GNASH:
A Preequilibrium, Statistical Nuclear-Model Code for
Calculation of Cross Sections and Emission Spectra

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GNASH: A PREEQUILIBRIUM, STATISTICAL NUCLEAR-MODEL CODE FOR CALCULATION OF CROSS SECTIONS AND EMISSION SPECTRA

by

P. G. Young and E. D. Arthur

ABSTRACT

A new multistep Hauser-Feshbach code that includes corrections for preequilibrium effects is described. The code can calculate up to 60 decay reactions (cross sections and energy spectra) in one computation, thereby providing considerable flexibility for handling processes with complicated reaction chains. Input parameter setup, problem output, and subroutine descriptions are given along with a sample problem calculation. A brief theoretical description is also included.

I. INTRODUCTION

The preequilibrium, statistical nuclear-model code GNASH provides a flexible method by which reaction and level cross sections, isomer ratios, and spectra (neutron, gamma-ray, and charged-particle) resulting from particle-induced reactions can be calculated. The code uses Hauser-Feshbach theory to calculate complicated sequences of reactions and includes a preequilibrium correction for binary channels. Gamma-ray competition is considered in detail for every decaying compound nucleus. Each calculation can handle decay sequences involving up to 10 compound nuclei, and each decaying compound nucleus can emit a maximum of 6 types of radiation (neutrons, gamma rays, protons, alphas, etc.). Angular-momentum effects and conservation of parity are included explicitly. Each residual nucleus in a calculation can contain up to 50 discrete levels, whereas its continuum region can be represented by up to 200 energy bins. The incident-particle types that are permitted are neutrons, protons, deuterons, tritons, $^3$He, and $^4$He. These particles and gamma rays can also be emitted from decaying compound nuclei. Angular distributions are not calculated; that is, isotropy is assumed in the center-of-mass (c.m.) system.
Figure 1 illustrates input data used in GNASH calculations and provides a summary of the major output features. The input includes cards that specify the reaction chains to be followed, the incident energies to be included, and the model and parameter options to be used in the calculation. Optical-model transmission coefficients are input for all particle types included, and the energy levels, spins, parities, and branching ratios are provided for all residual nuclei in the calculation.

A complex decay sequence involving multiparticle and gamma-ray emission, typical of the ones that can be handled in a single calculation, is shown in Fig. 2. The sequence is for neutrons incident on $^{59}$Co with sufficient energy to cause (n,5n) reactions to occur, and has been used to calculate proton- and alpha-production cross sections for neutrons up to 40 MeV in energy. The heavy arrows in Fig. 2 indicate the main reaction chains that were followed. A part of this calculation is included in this report as a sample problem. Other examples of calculations with GNASH appear in Refs. 3-8.

The GNASH code, developed for a Control Data Corp. (CDC) 7600 computer, uses 49 000 words of storage and up to 290 000 words of extended-core memory (depending on the problem) for storage of parameters used in a calculation. As an option, the code can use auxiliary files of transmission coefficient and energy-level data or obtain these data directly from cards.

Included in this report are descriptions of the theoretical expressions used in the calculations (Sec. II), mechanics of the calculation and important sub-
routines (Sec. III), input parameters and options for streamlined setup (Sec. IV), supplemental data or files needed (Sec. V), and output produced by the code (Sec. VI). Section VII contains a summary discussion, and the code listing and a sample problem are given in Appendixes A–E.

II. THEORETICAL BACKGROUND

A. Calculational Expressions

The statistical portion of the code includes angular-momentum and parity effects explicitly and generally follows the formalism of Uh1.9 In this section, we give a brief description of the expressions used in the calculation. Reference 9 should be consulted for more detail.

For the calculations of complex reactions involving several particles and compound nuclei, we assume that the reaction proceeds in stages with only one particle emitted at each step. Each newly formed intermediate nucleus, produced by particle decay of the previous compound nucleus, then disintegrates (if energetically possible) with probabilities determined from Hauser-Feshbach theory for binary reactions.1

The composition of nuclei involved in a calculation is as follows. At low excitation energies, discrete levels of energy $E$, total angular momentum $J$, and parity $\pi$ are included. Generally, experimentally determined values of $E$, $J^\pi$, and branching ratios are used for these levels. For higher excitation energies where discrete-level information may be lacking, a continuum level-density expression is used. For this purpose, the continuum region is divided into energy bins of width $\Delta E$.

The population of continuum bins $P(n+1)(UJ\pi)$ in the $(n+1)$th compound nucleus, formed by particle disintegration of the $n$th compound nucleus, is given by

$$P(n+1)(UJ\pi) = \int dU' \sum_{J'\pi'} P(n)(U'J'\pi') \frac{p_a(U'J'\pi',UJ\pi)}{\Gamma(U'J'\pi')} \rho(n+1)(UJ\pi), \quad (1)$$

where $P(n)(U'J'\pi')$ is the population of continuum energy bins in the $n$th compound nucleus after gamma-ray cascades have been considered, $U$ is the excitation energy, $\rho$ is the level density, and $a$ defines the type of radiation emitted by the $n$th compound nucleus to form the $(n+1)$th nucleus. The population of the first compound nucleus is determined from its formation cross section, which can be found

1
from the appropriate sum over transmission coefficients taken at the c.m. energy 
\[ \varepsilon \] of the incident particles,

\[ P^{(1)}(UJ'\pi') = \frac{\pi}{k^2} \frac{(2J + 1)}{(2I + 1)(2s + 1)} \sum_s \sum_\ell T_\ell(\varepsilon) f_\ell(u - B) \]  
(2)

Here \( k \) is the relative-motion wave number, \( I(\pi_T) \) and \( i(\pi_p) \) are the spins (parity) of the target nucleus and projectile, and \( J(\pi) \) is the total angular momentum (parity) of the compound system. The quantity \( f_\ell \) is a parity operator given by \( f_\ell = 1/2 [\pi + (-1)^\ell \pi_T \pi_p] \), \( T_\ell(\varepsilon) \) is the transmission coefficient having orbital angular momentum \( \ell \), \( s \) is the channel spin, and \( B \) is the binding energy of the incident particle in the compound nucleus. The partial decay widths used in Eq. (1) for reaction channel \( a \) have the general form

\[ \Gamma_a^{(n)}(U'J'\pi',UJ\pi) = \frac{1}{2\pi\rho(U'J'\pi')} \sum_s \sum_\ell T_\ell(U' - U - B_a)f_\ell \]  
(3)

for widths involving transitions from continuum bins in the compound nucleus to continuum bins in the residual nucleus. Here the parity operator \( f_\ell \) has the form \( f_\ell = 1/2 [\pi\pi' + (-1)^\ell \pi_a] \), where \( \pi_a \) is the parity of the emitted particle, and \( B_a \) is the binding energy of the emitted particle.

Similar expressions hold for the population of discrete levels:

\[ P^{(n+1)}(E_{\lambda},J_{\lambda},\pi_{\lambda}) = \int dU' \sum_{J'\pi'} P^{(n)}(U'J'\pi') \frac{\Gamma_a^{(n)}(U'J'\pi',E_{\lambda},J_{\lambda},\pi_{\lambda})}{\Gamma(U'J'\pi')} , \]  
(4)

where the partial width for continuum to discrete level transitions has the form

\[ \Gamma_a(U'J'\pi',E_{\lambda},J_{\lambda},\pi_{\lambda}) = \sum_s \sum_\ell T_\ell(U' - E_{\lambda} - B_a)f_\ell \]  
(5)

Here the sums are taken over channel spin \( s \) and orbital angular momentum \( \ell \).

The total width appearing in the denominators of Eqs. (1) and (4) is then the sum over continuum bins \( (UJn) \) or discrete levels \( (E_{\lambda},J_{\lambda},\pi_{\lambda}) \) of the appropriate partial width \( \Gamma_a(U'J'\pi',UJn) \) or \( \Gamma_a(U'J'\pi',E_{\lambda},J_{\lambda},\pi_{\lambda}) \) for each reaction channel \( a \).

For many calculations of interest, nonstatistical or preequilibrium effects become important; therefore, a simplified preequilibrium expression formulated by Braga-Marcuzzan \(^{10}\) and based upon the exciton model of Griffin \(^{11}\) and Blann \(^{12}\) has
been used to correct reaction and level-excitation cross sections as well as spectra for preequilibrium effects:

\[
\left( \frac{d\sigma}{dE} \right)_{\text{preq}} \propto \frac{\sigma_{\text{inv}}(E) \sigma_{\text{R}}}{|M|^2 \frac{4}{g \varepsilon^3}} \sum_{n=3}^{\bar{n}} (U/E)^{n-2} (n+1)^2 (n-1)
\]

In this expression \( E \) and \( U \) are the excitation energies of the compound and residual nuclei, respectively; \( \sigma_R \) is the incident-particle reaction cross section; \( m, \varepsilon, \) and \( \sigma_{\text{inv}}(E) \) are the mass, kinetic energy, and inverse cross section for the outgoing particle; \( g \) is the average single-particle level spacing from the Fermi-gas model; and \( n \) is the number of particles and holes \( (n = p + h) \) in the compound nucleus. The sum extends from the initial exciton number 3 to \( \bar{n} \), the limiting value attained when equilibrium is reached.

We assumed that the absolute square of the average matrix element of residual two-body interactions had the form \( |M|^2 = KA^{-3}E^{-1} \) (\( A \) is the mass of the nucleus involved), determined by Kalbach-Cline. \(^{13}\) The normalization constant \( K \) was obtained from fits to various sets of data, including both spectra and integrated cross sections (for example, see Refs. 14 and 15). The code evaluates the normalization factor using the expression

\[
\alpha = \frac{|M|^2 g^4}{A}
\]

We determined the value of \( \alpha \) for neutron- and proton-induced reactions to be 0.0005 \( \pm \) 0.0001, in agreement with the Braga-Marcuzzan value of 0.00045. \(^{10}\) Our result corresponds to \( K = 150 \pm 30 \text{ MeV}^3 \), which can be compared to the value of 100 \( \pm \) 35 \text{ MeV}^3 obtained by Kalbach-Cline. \(^{13}\) To provide flexibility in the code for calculation of preequilibrium emission, we made the normalization factor dependent on the type of particle emitted. Thus, effects such as the possible existence of preformed particles can be included. When the outgoing particles are neutrons and protons, the \( \alpha \) values are known fairly reliably, but those for outgoing alphas are less accurately known. Because of the lack of experimental data on \( d, t, \) and \( ^3\text{He} \) emission, even more uncertainty in \( \alpha \) exists for these.

