.0E15*AM
      EL=1.0E15*EL
      TEMPC=1.0E15*TEMPC
      TEMPD=1.0E15*TEMPD
      TEMPM=1.0E15*TEMPM
      TEMEL=1.0E15*TEMEL
   50 GO TO(41,42,12345),KW
12345 RETURN
      END
```

```
              SOURCE,EBCDIC,NOLIST,NODECK,LOAD,MAP,NOEDIT,ID,NOXREF
      SUBROUTINE QUICKW                                                 QUIC0010
      COMMON/TRTI/TR(62,62),TI(62,62),AIMW,AX,KI,REW,Y                  QUIC0020
      AKI=SIGN(1.,AX)                                                   QUIC0030
      X=ABS(AX)                                                         QUIC0040
      TEST=X*X+Y*Y                                                      QUIC0050
      IF(TEST.LT.36.)GO TO 10                                           QUIC0060
      IF(TEST.LT.144.)GO TO 2                                           QUIC0070
      IF(TEST.LT.10000.)GO TO 3                                         QUIC0080
      A1=1./(1.7724539*TEST)
      REW=Y*A1                                                          QUIC0100
      IF(KI.GT.0)AIMW=X*A1*AKI                                          QUIC0110
      RETURN                                                            QUIC0120
   10 II=X*10.                                                          QUIC0130
      JJ=Y*10.                                                          QUIC0140
      I=II+2                                                            QUIC0150
      J=JJ+2                                                            QUIC0160
      N=J-1                                                             QUIC0170
      P=10.*X-II                                                        QUIC0180
      Q=10.*Y-JJ                                                        QUIC0190
   15 P2=P*P                                                            QUIC0200
      Q2=Q*Q                                                            QUIC0210
      PQ=P*Q                                                            QUIC0220
      HP=.5*P                                                           QUIC0230
      HQ=.5*Q                                                           QUIC0240
      HQ2=.5*Q2                                                         QUIC0250
      HP2=.5*P2                                                         QUIC0260
      A1=HQ2-HQ                                                         QUIC0270
      A2=HP2-HP                                                         QUIC0280
      A3=1.+PQ-P2-Q2                                                    QUIC0290
      A4=HP2-PQ+HP                                                      QUIC0300
      A5=HQ2-PQ+HQ                                                      QUIC0310
      REW=A1*TR(I,N   )+A2*TR(I-1,J)+A3*TR(I,J)+A4*TR(I+1,J)+A5*TR(I,J+1)QUIC0320
     1+PQ*TR(I+1,J+1)                                                   QUIC0330
      IF(KI.LE.0) GO TO 8                                               QUIC0340
    5 AIMW=A1*TI(I,N   )+A2*TI(I-1,J)+A3*TI(I,J)+A4*TI(I+1,J)+A5*TI(I,J+1QUIC0350