The total preequilibrium component, obtained by summing over each outgoing particle channel involved in the decay of the first compound nucleus, then determines a fraction by which the total compound-nucleus reaction cross section is reduced. Because the preequilibrium model used in the code does not include effects of spin and parity, we assumed that the preequilibrium component had the same spin and parity distribution as the statistical population component.
B. Supplemental Quantities: Transmission Coefficients and Level Densities

To provide particle transmission coefficients, external optical model routines or codes must be used. GNASH accepts transmission coefficients in the COMNUC\textsuperscript{16} form (see Sec. V) as a function of total angular momentum $J$ and converts them to $T_{\lambda}$ using the expression

$$T_{\lambda}(\epsilon) = \frac{1}{(2\lambda + 1)} \left[ (\lambda + 1)T_{\lambda,\lambda+s} + \lambda T_{\lambda,\lambda-s} \right]. \quad (8)$$

To provide gamma-ray transmission coefficients, either the Weisskopf approximation\textsuperscript{17} or the Brink-Axel giant dipole resonance form can be used. Specifically, the Weisskopf approximation for $E_1$ transitions yields

$$T_{E_1}^{E_1}(U,U') = C_{W}^{E_1} E_3^3, \quad (9)$$

whereas the Brink-Axel form gives

$$T_{E_1}^{E_1}(U,U') = C_{BA}^{E_1} \frac{2}{\hbar^2 c E_\gamma} \frac{E_2^2}{\gamma} \frac{0.013A}{\Gamma} \frac{E_R^2 - E_\gamma^2}{(E_R^2 - E_\gamma^2)^2 + E_\gamma^2}, \quad (10)$$

Here $E_\gamma = U - U'$, $\Gamma$ is the giant dipole resonance width ($\Gamma = 5 \text{ MeV}$), and $E_R$, the resonance energy in millions of electron volts, is given by $E_R = 80A^{-1/3}$. The normalization constants $C_{W}^{E_1}$ and $C_{BA}^{E_1}$ are obtained from the ratio of the average experimental gamma-ray width $\langle T_{\gamma} \rangle$ to the observed resonance spacing $\langle D \rangle$ for $s$-wave neutrons through evaluation of the expression (at the neutron binding energy $E_B$)

$$\left( \frac{\langle T_{\gamma} \rangle}{\langle D \rangle} \right)_{E_B} = \frac{1}{2\pi} \int_{0}^{E_B} \sum_{\lambda,J'} T_{E_1}^{E_1}(B_n,U') \rho(U'J'\pi') dU', \quad (11)$$

where $T_{E_1}$ is computed using either the Weisskopf or Brink-Axel forms.

In the code, gamma-ray cascades through $E_2$, $E_3$, $M_1$, $M_2$, and $M_3$ transitions are permitted also. Transmission coefficients for these are computed using the Weisskopf form ($\approx C_{W}^{E_2}$), and the ratios $C^{E_1}/C^{E_1}$, $C^{E_3}/C^{E_1}$, $\ldots$, $C^{M_3}/C^{E_1}$ are determined from the Weisskopf estimate\textsuperscript{17} or are input directly during setup of the calculation.
The level-density expressions are those of Gilbert and Cameron \textsuperscript{20} with the pairing and shell parameters of Cook. \textsuperscript{21} A Fermi-gas level-density form is used at higher excitation energies,

\[
\rho(E,J) = \frac{\sqrt{\pi}}{24} \frac{\exp \left( 2 \sqrt{aU} \right)}{a^{1/4}U^{5/4}} \frac{(2J + 1) \exp \left[ -\frac{(J + 1/2)^2}{2a^2} \right]}{2 \sqrt{2\pi} \sigma^3}
\]

and is matched to a constant temperature expression used for lower excitation energies,

\[
\rho(E,J) = \frac{1}{2T} \exp \left[ \frac{(E - E_0)}{T} \right] \frac{(2J + 1) \exp \left[ -\frac{(J + 1/2)^2}{2\sigma^2} \right]}{2 \sqrt{2\pi} \sigma^3}
\]

The definitions for the quantities in Eqs. (12) and (13) are given in Ref. 20 and will not be repeated here. The experimentally determined number of levels up to a particular excitation energy are used (where possible) to determine parameters for the constant-temperature expression so that a good match is made. The level-density parameter \(a\) is either input directly into calculations or determined using the Gilbert-Cameron prescription

\[
a/A = 0.00917 \left[ S(Z) + S(N) \right] + C
\]

where \(S(Z)\) and \(S(N)\) are shell effect terms \textsuperscript{21} and \(C\), a correction term, depends on whether the nucleus is deformed \((C = 0.120)\) or spherical \((C = 0.142)\). \textsuperscript{20}

\section*{III. CODE SUBROUTINES}

To explain the workings of the GNASI code and to aid in its use, a short description of its subroutines is given here. The code listing is in Appendix A.

\textbf{MAIN} - The main control routine of the program. It reads in data describing incident-particle and target types, problem and decay chains involved, etc. (see Sec. IV), and calls subroutines LEVREP, TCPREP, and SETUP for initial problem setup. At each energy for which a calculation occurs, SETUP2 and SPECTRA are called. After the calculation, DATAOUT is called to provide a summary of the results.

\textbf{LCSPACE} - Sets up extended-core-storage (ECS) locations, zeroes extended-core locations, determines parent reactions, and creates population-storage buffers.

\textbf{CHAINS} - Called if automatic setup of chains is desired.
ENERGY - Determines masses, separation energies, and ground-state spins and parities from the GROUND2 data file (Appendix B).

XMAGIC - Determines whether a nucleus is "odd" or "even," according to the Gilbert-Cameron level-density prescription.

LEVPREP - Prepares a binary level-data file ordered properly for the calculation from an input binary-coded decimal (BCD) level file or cards. Stores Jπ data in extended-core arrays.

TCPREP - Reads in transmission-coefficient data, eliminates J-dependence of spin 1/2 arrays, reorders spin 0 and spin 1 arrays, determines the number of nonzero coefficients, and stores transmission-coefficient data in ECS.

SETUP - Provides general setup information by determining accumulated separation energies for the decaying nuclei, identifies incident particle as well as secondary particles and photons, determines whether a residual nucleus is even or odd, sets up Jπ arrays, and initializes level densities and Gilbert-Cameron level-density parameters.

SETUP2 - Provides setup information for each incident energy in a calculation. Sets up energies, determines integration end points, and generates incident-channel transmission coefficients.

SPECTRA - The main subroutine of the program in which the widths (total and partial) and population increments used to compute the spectra are calculated for all compound nuclei and decay reactions occurring in a specified decay chain. Figure 3 illustrates the treatment of the decay sequence in which gamma rays and particles may be emitted from one or several compound nuclei. Through several nested DO loops, the entire reaction sequence is handled. The outermost loop sums over decaying compound nuclei involved in the reaction sequence. The second loop sums over energy bins in the decaying compound nucleus. The third loop provides flags that indicate whether total decay widths should be calculated (first execution) or whether populations of continuum-continuum or continuum-level transitions should be calculated (second execution). A fourth loop sums over reaction types occurring in the decay of a continuum bin in the compound nucleus. Thus, all decays (either gamma-ray or particle) are handled in the same manner. The decays to continuum bins or discrete levels in a particular residual nucleus are then obtained from sums over the fifth loop. If preequilibrium effects are to be included, PRECMP is called to modify the continuum and level populations computed above. The GRLINES subroutine is then called to compute discrete gamma-ray cross sections and to add these cross sections to the computed gamma-ray spectra.

LEVDS - Provides pairing and shell corrections from the tables of Cook et al. to be used in the computation of level densities using the Gilbert-Cameron Fermi-gas level-density expression. Calls GILCAM to provide information for the Gilbert-Cameron constant-temperature level-density expression.

GILCAM - Where possible, computes energy matching parameters for the Gilbert-Cameron constant-temperature expression using input data that describe the number of levels present up to a given excitation energy.
A. Loop over all decaying nuclei

B. Loop over energy bins \( \psi(U'J'\pi') \)
   compound nucleus \( I \)

C. Width-summing loop
   \[
   \begin{cases}
   M = 1 + \Gamma_{\text{tot}} \\
   M = 2 + P
   \end{cases}
   \]

D. Loop over decay reaction types

E1. Loop over continuum bins \( \psi'(U'J'\pi') \)
    of residual nucleus \( I' \)
   \[
   \begin{align*}
   M = 1 & \quad \text{compute} \\
   \Gamma_{\text{tot}}(I,\psi) &= \Gamma_{\text{tot}}(I,\psi) + \Gamma(I,\psi;I'\psi')\rho(I'\psi')\Delta E \\
   M = 2 & \quad \text{compute} \\
   DP &= \Gamma(I,\psi;I'\psi')\rho(I'\psi')P(I\psi)\Delta E/\Gamma_{\text{tot}}(I\psi) \\
   P(I'\psi') &= P(I'\psi') + DP
   \end{align*}
   \]

E2. Loop over residual-nucleus discrete levels \( \psi'(E'I'\pi') \)
   \[
   \begin{align*}
   M = 1 & \quad \text{compute} \\
   \Gamma_{\text{tot}}(I,\psi) &= \Gamma_{\text{tot}}(I,\psi) + \Gamma(I,\psi;I'\psi') \\
   M = 2 & \quad \text{compute} \\
   PL(I'\psi') &= PL(I'\psi') + \Gamma(I,\psi;I'\psi')P(I\psi)/\Gamma_{\text{tot}}(I\psi)
   \end{align*}
   \]

Close D loop

Close B and C loops

Close A loop

Fig. 3.
Schematic flow diagram for the SPECTRA subroutine.
LCMLOAD - Computes transmission coefficients, level-density values, and Yrast values on an integration energy mesh for each nucleus involved in a particular segment of the decay chain.

GAMSET - Sets up the gamma-ray cascade calculation, determines Weisskopf or Brink-Axel parameters, and computes gamma-ray transmission coefficients.

WEISSKF - Normalizes Weisskopf or Brink-Axel gamma-ray strength expressions to the input values of \((2n\langle I'\rangle)/\langle D\rangle\) determined from s-wave neutron resonance data.

INCHSUM - Performs sums over s and \(\ell\) of the incident channel for a given compound nucleus spin and parity.

SUMER - Adds computed population increase into spectra and level-population arrays.

GRLINES - Computes discrete gamma-ray cross sections; sums spectra to obtain integrated cross sections.

DATAOUT - Main output subroutine. Depending on which print options are selected, widths, individual and composite spectra, cross sections, discrete levels, gamma-ray data, and level-density parameters can be printed.

ISERCH - Determines the parameters necessary for the interpolation routine.

PRECMP - Determines preequilibrium contribution, renormalizes compound-nucleus cross sections, adds preequilibrium contribution into calculated particle spectra, and modifies continuum and level populations to account for preequilibrium effects.

INTERP - Main interpolation routine.

IV. MAIN CODE INPUT PARAMETERS

We attempted to keep the GNASH input as simple as possible. Thus all masses, separation energies, and ground-state spins and parities are taken from a data file (GROUND2, listed in Appendix B), which accompanies the program. The masses in the file are either the 1971 adjusted experimental values of Wapstra,22 or interpolated or extrapolated values from fits to the measured masses using the semi-empirical relations of Garvey et al.23 The ground-state spins and parities are based on experimental measurements.24 If \(J\) or \(\pi\) is unknown, a value of 99 appears in the file. Unknown spins and parities are flagged during execution, and \(J^\pi = 0^+\) (even \(A\)) or \(J^\pi = 1/2^+\) (odd \(A\)) is used in the actual calculation.

The input parameters required for the main GNASH code are described in Table I, and a sample input is given in Appendix C. The following sequence of input data cards is used:
(A) (2 cards) FORMAT (8A10): TITLE(N), N = 1, 16
(B) (1 card) FORMAT (5I4): IPRTLEV, IPRTTC, IPRTWID, IPRTSP, IPRTGC
(C) (1 card) FORMAT (5I4): INPOPT, KLIN, KTIN, NIBD, LMAXOPT
(D) (1 card) FORMAT (6I4): NI, NMP, LGROPT, LPEQ, NJMAX, ICAPT
(E) (1 card) FORMAT (4E10.3): ZAP, ZAT, DE, FSIGCN
(F) (1 card) FORMAT (1I4): NELAB
(G) (1-3 cards) FORMAT (8E10.3): ELABS(N), N = 1, NELAB
(H) (0-70 cards) Reaction-chain data. The form and complexity of this segment
depends on the particular input option chosen, as follows:

1) INPOPT = 1, 2, or 3 (0 cards)
   Reaction chains are set up automatically.

2) INPOPT = -1 (1-10 cards) (DO loop I = 1, NI)
   FORMAT (8E10.3): ZACN(I), XNIP(I), SWS(I), [ZZA1(IP),
   IP = 2, NIP]

3) INPOPT = 0 (2-70 cards)
   (a) Outer DO loop I = 1, NI
   (1 card per I) FORMAT (5E10.3): ZACN(I), XNIP(I),
   CNPI(I), CNPI(P), SWS(I)
   (b) Inner DO loop IP = 1, NIP
   (1-6 cards per I) FORMAT (5E10.3): ZA1(IR), XNL(IR),
   A(IR), XNLGC(IR), ECGC(IR), where IR is a running re-
   action index that defines a unique I, IP for each re-
   action sequence.

(I) (1-6 cards) (DO loop MP = 1, NMP)
   FORMAT (8X, A1, I1, E10.3): LMGHOL(MP), LG, RE1(MP)

(J) (0-1 cards) Input depends on LPEQ parameter, as follows:

1) LPEQ = 0 (0 cards)

2) LPEQ = 1 (1 card)
   FORMAT (6E10.3): [ALPHA1(IDX), IDX = 1, 6]

TABLE I

MAIN INPUT PARAMETERS FOR GNASH

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE</td>
<td>Two cards of Hollerith information to describe the problem being calculated.</td>
</tr>
<tr>
<td>IPRTLEV</td>
<td>Print control for discrete-level data. Set IPRTLEV = 0(1) to omit (include) print of discrete-level information.</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td>IPRTTC</td>
<td>Print control for transmission coefficients. Set IPRTTC = 0(1) to omit (include) print of input transmission coefficients. Set IPRTTC &gt; 1 to print input values and interpolated transmission coefficients at every (IPRTTC-1)th energy on the basic integration energy mesh.</td>
</tr>
<tr>
<td>IPRTWID</td>
<td>Print control for reaction decay widths. Set IPRTWID = 0(1) to omit (include) print of decay widths for each reaction channel on the basic integration energy mesh.</td>
</tr>
<tr>
<td>IPRTSP</td>
<td>Print control for calculated energy spectra, as follows: IPRTSP = 0 to omit print of all calculated energy spectra. = 1 to only print composite spectra for each radiation type in the calculation, that is, composite spectra for emitted gamma rays, neutrons, protons, etc. = 2 to print individual spectra from each decay process included in the calculation, omitting the composite spectra. = 3 to print both individual reaction and composite spectra.</td>
</tr>
<tr>
<td>IPRTGC</td>
<td>Print control for level-density information. Set IPRTGC = 0(1) to omit (include) print of level-density parameters for each residual nucleus in the calculation. Set IPRTGC &gt; 1 to print parameters and computed level densities at every (IPRTGC-1)th energy on the basic integration energy mesh for each residual nucleus.</td>
</tr>
<tr>
<td>INPOPT</td>
<td>Input control for designating the input option chosen to specify the reaction chains followed in the calculation. The following options are available: INPOPT = 0 is the most general input option available for specifying the reaction chains and the various parameters associated with each chain. For example, it permits (but does not require) input of level-density parameters for each residual nucleus in a calculation. See description of card input for details of reaction-chain input. = -1 also permits general specification of reaction chains but uses automatic features to simplify input. With this option, the code uses a built-in level-density parameterization and automatically determines parentage of each decaying compound nucleus by assuming that all previous, unassigned reactions leading to a given compound nucleus contribute to its initial population of states.</td>
</tr>
</tbody>
</table>
TABLE I (cont)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>KLIN</td>
<td>Input fileset for discrete energy-level data (= 5 for card input, = blank or 8 for input on disk or tape file 8).</td>
</tr>
<tr>
<td>KTIN</td>
<td>Input fileset for transmission-coefficient data (= 5 for card input, = blank or 10 for input on disk or tape file 10).</td>
</tr>
<tr>
<td>NIBD</td>
<td>Number of large-core buffers set up for storing state populations in reaction products that will further decay. The default value for NIBD is 10, which is also the maximum dimension.</td>
</tr>
<tr>
<td>LMAXOPT</td>
<td>Control for limiting the number of transmission coefficients ( T^j_0 ) included in a calculation by requiring that ( (2\ell + 1)T &gt; T^j_0 \times 10^{-</td>
</tr>
<tr>
<td>NI</td>
<td>Number of compound nuclei that are permitted to decay in the reaction chain (maximum of 10).</td>
</tr>
<tr>
<td>NMP</td>
<td>Number of gamma-ray multipolarities permitted in radiative decays (maximum of 6).</td>
</tr>
<tr>
<td>LGROPT</td>
<td>Control for indicating the model desired for calculating gamma-ray transition probabilities, as follows: [ LGROPT = 1 \quad \text{for the Weisskopf approximation.} ] [ = 2 \quad \text{for the Brink-Axel approximation.} ]</td>
</tr>
<tr>
<td>LPEQ</td>
<td>Preequilibrium control. Set LPEQ = 0(1) to omit (include) preequilibrium processes in the calculation.</td>
</tr>
<tr>
<td>NJMAX</td>
<td>Maximum number of values of total angular momentum permitted in the calculation (dimensioned for 40, which is also the default value). For even-A cases, ( J_{\text{max}} = NJMAX - 1 ); for odd-A cases, ( J_{\text{max}} = (2 \times NJMAX - 1)/2 ).</td>
</tr>
<tr>
<td>Parameter</td>
<td>Description</td>
</tr>
<tr>
<td>-----------</td>
<td>-------------</td>
</tr>
<tr>
<td>ICAPT</td>
<td>Gamma-ray cascade control for initial compound nucleus: ICAPT = 0 to omit full gamma-ray cascade calculation in the initial compound nucleus (all subsequent compound nuclei do include the full cascade). ICAPT = 1 to include the full gamma-ray cascade in calculation in all compound nuclei.</td>
</tr>
<tr>
<td>ZAP</td>
<td>1000 * Z + A for the incident particle or projectile, where Z is atomic number and A is the (integer) mass number.</td>
</tr>
<tr>
<td>ZAT</td>
<td>1000 * Z + A for the target nucleus.</td>
</tr>
<tr>
<td>DE</td>
<td>Energy increment for the basic integration energy mesh (in millions of electron volts). A maximum of 200 energy steps is permitted. If the chosen value of DE is too small, the code automatically increases it to satisfy the 200-step limit.</td>
</tr>
<tr>
<td>FGSICGN</td>
<td>Constant multiplier applied to all calculated quantities (default value is 1.0).</td>
</tr>
<tr>
<td>NELAB</td>
<td>Number of incident neutron energies included in the calculation (maximum of 20).</td>
</tr>
<tr>
<td>ELABS(N)</td>
<td>Incident particle energies in millions of electron volts for the calculation.</td>
</tr>
<tr>
<td>ZACN(I)</td>
<td>1000 * Z + A for each compound nucleus that is permitted to decay (I is the index that specifies the decaying compound nucleus.)</td>
</tr>
<tr>
<td>XNIP(I)</td>
<td>Number of decay channels included for compound nucleus ZACN(I). The minimum value is 1., and the maximum is 6. The fixed-point value of XNIP(I) is NIP in the code, and the decay index IP runs from IP = 1 to NIP for each compound nucleus.</td>
</tr>
<tr>
<td>SWS(I)</td>
<td>Value of the gamma-ray strength function for s-wave neutrons, 2π&lt;Γν&gt;/&lt;D&gt;, that is used to normalize the gamma-ray transition probabilities. A negative value of SWS can be used to directly input a normalization factor of</td>
</tr>
<tr>
<td>ZZA1(IP)</td>
<td>1000 * Z + A for the radiation emitted from ZACN(I) by decay into channel IP. Note that ZZA1(1) = 0. (gamma ray) is assumed in all cases. Other possible values are 1., 1001., 1002., 1003., 2003., and 2004. (maximum of IP = 6).</td>
</tr>
<tr>
<td>CNPI(I)</td>
<td>Parentage designator that indicates the previous compound nucleus index IP whose decay leads to the formation of ZACN(I).</td>
</tr>
</tbody>
</table>
TABLE I (cont)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNPIP(I)</td>
<td>Parentage designator that indicates the previous decay index IP that leads to the formation of ZACN(I).</td>
</tr>
<tr>
<td>ZA1(IR)</td>
<td>Same as ZZA1(IP) described above. Note that the running reaction index IR defines a unique I, IP for each reaction sequence.</td>
</tr>
<tr>
<td>XNL(IR)</td>
<td>Number of discrete levels to be included in the calculation for the residual nucleus formed in reaction IR. If XNL(IR) = 0., then the total number of levels input in the Level-Data File (described in Sec. V) is used.</td>
</tr>
<tr>
<td>A(IR)</td>
<td>Level-density parameter, a, for use in the Gilbert-Cameron (^{20}) formula for the residual nucleus formed by reaction IR. Set A(IR) = 0. to use built-in values [see Eq. (14)].</td>
</tr>
<tr>
<td>XNLGC(IR) and ECGC(IR)</td>
<td>Number of discrete levels, XNLGC(IR), at excitation energy ECGC(IR) that are matched in the code to the Gilbert-Cameron formula for the continuum level density. If both these parameters are set equal to 0., then the total number of levels input in the Level-Data File is used.</td>
</tr>
<tr>
<td>LMGHOL(MP)</td>
<td>Hollerith E or M to designate the MPth radiative transition as electric or magnetic.</td>
</tr>
<tr>
<td>LG</td>
<td>Multipole order of the MPth transition.</td>
</tr>
<tr>
<td>REl(MP)</td>
<td>Ratio of the strength of the MPth transition to the strength of the El transition. Set REl(MP) = 0. to use a built-in value.</td>
</tr>
<tr>
<td>ALPHA1(IDX)</td>
<td>Preequilibrium normalization constants [see Eq. (7)] for reactions involving emitted neutrons, protons, deuterons, tritons, (^3)He, and (^4)He for IDX = 1 through 6, respectively. Set ALPHA1(IDX) = 0. to use the built-in values.</td>
</tr>
</tbody>
</table>