     1)+PQ*TI(I+1,J+1)                                                  QUIC0360
      AIMW=AIMW*AKI                                                     QUIC0370
      GOTO8                                                             QUIC0380
    2 A1=X*X -Y*Y                                                       QUIC0390
      A2=2.*X*Y                                                         QUIC0400
      A3=A2*A2                                                          QUIC0410
      A4=A1-.2752551                                                    QUIC0420
      A5=A1-2.724745                                                    QUIC0430
      D1=.5124242/(A4*A4+A3)                                            QUIC0440
      D2=.05176536/( A5*A5+A3)                                          QUIC0450
      REW=D1*(A2*X-A4*Y)+D2*(A2*X-A5*Y)                                 QUIC0460
      IF(KI.LE.0) GO TO 8                                               QUIC0470
    7 AIMW=D1*(A4*X    +A2*Y)+D2*(A5*X+A2*Y)                            QUIC0480
      AIMW=AIMW*AKI                                                     QUIC0490
      GOTO8                                                             QUIC0500
    3 A1=(X*X -Y*Y )*2.
      A2=4.*X*Y                                                         QUIC0520
      A4=A1-1.                                                          QUIC0530
      D1=1.1283792/(A4*A4+A2*A2)                                        QUIC0540
      REW=D1*(A2*X-A4*Y)                                                QUIC0550
      IF(KI.LE.0) GO TO 8                                               QUIC0560
    9 AIMW=D1*(A4*X+A2*Y)                                               QUIC0570
      AIMW=AIMW*AKI                                                     QUIC0580
    8 RETURN                                                            QUIC0590
      END                                                               QUIC0600
```

Appendix II. Sample Program

A. Listing of Input

PROGRAM PAPIN VERSION FEBRUARY 1981

NUMBER OF LADDERS=100
0.1000 100000.0
1.
NEUTRON ENERGY= 4000.00
SCATTERING LENGTH= 0.8900
ATOMIC WEIGHT= 236.006
CHANNEL RADIUS= 0.8400
TEMPERATURE= 2000.00
TOTAL-REFERENCE-CROSS-SECTION= 17.9500
NRZ=100
NUCLEAR SPIN= 0.0
INITIAL THICKNES IN ATOM/BARN= 0.0100
COMPENSATION CROSS SECTION= 1.2050
1 2 2

UNRESOLVED RESONANCE PARAMETERS

L	J	D	AGNO	AMUN	AGG
1	0.5000E 00	0.2000E 02	0.2100E-02	1.0	0.2350E-01
2	0.5000E 00	0.2000E 02	0.1549E-02	1.0	0.2350E-01
2	0.1500E 01	0.1000E 02	0.7745E-03	1.0	0.2350E-01
3	0.1500E 01	0.1000E 02	0.2500E-02	1.0	0.2350E-01
3	0.2500E 01	0.6667E 01	0.1667E-02	1.0	0.2350E-01

B. Listing of Output

PROBABILITY TABLE

UPPER LIMIT	PROBABILITY	ERROR	TOTAL-X-S	ERROR	CAPTURE X-S	ERROR
2.00000	0.0	0.0	0.0	0.0	0.0	0.0
2.48189	0.3000E-03	0.2216E-03	0.2238E 01	0.7436E-02	0.2221E 00	0.7498E-02
3.07990	0.1000E-03	0.9950E-04	0.3059E 01	0.2184E-03	0.1030E 00	0.1057E-04
3.82199	0.3000E-03	0.1706E-03	0.3653E 01	0.9800E-02	0.4123E 00	0.2021E-01
4.74288	0.1500E-02	0.3841E-03	0.4418E 01	0.2470E-01	0.2762E 00	0.2420E-01