V. ADDITIONAL INPUT PARAMETERS

A. Discrete-Level Data

Following the main input, a separate subroutine (LEVPREP) is called to input discrete-level data. These data can either be selected from a general data file on disk or magnetic tape (KLIN = 8) or they can be input directly on cards for the cases required (KLin = 5). In either case, the overall ordering of the information must be for increasing ZA (1000Z + A). The discrete-level input parameters are described in Table II, and input for the sample problem of Appendix C is given in the first part of Appendix D (pp. D-1 through D-5). The following
sequence of cards (or card images) is required for each residual nucleus requiring level data:

(A) (1 card) FORMAT (I8, I5, F12.6): ID, NL, F

(B) Outer loop on levels (DO loop \( N = 1, NL \))

```
FORMAT (I6, F12.6, 2F6.1, E12.5, I6): NX, EL(N), AJ(N), AT(N), TAU, NT
```

(C) Inner loop for each level (DO loop \( K = 1, NT \))

```
FORMAT (12X, I6, 2F12.6): NF, P, CP
```

TABLE II

**DISCRETE-LEVEL INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ID</td>
<td>1000 * Z + A of the nucleus whose levels are being input.</td>
</tr>
<tr>
<td>NL</td>
<td>Number of levels being input.</td>
</tr>
<tr>
<td>F</td>
<td>For card input, set ( F = -1 ) for the last nucleus (highest ID) for which level data is input. Otherwise, set ( F = 0 ).</td>
</tr>
<tr>
<td>NX</td>
<td>Level number (= N), that is, N = 1 for the ground state, N = 2 for the first excited state, etc.</td>
</tr>
<tr>
<td>EL(N)</td>
<td>Energy in million electron volts of the Nth level; that is, EL(1) = 0.</td>
</tr>
<tr>
<td>AJ(N)</td>
<td>Spin and parity of the Nth level. The sign of AJ(N) indicates the parity. For example, -0. is interpreted as a ( J^P = 0^- ) state.</td>
</tr>
<tr>
<td>AT(N)</td>
<td>Isospin of the Nth level (if unknown, it is set equal to 99.0). AT(N) is not used in the calculation at present.</td>
</tr>
<tr>
<td>TAU</td>
<td>Half-life of the state in seconds (if unknown, it is set equal to 99.0 or 0.0). TAU is not used in the calculation.</td>
</tr>
<tr>
<td>NT</td>
<td>Number of gamma-ray branches from the Nth level to lower levels.</td>
</tr>
<tr>
<td>NF</td>
<td>Level number indicator for a level to which a gamma-ray transition is occurring.</td>
</tr>
<tr>
<td>P</td>
<td>Gamma-ray branching ratio for the transition defined by ( N \rightarrow NF ). For bound states, ( \sum P(N \rightarrow NF) = 1 ). For unbound states, ( \sum P(N \rightarrow NF) ) = the total probability for decays other than particle emission.</td>
</tr>
<tr>
<td>CP</td>
<td>Probability that the transitions characterized by ( P(N \rightarrow NF) ) are gamma-ray transitions. If, for example, there is a 20% probability that electron conversion is the decay mechanism, then ( CP = 0.80 ).</td>
</tr>
</tbody>
</table>
### TABLE III

**TRANSMISSION-COEFFICIENT INPUT PARAMETERS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPART</td>
<td>Number of particles for which transmission coefficients are input.</td>
</tr>
<tr>
<td>BCDTC(8)</td>
<td>Seventy-five columns of Hollerith descriptive information.</td>
</tr>
<tr>
<td>XBCD</td>
<td>Alphanumeric particle identifiers, as follows: _NEUTRON, _PROTON, _DEUTERON, _TRITON, _HE-3, _ALPHA; that is, a blank column precedes each identifier.</td>
</tr>
<tr>
<td>NE</td>
<td>Number of energies included in energy grid for transmission coefficients.</td>
</tr>
<tr>
<td>NN</td>
<td>Number of coefficients input at each energy in the COMNUC format.</td>
</tr>
<tr>
<td>K</td>
<td>Optional card counter. Can be used to check ordering of cards.</td>
</tr>
<tr>
<td>ETC(J,ID)</td>
<td>Energy grid for transmission coefficients. The index J specifies the energy and ID is an internal identifier that specifies the particle.</td>
</tr>
<tr>
<td>TDUM(L)</td>
<td>Transmission-coefficient array. The index L runs from 1 to NN for each energy on the grid. The coefficients are collapsed to remove J-dependence and are stored as functions of energy for each particle.</td>
</tr>
</tbody>
</table>

### B. Transmission Coefficients

Transmission coefficients for the projectile and outgoing particles are input in the subroutine TCPREP, following the discrete-level data input. Again, these data can be provided on a disk or magnetic tape file (KTIN = 10), or directly from cards (KTIN = 5). We have adopted the format used by COMNUC\textsuperscript{16} for transmission coefficients, and data for the various particles can be input in any order. The input parameters are described in Table III, and transmission coefficients for the sample problem follows the level data in Appendix D (pp. D-6 through D-14). The following sequences of cards (or card images) is required:

(A) (1 card) FORMAT (14, 1X, 7A10, A5): NPART, [BCDTC(I), I = 1, 8]

(B) Outer loop on particles (DO loop N = 1, NPART)

(1 card per N loop) FORMAT (42X, A10, 12X, 2I4, A8): XBCD, NE, NN, K
VI. CODE OUTPUT

The code output from the sample problem described in Appendixes C and D is given in Appendix E. The amount of detail included in the output depends upon the values of the parameters IPRTLEV, IPRTTC, IPRTWID, IPRTSP, and IPRTGC, described in Table I. The problem output, the result of a typical setup used at the Los Alamos Scientific Laboratory, consists essentially of six parts:

1. Input data (pp. E-1 and E-2), including the parentage indicators, masses (XMR), separation energies (S), and buffering information automatically determined by the code. Note that the number of discrete levels (NLEV) and the level-density parameters (A, NLGC, and ECGC) have not been determined yet unless they were input directly into the calculation. Also note in the column at the far right that the number of population-storage buffers is the minimum possible (4) for this particular calculation. Buffer No. 1 is reused in the decay of the ZA = 27059 nucleus for storage of the ZA = 27058 level populations. The buffer numbers set to zero indicate residual nuclei that are not allowed to further decay in the calculation.

2. Timing information (p. E-3), printed as the code progresses through the main computer loops in subroutine SPECTRA, and normalization constants for the gamma-ray transition strengths (input directly in the example).


4. Calculated cross sections, average energies, and secondary spectra of emitted radiation from individual reactions (pp. E-5 and E-6) and composite spectra for the various species of emitted radiation (p. E-7). Cross sections for reactions to discrete states, and gamma rays from de-excitation of excited states are included in the spectral listings. Above each spectral column appear the integrated level decay, level excitation, and total production cross sections and average emitted energy for the particular reaction. Multiparticle cross sections such as $\sigma_{n,2n}$ and $\sigma_{n,np}$ can be deduced from the integrated cross sections. The energies associated with the emission spectra are midpoint values from the integration energy bins. Both the spectral energies and cross sections are given in the c.m. system of the recoiling nucleus plus particle or gamma ray. For medium or heavy mass nuclei, the c.m.–to–laboratory transformation factors are essentially unity.

5. Discrete-level excitation and gamma-ray de-excitation cross sections (pp. E-8 through E-15). The gamma-ray de-excitation cross sections only appear
for the decaying compound nuclei and in those cases the level and gamma-ray production cross sections include cascade effects.

(6) Summary of the parameters used in the Gilbert-Cameron level-density formulas (p. E-12). The quantities $E_0$ [Eq. (13)] and $E_{\text{MATCH}}$ [energy where Eqs. (12) and (13) are matched] are determined from the number of discrete levels at excitation energy $E_{\text{CUT}}$ and the level-density parameter $a$. The neutron and proton pairing corrections ($P_N$ and $P_Z$) and shell corrections ($S_N$ and $S_Z$) are listed, together with the neutron-separation energies (S) for each residual nucleus. The quantity $S_{\text{AC}}$ is the "accumulated separation energy," that is, the energy of each decaying compound nucleus relative to the first compound nucleus.

VII. DISCUSSION

The transmission coefficients given in Appendix D, which were used for the sample problem, were calculated from the Wilmore-Hodgson\textsuperscript{25} global optical parameters for neutrons, the Bechetti-Greenlees\textsuperscript{26} parameters for protons, and the Igo\textsuperscript{27} parameters for alphas. The gamma-ray strength normalizations, which were input directly for the sample problem, were originally determined by normalizing the calculations for each compound nucleus to values of $2\pi\langle T^\gamma \rangle/\langle D \rangle$ of approximately $25 \times 10^{-4}$ for the Co isotopes and $2 \times 10^{-3}$ and $3 \times 10^{-4}$ for $^{56}\text{Mn}$ and $^{59}\text{Fe}$. Note that the sample problem results are for illustrative purposes only. A tighter integration mesh and more careful selection of model parameters would be advisable for a serious calculation. Additional examples of $n + ^{59}\text{Co}$ reaction cross-section calculations are compared to experimental data in Figs. 4-7. These results were obtained with the global optical parameters described above, but with a tighter integration mesh in GNASH than the one in our sample problem.

Thus far the validation of the GNASH code\textsuperscript{2-8} has been for incident neutrons or protons with energies mainly below 25 MeV. At energies above 25-30 MeV, the binary reactions are dominated by the preequilibrium component, and calculations become increasingly sensitive to the accuracy of that approximation. At incident energies below $\sim$100 keV, use of GNASH becomes inefficient because of restrictions on the integration step size. Caution should also be exercised in using global parameter sets for generating transmission coefficients; we think the discrepancy between calculated and measured values of the $^{59}\text{Co}(n,\alpha)$ cross section in Fig. 6 resulted in part from inadequate optical parameters for alpha particles.

For complicated reaction sequences or higher energy calculations, computational times can be excessive. Because computational times are very problem dependent, the following parameters, which are most important in determining the
Comparison of calculated nonelastic and inelastic neutron cross sections for $^{59}\text{Co}$ with various experimental data. The solid curves represent the GNASH calculations.

Fig. 5.
Calculated and measured values of the $^{59}\text{Co}(n,p)$ cross section. The solid curve represents the GNASH calculations.

Fig. 6.
Calculated and measured values of the $^{59}\text{Co}(n,\alpha)$ cross section. The solid curve represents the GNASH calculations.
times, should be chosen carefully: energy-bin width (DE), the maximum number of total angular momentum states in the compound nucleus (NJMAX), the criteria for limiting the number of transmission coefficients (LMAXOPT), and the number of decaying nuclei (NI) in the calculation. In addition, the gamma-ray cascade calculation for the initial compound nucleus should always be turned off (ICAPT = 0) unless the spectrum of capture gamma rays is specifically required. A summary of running times for n + $^{59}$Co calculations to 40 MeV using the reaction chain of Fig. 2 is shown in Fig. 8. For these calculations, the following parameters were used: DE = 1 MeV, NJMAX = 40, NI = 5, and ICAPT = 0. When they were performed, the option for limiting the number of transmission coefficients had not yet been implemented, so in effect the results were obtained with LMAXOPT = 15. The times given in Fig. 8 can therefore be significantly reduced (~35%) without accuracy loss by using the LMAXOPT parameter.

ACKNOWLEDGMENT

The authors wish to thank D. G. Foster, Jr., for providing the data file that contains ground-state masses, separation energies, spins, and parities.

Fig. 7. Calculated and measured (n,2n) and (n,3n) cross sections for $^{59}$Co. The solid curves represent the GNASH calculations; the triangles indicate the (n,3n) measurements.

Fig. 8. CDC 7600 central-processor time for GNASH calculations of n + $^{59}$Co reactions out to 40 MeV. These times can be further reduced by careful limitation of the maximum order of transmission coefficients used in the calculation. See text for details.
REFERENCES


14. D. Hermsdorf, A. Meister, S. Sassonoff, D. Seeliger, K. Seidel, and F. Shahin, "Differenzielle Neutronenemissionsquerschnitte $\sigma_{M M}^{E_0, E, 0}$ bei 14,6 MeV Einschußenergie für die Elemente Be, C, Na, Mg, Al, Si, P, S, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Se, Br, Zr, Nb, Cd, In, Sn, Sb, I, Ta, W, Au, Hg, Pb, und Bi," Zentralinstitut für Kernforschung Rossendorf Bie Dresden ZFK-277 (1974).


APPENDIX A

PROGRAM LISTING

 gamma-ray, neutron, and assorted spectra from heavy nuclei

input level data if cards not used

input transmission coefficients if cards not used

level scratch file = available for punch or disc o/p

input ground-state excess, spin, and parity

input width print

input spectra print

input transmission coefficients only

input individual spectra only

input composite and individual spectra

input transmission coefficients at every output level data file (KL)

input transmission coefficients if cards not used

input internal binary level data file (KL)

input transmission coefficients at every output level data file (KL)

input level data print

input transmission coefficients at every output level data file (KL)

on the basic integration energy mesh

input level density parameters

input gamma ray transition probabilities

input unnormalized gamma ray transition probabilities

input manually read in reaction chains but code automatically main

assigns parentage, CNI(1) AND CNI(2) are assumed to be main

all unassigned higher reactions that produce ZACN(I) main

input manually I/P reaction chains and parentage indicators main

automatically follow neutron chain with G,N,DECAYS main

automatically follow neutron chain with G,N,P,A DECAYS main

and pick up gammas from P and A DECAYS main

SWS(I) = * TO normalize S-WAVE STRENGTH TO SWS(I) main

SWS(I) = * TO use unnormalized gamma ray transition probabilities main

ABS(SWS(I))

2 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

3 FORMAT(*13H8,13H,8X,5HMEV,F7.3)

4 3TO*57*130

5 3TO*57*130

6 3TO*57*130

7 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

8 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

9 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

10 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

11 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

12 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

13 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

14 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

15 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

16 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

17 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

18 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

19 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

20 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

21 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

22 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

23 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

24 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

25 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

26 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

27 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

28 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

29 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

30 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

31 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

32 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

33 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

34 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

35 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

36 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

37 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

38 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

39 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

40 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

41 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

42 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

43 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

44 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

45 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

46 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

47 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

48 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

49 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

50 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

51 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

52 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

53 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

54 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

55 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

56 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

57 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

58 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

59 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)

60 FORMAT(*13H8,13H,8X,5HDE,F7.3,3X,15HMEV,F7.3)
TAPE 12 = BUFFER INPUT

WRITE(6,32)
FORMAT(1H1)
READ(KI,33) ZINPU
IF(EOF,KI) 300,301
WRITE(6,34) ZINPU
WRITE(12,33) ZINPU
GO TO 35

CONTINUE

NOW TAPE 12 = INPUT

KI=12
ENDFILE KI
REWIND KI

MAIN INPUT SECTION
EXMN = ENERGY(1,0)
READ(KI,3) TITLE
IF(EOF,KI)100,101
WRITE(6,0) TITLE
READ(KI,1) IPRTLEV, IPRTYC, IPRTWID, IPRTSP, IPRTGC
READ(KI,1) INPOPT, KLIN, KTIN, NIBD, LMAXOPT
IF(NIอะ, GT, 0) NIBDIM=NIBD
IF(KLIN, LE, 8) KLIN=8
IF(KLIN, LE, 12) KLIN=12
WRITE(6,7) INPOPT, KLIN, KTIN, NIBD, LMAXOPT
WRITE(6,8) INPOPT, KLIN, KTIN, NIBD, LMAXOPT
EPSILON=1, RE=9
IF(LMAXOPT, GT, 0) LMAXOPT=LMAXOPT
IF(LMAXOPT, NE, 0) EPSILON=10, **LMAXOPT
READ(KI,1) NI, NMP, LGROPT, LPEG, NJMAX, ICAPT
IF(NJMAX, EQ, 0) NJMAX=NJDIM
READ(KI,2) ZAP, ZAT, DE, FSIGCN
UCUTOFF = 0,1
READ(KI,1) NELAB
READ(KI,2) (ELAB(I), IM, 1, NELAB)
EXMT = ENERGY(ZAT)
XJT = SPIN
PIT = PARITY
XMT = EXACTM(ZAT, EXMT)
BIC = EXMT + ENERGY(ZAP) + ENERGY(ZAT+ZAP)
IF(FSIGCN, EQ, 0, ) FSIGCN=1,0
IR=0
DO 104 I=1, NI
IF(INPOPT, EQ, 0) READ(KI,2) ZACN(I), XNIP(I), CNPI(I), CNP1P(I), 8MS(I)
Z111(I)=0
IF(INPOPT, EQ, 1) READ(K1,2) ZACN(I), XNIP(I), SWS(I), (Z111(IP), IP=2, 6)
IF(INPOPT, GE, 1) CALL CHAINS(I, IR)
ZAC = ZACN(I)
EXMC = ENERGY(ZAC)
EXSWS(I) = ENERGY(ZAC-1,0) + EXMN - EXMC
NIP=KNP1P(I)
DO 104 I=1, NIP
IR=IR+1
LR(IP, I)=IR
XNL(IR)=0,
A(IR)=0,
XNLGC(IR)=0.