5.88566	0.1900E-02	0.4170E-03	0.5378E 01	0.2818E-01	0.1774E 00	0.1134E-01
7.30379	0.1090E-01	0.1069E-02	0.6715E 01	0.2741E-01	0.2293E 00	0.1019E-01
9.06362	0.4060E-01	0.2130E-02	0.8355E 01	0.2060E-01	0.2459E 00	0.1230E-01
11.24746	0.2302E 00	0.6509E-02	0.1040E 02	0.1161E-01	0.2547E 00	0.6374E-02
13.95750	0.3264E 00	0.7131E-02	0.1237E 02	0.1456E-01	0.4371E 00	0.9793E-02
17.32051	0.1317E 00	0.3493E-02	0.1530E 02	0.2721E-01	0.9983E 00	0.2289E-01
21.49382	0.7170E-01	0.2446E-02	0.1918E 02	0.4829E-01	0.1574E 01	0.3526E-01
26.67268	0.4910E-01	0.2112E-02	0.2393E 02	0.6248E-01	0.2066E 01	0.4113E-01
33.09937	0.3940E-01	0.1948E-02	0.2956E 02	0.9742E-01	0.2337E 01	0.5431E-01
41.07455	0.2860E-01	0.1667E-02	0.3677E 02	0.1319E 00	0.2641E 01	0.6433E-01
50.97131	0.2320E-01	0.1489E-02	0.4555E 02	0.1745E 00	0.2777E 01	0.8820E-01
63.25269	0.1690E-01	0.1247E-02	0.5699E 02	0.2854E 00	0.3040E 01	0.6321E-01
78.49319	0.1170E-01	0.1068E-02	0.7008E 02	0.3107E 00	0.3259E 01	0.7218E-01
97.40585	0.8800E-02	0.9724E-03	0.8740E 02	0.4890E 00	0.3304E 01	0.9904E-01
120.87546	0.4300E-02	0.6820E-03	0.1075E 03	0.5194E 00	0.3413E 01	0.5015E-01
150.00000	0.1400E-02	0.3470E-03	0.1316E 03	0.8188E 00	0.3137E 01	0.5692E-01
10000.00000	0.1000E-02	0.3000E-03	0.1742E 03	0.2632E 01	0.3118E 01	0.5865E-01

AVERAGE-TOT-CS= 18.0719 ERROR 0.1887 AVERAGE-GAMMA-CS= 0.9332 ERROR 0.0103

BONDARENKO GROUP CROSS SECTIONS

AWFT AVERAGE WEIGHTED FLUX TOTAL X-SECTION, AWCT AVERAGE WEIGHTED CURRENT TOTAL X-SECTION

DILUTION	CAPTURE X-SECTION	ERROR	AWFT X-SECTION	ERROR	AWCT-X-SECTION	ERROR
1.0	0.6399	0.0067	13.7304	0.0691	11.9915	0.0810
10.0	0.7095	0.0073	14.5896	0.0823	12.9935	0.0579
100.0	0.8566	0.0091	16.6582	0.1364	15.6380	0.1122
1000.0	0.9223	0.0101	17.8477	0.1795	17.6360	0.4625

BONDARENKO SELF-SHIELDING FACTORS

BFT BONDARENKO WEIGHTED FLUX SELF SHIELDING FACTOR
BFC BONDARENKO WEIGHTED CURRENT SELF SHIELDING FACTOR

DILUTION	CAPTURE FACTOR	ERROR	BFC FACTOR	ERROR	BFF FACTOR	ERROR
1.0	0.68577	0.01045	0.66619	0.00831	0.75986	0.00881
10.0	0.76040	0.01152	0.72186	0.00823	0.80629	0.00957
100.0	0.91807	0.01407	0.86878	0.01104	0.92156	0.01223
1000.0	0.98846	0.01541	0.97978	0.02767	0.98771	0.01432

AVERAGE TRASMISSION AT, TRASMISSION SELF SHIELDING FACTOR TSSF
AVERAGE SELF INDICATION RATIO SIR AND SELF INDICATION SELF SHIELDING FACTOR SIRSS

ATOM/BARN	AT	ERR.	TSSF	ERROR	SIR	ERROR	SIRSS	ERROR
0.0200	0.72104	[illegible]	1.0325	0.0038	0.5927	0.0089	0.7920	0.0081
0.0300	0.62230	0.0033	1.0663	0.0056	0.4760	0.0070	0.7610	0.0075
0.0400	0.54045	0.0036	1.1081	0.0075	0.3888	0.0057	0.7438	0.0072
0.0500	0.47153	0.0038	1.1569	0.0093	0.3216	0.0048	0.7362	0.0073
0.0600	0.41206	0.0038	1.2121	0.0112	0.2686	0.0041	0.7359	0.0078
0.0700	0.36252	0.0037	1.2736	0.0130	0.2261	0.0036	0.7413	0.0086
0.0800	0.31906	0.0035	1.3413	0.0149	0.1915	0.0033	0.7514	0.0097
0.0900	0.28137	0.0033	1.4154	0.0168	0.1631	0.0029	0.7658	0.0109
0.1000	0.24856	0.0031	1.4962	0.0186	0.1396	0.0027	0.7840	0.0123
0.1100	0.21991	0.0029	1.5840	0.0205	0.1199	0.0024	0.8057	0.0137

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