IF(INPO,T.EQ.,0)READ(KI,2)ZA1(IR),XNL(IR),A(IR),XNLGC(IR),ECGC(IR)
CALL LCSPACE
ACN=A(1)
DEF(IR)=A(IR)XNLGC(IR)ECGC(IR)

IF(INPO,T.EQ.,1)ZAI(IR)ZAI(IP)
ZA2(IR)=ZACN(I)ZA1(IR)
DEF(IR)=XMAGIC(ZA2(IR))
ZAR=ZA2(IR)
EXMR=ENERGY(ZAR)
XM2(IR)=EXACTM(ZAR,EXMR)
S(IR)=EXMR+ENERGY(ZA1(IR))=EXMC

104 CONTINUE
NIR=IR
CALL LCSPACE
ACN=A(1)
DEF(IR)=A(IR)XNLGC(IR)ECGC(IR)

DO 106 IP=1,NIP
WRITE(6,13)I,ZACN(I),XNPI(I),CNPI(I),CNPI(I),XNPS(I),XXMPS(I)
NIP=CNPI(I)
DO 106 IP=1,NIP
IR=LP(IP,I)
IB=IBUF(IP,I)
IF(IB.GT,NIRDIM)IB=NIRDIM
WRITE(6,14)IP,ZAI(IR),ZA2(IR),XM2(IR),S(IR),XNL(IR),
1 1 DEF(IR),A(IR),XNLGC(IR),ECGC(IR),IB
IF(LGROPT,EQ.,1)WRITE(6,17)
IF(LGROPT,EQ.,2)WRITE(6,18)
WRITE(6,15)
DO 110 MP=1,NMP
READ(KI,5)LMKHOL(MP),LG,RE1(MP)
IF(LMKHOL(MP),EQ.,1)GMP(MP)GMP(MP)+1,0
IF(LMKHOL(MP),EQ.,0)GMP(MP)GMP(MP)=1,0
IF(LMKHOL(MP),EQ.,0)GMP(MP)=1,0
1 1 RE1(MP)=1,0
110 WRITE(6,16)MP,LMKHOL(MP),LG,RE1(MP)
IF(LPEQ,EQ.,1)READ(KI,2)ALPHA1
DO 201 IDX=1,6
IF(ALPHA1(IDX),EQ.,0)202,201
202 ALPHA1(IDX)=ALPHA1(IDX)
CONTINUE
201 WRITE(6,26)(BCD(IDX),IDX=1,6),ALPHA1,ALPHA
READ LEVEL INFORMATION
CALL LEVPREP(KLIN,KL)
READ TRANSMISSION COEFFICIENT DATA
CALL TCPREP(KLIN,EPSILON)
SET UP FOR CALCULATION
CALL SETUP
INCIDENT ENERGY LOOP
DO 200 IELAB=1,NELAB
CALL SECOND(KEEP)
ELAB=ELAB(IELAB)
CALL SETUP2
CALCULATE SPECTRUM
CALL SPECTRA(ACN,FSIGCN)

PRINT AND WRITE OUTPUT RESULTS
CALL DATAOUT
CONTINUE
CONTINUE
CONTINUE
GO TO 100
STOP
END

SUBROUTINE LCSPACE

SET UP LCM STORAGE, ZERO ARRAY, AND VARIABLE STORAGE BUFFERS

COMMON, RHO(40,200), T(30,200), P(60), SP(200,6), PP(80), SPP(200,7)
COMMON/BASIC1/N, NIPD(10), NEWL(6,10), ZA(60), ZA2(60), XM2(60)
COMMON/BASIC2/I, IPI(10), XSP(10), JSN(10), CNP(10), BASIC3
COMMON/LCINDEX/ILBLC, IGLC, ITLC, IELLC, IAJLC, IATLC, NIOMD, NIPDIM, NIDOM, NIGDOM, NLODIM
COMMON/LCIDEX/NIP0M, NIP6M, NIP1M, NIP2M, NIP3M, NIP4M, NIP5M
COMMON/LCMAX/ITLC, IATLC, IAJLC, IATLC, NLEVID, NLDIM, NLLEVID
COMMON/TCOEF/TITLE(16), ELAFI, OFI, ZAMT, NKKM(10), CNPI(10)

LEVEL1
1 EQ(200), SG(40), NQRAYS(60)

LEVEL2
COMMON/RASIC2/TITLE(16), ELAFI, OFI, ZAMT, NKKM(10), CNPI(10), BASIC2

LEVEL3
1 CHN(10), S(60), SAC(10), IDI(60), IDP, IODE(60), IBUF(6,10), BASIC3
2 ECM, UP, NKM/X, JRM, NKKM(60), NIDOM, TCP(30), GMKP(40), A(60), A2(60), BASIC4
3 RHO(6), XJT, NPDPMAX, NT(6), NL, IDEC(10), NKKCN(10), ECON, BASIC5
4 JPI(40,2), XMP, XJP, PIT, NLP, XNL, KL, IDSTAT(7), SIC, CSL, CSH, PILL(30), RASIC6
5 INCAPT, PBLUF(50,10), INPOPT, TKEEP

DIMENSION SCRUF(400), IJJ(10), IPJ(10)

EQUIVALENCE (SCRUF, RHO)

SET LCM STORAGE INDEXES

NIDOM=NIDIM*NIPDIM
IPLBLC=0
ILBLC=IPLBLC+NIDIM*NKDIM*NIDOM
IZERO=ILBLC+NLKDIM*NIDOM
ISPLC=IZERO+AM00
IPLLC=ISPLC+NIDIM*NIDOM
IEGLC=IPLLC+NLEVID*NIDOM
ISGLC=IEGLC+NLEVID*NIDOM
ITLC=ISGLC+NLEVID*NIDOM
IAJL=ITLC+NLEVID*NIDOM
IATLC=IAJL+NLEVID*NIDOM
LCMD=IAJL+NLEVID*NIDOM
WRITE(6,1) LCMD

1 FORMAT(* LCM SPACE REQUIRED (EXCLUDING DISC BUFFERS) IS *,17)

2 FORMAT(* NUMBER OF LCM BUFFERS IS *,12, *MAXIMUM NUMBER OF ENERGIES)

WRITE(6,2) NIDIM, NIDOM

SET UP LCM ZERO ARRAY
DO 10 K=1,1000
10 SCRUF(K)=0.

A-5
DETERMINE PARENT REACTIONS

IF(INPOPT.GE.1) GO TO 420

SET UP POPULATION STORAGE BUFFERS FOR LCM

CALL ECRO(IBUF, IZEROLC+68, IERR)

CONTINUE
CONTINUE

SUBROUTINE CHAINS(I,IRX)

COMMON/BASIC1/N1,XNIP(I),NIR,LR(6,10),ZA1(60),ZA2(60),XM2(60),

1 ZACN(I),CSGR(60),CST0T(60),CSL0V(60),CSID(8),EAVID(8),EAV(60),

COMMON/BASIC2/TITLE(16),ELAB,D1ZAP,ZAT,XMT, NKKM(10),CNPI(I),

1 CNPI(I),S(60),SIC(10),ID1(60),IDP,IDE2(60),IFUF(6,10),

2 ECI,UP,NKMAK,NJK(60),NKDIM,TCP(30),QMDP(40),A(60),A2(60),

3 RMT(6),XJP,NOPMAX,NTCZ(6),NJDIM, IOC(N(1),NKKCN(1),ECO,BASIC2 5

4 JPI(60),2,XP,JP,NLP,XNL,KNL,IOSTAT(7),STIC,CSL,CSH,PLILL(30),

5 ICAPT,PLBUF(90,10),INPOPT,TEEP BASIC2 7

COMMON/LEVDEF(60),XNLGC(60),ECGC(60),UCUTOFF,DEFCH,TGC(60),

1 ERGC(60),EHA,TGC(60),PATR(60),XMR3(60),XNLN(60),SZ(100),SN(150),

2 PZ(190),PN(150) LEVDEN 4

COMMON /SPNPAR/ SPIN,PARI,TY,KGRD LEVDEN 5

COMMON/LEVEL1/EL(50),AJ(50),AT(50),XNL(60),ELMAX(60),NLEVDM LEVEL1 2

1,EG(240),SG(240),NRAYS(60) LEVEL1 3

COMMON/GAMMA/WMP,LCROPT,SWLS(60),GML(6),GMP(6),RW(6),LMDHOL(6),

GAMMA 2

1 TGR(200,6),WXCON,CAXEL,GAXEL,FRAXEL,EXWS(10),WKNORM

2 ZAX(4) DIMENSION ZAX(4) CHAINS11

DATA ZAX/0.,1.,1001.,2004./ CHAINS12

XAT=1 CHAINS13

ZATOT=ZAP+ZAT

SHS(1)=0. CHAINS14

IR=IRX CHAINS15

GO TO (11,12,13), INPOPT CHAINS16

11 ZACN(I)=ZATOT=XI1,0001 CHAINS17

XNIP(I)=ZCHAINS18

1 CNPI(I)=XI1,0,99999 CHAINS19

CNPI(I)=ZCHAINS20

GO TO 58 CHAINS21

12 ZACN(I)=ZATOT=XI1,00001 CHAINS22

XNIP(I)=ZCHAINS23

1 CNPI(I)=XI1,0,99999 CHAINS24

CNPI(I)=ZCHAINS25

GO TO 58 CHAINS26

13 GO TO (21,22,23,24,25,21,22,23,21),1 CHAINS27

14 XI1=(I+1)/3 CHAINS28

ZACN(I)=ZATOT=XII CHAINS29

XNIP(I)=ZCHAINS30

1 CNPI(I)=XI1,3 CHAINS31

CNPI(I)=ZCHAINS32

GO TO 58 CHAINS33

22 ZACN(I)=ZACN(I-1)=ZAX(3) CHAINS34

CNPI(I)=ZCHAINS35

CNPI(I)=ZCHAINS36

GO TO 58 CHAINS37

23 ZACN(I)=ZACN(I-2)=ZAX(4) CHAINS38

A-7
C FUNCTION ENERGY(ZA)
C ***** ENERGY LOOKS UP VALUES OF GROUND STATE MASS EXCESS (MEV).
C ***** SPIN AND PARITY, MISSING DATA PRODUCE A FATAL ERROR.
C
COMMON /KSPINPAR/ SPIN, PARITY, KGRO
DIMENSION I0(I1), I1(I1), Z(J0(11), J1(11), K0(12), E1(2055))
DIMENSION SPINPAR(2055)
DATA PAR /1H, 1H, 1H/ ENERGY 1
DATA INPGRD /1/ ENERGY 2
1 FORMAT(28H ***** GROUND STATE DATA FOR I6, I9H NOT IN TABLE *****) ENERGY 3
2 FORMAT(I2, 2H/1, 1H) ENERGY 4
3 FORMAT(I2, A1) ENERGY 5
4 FORMAT(2X A1) ENERGY 6
5 FORMAT(5X, **+++** GROUND STATE OF *F6, 0*, IS INCOMPLETELY DESCRIBED) ENERGY 7
6 FORMAT(5X, **+++** GROUND STATE OF *F6, 2*X,F6, 2*, **+++**)) ENERGY 8
C FIRST CALL CAUSES DATA TO BE READ IN ENERGY 9
IF(INPGRD.EQ.12345) GO TO 10 ENERGY 10
READ (KGRO, 100) I0, I1, I2, J0, J1, K0 ENERGY 11
100 FORMAT(8I10) ENERGY 12
READ(KGRO, 101)ENER ENERGY 13
101 FORMAT(6E13, 6) ENERGY 14
READ(KGRO, 102)SPINPAR ENERGY 15
102 FORMAT(8F13, 3) ENERGY 16
REWIND KGRO ENERGY 17
INPGRD = 12345 ENERGY 18
10 IF(ZA) = IZA, 15, 20 ENERGY 19
ENERGY 10
C Z=0, A=0 IS CONSIDERED A PHOTON.
15 ENERGY = SPIN = 0, $ PARITY = -1$, $ RETURN$ ENERGY 20
C
C FIND Requested NUCLEUS IN APPROPRIATE TABLE ENERGY 21
20 IZA = IFIX(ZA) $ JZ = IZA/1000$ ENERGY 22
IA = IZA - 1000*JZ $ N = IA - JZ$ ENERGY 23
NZ = N - JZ $ N2 = NZ - JZ$ ENERGY 24
DO 30 K=1, 11 $ N1 = K(JZ)$ ENERGY 25
30 CONTINUE ENERGY 26
DO 40 K=1, 11 $ N2 = K2(JZ)$ ENERGY 27
40 CONTINUE ENERGY 28
C REQUESTED ISOTOPE IS NOT IN TABLES ENERGY 29
40 PRINT 1, IZA $ STOP 7776$ ENERGY 30
C
50 CONTINUE ENERGY 31
IF (SPINPAR(IN) .LE. 0.) SPIN = SPINPAR(IN) + 100,
CONTINUE
IF ((SPIN,GE.99.) .AND. (SPIN,NE.99.)) RETURN
PRINT 6, SPIN, PARITY
RETURN
END
FUNCTION XMAGIC(ZA)
DIMENSION XMA@G(10)
DATA NMAG/81, XMAG/2*10, 28, 0*2, 82, 0*12,
1Z=ZA*1000, 3 Z=12
A=ZA-Z=1000,
AN=Z
IF(Z.LT.50.)GO TO 15
IF(AN.LT.80.)GO TO 15
XMAGIC=1.
DO 10 N=5,8
Cl=AB(XMAG(N)-2)
C2=AB(XMAG(N)+2)
10 CONTINUE
RETURN
XMAGIC=0.
RETURN
SUBROUTINE LEVPREP(K1,K2)
PREPARES BINARY LEVEL DATA FILE ON K2 FROM I/P BCD FILE K1. ALSO
STORES ENERGY AND J-PI DATA IN LCM ARRAYS ELLC(N,IP,I) AND
AJLC(N,IP,I)
1 FORMAT(18,19,3F12.6,18) LEVPREP5
2 FORMAT(16,F12.6,PF8.1,E12.5,16,24X,16) LEVPREP9
3 FORMAT(16,F12.6,2F12.6,E12.5,12X,16) LEVPREP10
4 FORMAT(/ = LEVEL DATA FOR ZA=19,0 NOT FOUND, USE GROUND STATE
1ONLY. ) LEVPREP11
COMMON/SPINPAR,SPIN,PARIY,KRD
COMMON/INDEX/IPRLC,IGLC,IZEROLC,ISPLC,IPLLC,IEGLC,ISGLC,ITLC,
1STLC,IRHOLC,ITLC,ATLC,IAJLC,IAJLCL,NIDIM,NIDIN,NIDIM,NIDIM,NIDIM,NIDIM,
2 NIDIM,NIDIM
COMMON/LEVEL1/FL(50),AJ(50),AT(50),XNL(60),ELMAX(60),NLEVDM,
1EG(20),SG(20),NGRAYS(60)
COMMON/BASIC1/N1,XNP(19),NIR,LR(6,10),ZA1(60),ZA2(60),XM2(60),
1ZACN(19),CSGR(60),CBOTO(60),CBEV(60),CSID(60),EAVID(60),ZAV(60)
COMMON/PREG1/EPSIG(200,6),NLEV,NPIT,NIT
DIMENSION ZATAB(60),DUMMY(120)
CALL SORT1(NIR,0,ZATAB,DUMMY)
MTAB = 1
DETERMINE REQUIRED ZA TABLE
K3=11
DO 17 N=1,NIR
17 ZATAB(N)=ZA(N)
CALL SORT1(NIR,0,ZATAB,DUMMY)
MTAB = 1
CSTOT(N) = ZATAB(N)

DOB = ATAB + 1

CSTOT(NTAB) = ZATAB(N)

CONTINUE

DO 19 N = 1, NTAB

19 ZATAB(N) = CSTOT(N)

G

SELECT LEVEL DATA FOR REQUIRED ZAS

IF(K1, EQ, 8) REMIND K1

READ(K1, 1) ID, NL, F, A, AE, LDATE

KIEOF = IOCHECK(K1, 1)

IF(KIEOF .GE. 4) GO TO 29

CONTINUE

DO 21 N = 1, NTAB

IZA2 = ZATAB(N)

IF(IO, EQ, IZA2) ISET = 1

CONTINUE

GO TO (22, 23), ISET

22 WRITE(K3, 1) ID, NL, F, AE, LDATE

23 DO 28 N = 1, NL

READ(K1, 2) NX, EL(N), AJ(N), AT(N), TAU, NT, IS

GO TO (24, 25), ISET

24 WRITE(K3, 3) NX, EL(N), AJ(N), AT(N), TAU, NT, IS

25 IF(CONT, LT, 1) GO TO 28

DO 27 K = 1, NT

READ(K1, 3) LL, NF, P, CP, AMR, L1, L2, IS

GO TO (26, 27), ISET

26 WRITE(K3, 4) LL, NF, P, CP, AMR, L1, L2, IS

27 CONTINUE

28 CONTINUE

IF(F, GE, 0) GO TO 20

29 K1 = K3

REMIN K2

D

DETERMINE BINARY FILE IN ORDER OF REACTION CHAIN

REMIN K2

DO 100, IR = 1, NIR

IZA2 = ZA2(IR)

REMIN K1

30 READ(K1, 1) ID, NL, F, A, AE, LDATE

KIEOF = IOCHECK(K1, 1)

IF(KIEOF, LE, 4) GO TO 50

WRITE(6, 4) IZA2

XNL(IR) = 1, 0

XL = 1

EL(1) = 0

AT(1) = 99

TAU = 99

NT = 0

EDUM = ENERGY(ZAP(IR))

AJ(1) = PARITY*SPIN

IF(ZA1(IR), NE, 0) GO TO 45

WRITE(K2) IZA2, XL, LDATE

WRITE(K2) EL(1), AJ(1), AT(1), TAU, NT

GO TO 45

50 ISET = 2

IF(IO, EQ, IZA2) ISET = 1

GO TO (31, 32), ISET

31 IF(XNL(IR), LT, 0, 5) XNL(IR) = NL

A-10
NLMAX=XNL(IR)
NL=MIN(NL,NLMAX)
XNL(IR)=NLL
IF(ZA1(IR).NE.0.) GO TO 32
WRITE(K2) NL,NLL,LDATE
32 DO 40 N=1,NL
READ(K1,2) NX,EL(N),AJ(N),AT(N),TAU,NT,IS
GO TO (35,36),ISET
35 IF((ZA1(IR).NE.0.).OR.(N.GT.NLL)) GO TO 36
WRITE(K2) FL(N),AJ(N),AT(N),TAU,NT
36 IF(NL.LT.1) GO TO 40
DO 38 K=1,NT
READ(K1,3)
GO TO (37,38),ISET
37 IF(NL.GT.NLMAX) GO TO 38
WRITE(K2) NF,P,CP,AMR,L1,L2,IS
38 CONTINUE
40 CONTINUE
GO TO (45,10),ISET
45 INDEX=IELLC*(IR-1)+NLEV
CALL ECWR(EL,INDEX,NLL,IERR)
INDEX=IAJLC*(IR-1)+NLEV
CALL ECWR(AJ,INDEX,NLL,IERR)
INDEX=IAIJC*(IR-1)+NLEV
CALL ECHR(AT,INDEX,NLL,IERR)
ELMAX(IR)=FL(NLL)
CONTINUE
END FILE
RETURN
WRITE(6,U)
STOP

COMMON/INDEX/IPBLCD,IGLC,IZEROLC,ISPLC,IIPLC,IEGLC,ISGLC,ITLC,LCNEW
1 ISTLC,IRHOLC,ITLC,IELLC,IAJLC,IAIJLC,NIDIM,NIPDIM,NIDIM,NIDIM,NIDIM,NIDIM,
2 NIDIM,NTDIM
COMMON/LEVEL1/EL(50),AJ(50),AT(50),XNL(60),ELMAX(60),NLEV
1,EG(240),5A(240),NGRAY(60)
COMMON/TCOF/KTC(25,5),TK(25,5),BCL(7),XSPIN(7),NLDIM,
1 NPART,NFE(6),NO(6),NTC(6),IZAID(7),XMASS(7),NEEDIM,NLEIN(6,25),
2 NLE(6,200),JRAST(200,6)
COMMON/PRNTOUT/IPRTLEV,IPRTTC,IPRTMLC,IPRTWID,IPRTSP,IPRTC
DIMENSION TDUM(62),BCLTC(8)

C MAIN PARTICLE LOOP
IF(K1.EQ.1)REWIND K1
READ(K1,3)NPART,BCLTC
WRITE(6,6) NPART,BCLTC
DO 100 Nw1, NPAR7
KP=2
READ(K1,1) XBCD, NE, NN, K

IDENTIFY I/P PARTICLE
DO 20 ID=1,6
IF(XBCD.EQ.BCD(ID)) GO TO 22
CONTINUE
WRITE(6,5) XBCD
STOP

20 NEE(ID) = NE

READ ENERGY ARRAY
DO 30 I=2,NE,6
KP=KP+1
IU=I+5
READ(K1,2) (ETC(J,ID), J=1, IU), K
30 CONTINUE

MAIN ENERGY LOOP
DO 80 I=2,NE

READ TRANSMISSION COEFFICIENT DATA
DO 35 J=1,NN,6
KP=KP+1
JU=J+5
READ(K1,2) (TDUM(L), L=J, JU), K
DO 336 L=J, JU
IF(TDUM(L).LE.2.0E-14) TDUM(L)=0.
CONTINUE
336 CONTINUE
IF((ID.EQ.3).OR.(ID.EQ.6)) GO TO 60

ELIMINATE J-DEPENDENCE OF SPIN 1/2 ARRAYS
TC(I,1) = TDUM(1)
DO 50 J=2,NN,4
XL = (J-1)/2 + MOD(J/2,2) - 1
JJ=J-1
DO 42 JL=1,2
JJ=JJ+1
IF(JJ.GT.NN) GO TO 70
XL=XL+1,0
LP=XL+1,0
IF(LP.LE.NLDIM) GO TO 40
LP=LP+1
GO TO 70
40 IF(JJ.GE.2).LE.NN) GO TO 42
TC(I,L) = TDUM(JJ)
GO TO 48
42 TC(I,L) = ((XL+1.)*TDUM(JJ+2) + XL*TDUM(JJ))./(2.*XL+1.)
48 CONTINUE
50 CONTINUE
GO TO 70

RE-ORDER SPIN 0 AND SPIN 1 ARRAYS
60 DO 66 L=1,NN
J = 2*L-MOD(L,2)
IF(J.GT.NN) GO TO 70
LP=L
66 TC(I,L) = TDUM(J)
70 CONTINUE
CONTINUE
NO(I,D)=LP

SET TC ARRAY TO ZERO FOR ZERO INCIDENT ENERGY
ETC(I,D)=X,
DO 25 L=1,LP
T(:,L)=0.

25 CONTINUE

FIND NUMBER OF NON-ZERO COEFFICIENTS
DO 84 II=2,NE
I = NE-II+2
DO 82 LX=1,LP
L = LP-LX+1
IF(TC(I,L)) 82,82,83
RATIOS = 1.0*TC(II,L)/TC(I,1)
IF(RATIO,GT,EPSILON) GO TO 84
CONTINUE

NLEIN(ID,I)= L
NLEIN(ID,NE) = NLEIN(ID,NE-1)
STORE TRANSMISSION COEFFICIENT DATA IN LCM
NPTS=LP*NEEDIM
NTC(ID)= NPTS
INDEX=ICL+ID*NEEDIM
CALL ECWR(TC, INDEX,NPTS,IERR)
PRINT OPTION
IF(IPRTTC,LT,1) GO TO 100
00 90 I=1,NE
WRITE(6,8) ETC(ID)
LP = NLEIN(ID,J)
WRITE(6,9) (TC(I,L), L=J,LP)
CONTINUE
CONTINUE
RETURN

FORMAT(/ /* PARTICLE WITH IZAS*15,* NOT FOUND, ABORT JOB*/) SETUP 2
COMM/LINDEX/IPBL,IGLC,IIZERLC,ISPLC,IPLLC,IEGLC,ISLCLC,ITCLC, LCNDX 2
1 ISTCLC,IRHCLC,ITLC,IATLC,IAJLC,IAJLCEGLC,ISQLC,ITCLC, LCNDEX 3
2 NIDIM,NIROH
COMMON/RHOC(40,200),T(30,200),P(80),SP(200,6),PP(80),SPP(200,7)
1 SPMG(200),PL(50,6),G(200,6),RMOCTR(48)
COMM/TODF/E=TC(25,6),TCP(25,10),BCD(7),XSPIN(7),NLDIM,
1 NPART,NEE(6),NO(6),NTC(6),IAZ-ID(7),XMASS(7),NEEDIM,NLEIN(6,25), TCOEF 4
2 NLE(6,200),XDEST(200,6)
COMMON/LEVEL1/EL(50),AJ(50),AT(50),XLN(60),ELMAX(60),NELVDM LEVEL 1
1 XG(240),SG(240),NGRAY(60)
COMMON/BASIC1/XT,XNIR(10),XIR,L(6,10),ZA(10),ZA2(60),XH2(60), BASIC 2
1 ZACN(10),CSGR(60),CSTO(60),CSLE(60),CSID(8),EAVID(8),EAV(60), BASIC 3
COMMON/BASIC2/TITLE(6),ELAB,DE,ZAP,ZAT,XMT, NKKM(10),CPNI(10), BASIC 2
1 CNPNP(10),S(60),SAC(10),ID(60),TDP,ID2(60),IBUF(6,10), BASIC 2
2 ECH,UP,NKHMAX,NKK(60),NIDM,TCP(30),QMDP(40),A(60),R2(60), BASIC 2
3 NRHO(6),XJT, NPOPHAX,NTC(6),NIDM, IEDECN(10),NKKCN(10), ECON,BASIC 2
4 JP1(40,2),XP,JP,PIT,NLXNLPL,KL,IXSTAT(7),SIC,CSL,CSH,PILL(30), BASIC 2
5 ICAP,PLAIF(50,10),INPPT.TKEE BASIC 2
COMMON/LEVEL2/DEF(62),XNLG(68),ECGC(68),UCUTOFF,DEFCN,TGC(68), LEVDEN 2
1 EGC(68),EHTACG(68),PAIR(68),XMR3(68),XNLNN(60),SZ(100),SM(150), LEVDEN 3
2 PZ(120),PN(150)
LEVEND 4
COMMON /SPNPAR/ SPIN,PARITY,KGRD

C FIND ACCUMULATED SEPARATION ENERGIES FOR THE DECAYING NUCLEI
DO 15 I=1,NI
  15 SAC(I)=0.
DO 20 I=1,NI
  II=I
  DO 18 J=1,NI
  IX=II
  II=CNPI(IJ)
  IF(II,LT.1) GO TO 20
  IIP=CNPIP(IJ)
16 IF(II,LT.100) GO TO 17
  II=II/100
  IIP=IIP/100
  GO TO 16
17 CONTINUE
  IR=IR(IIP,II)
18 SAC(I) = SAC(I) + S(IR)
20 CONTINUE
C IDENTIFY INCIDENT PARTICLE
DO 30 ID=1,7
  IZA = ZAP
  IF(IZA.EQ.1) IZAID(ID) GO TO 32
30 CONTINUE
GO TO 1000
32 IDP=ID
XJP=XSPIN(IDP)
XMP=XMASS(IDP)
CSL = ABS(XJT-XJP)-1.0
CSH = XJT+XJP+0.001
C IDENTIFY SECONDARY REACTION PARTICLES AND PHOTONS
DO 36 ID=1,7
  IDSTAT(ID)=0
DO 40 IR=1,NIR
  IZA = ZAID(IR)
DO 36 ID=1,7
  IF(IZA.EQ.1) IZAID(ID) GO TO 39
38 CONTINUE
GO TO 1000
39 IDSTAT(ID)=1
40 ID(I)=ID
C IDENTIFY RESIDUAL NUCLEI AS TO ODD OR EVEN A
  IOE2=1 FOR ODD, IOE2=2 FOR EVEN A RESIDUAL NUCLEUS
C DO 50 IR=1,NIR
  IZA = ZA2(IR)
  IA= MOD(IZA,1000)
  IOE2(IR)= (3+(-1)**IA)/2
50 CONTINUE
C IDENTIFY DECAYING COMPOUND NUCLEI AS TO ODD OR EVEN
DO 60 I=1,NI
  IZA = ZACN(I)
  IA= MOD(IZA,1000)
  IOECN(I)= (3+(-1)**IA)/2
60 CONTINUE
C SET UP J=PI ARRAYS
JJet
DO 82 J=1,NJMAX
DO 82 IPI=1,2

A-14
INITIALIZE LEVEL DENSITIES AND GIL-CAM PARAMETERS

DO 90 IR=1,NIR

A2(IR) = A(IR)

IF(XNLGC(IR), LE, 0) XNLGC(IR) = XNL(IR)

IF(ECGC(IR), LE, 0) EGC(IR) = ELMAX(IR)

XNLLN(IR) = ALOG(XNLGC(IR))

90 XMR3(IR) = XM2(IR)**0.3333333

RETURN

END

SUBROUTINE SETUP2

SETUP ENERGIES AND DETERMINE INTEGRATION END POINTS

FCH = (XMT/(XMT+XMP))*ELAB

UP = ECH*SCIC

XMU = XMT*XMP /(XMT*XMP)

ECGN = 0.6509999/(XMU*ECH*(2*XJP+1.0)*(2*XJT+1.0))

75 EKMAX=0,

DO 77 IP=1,NIP

NKKM(IP) = FAxO(NKK(IR), NKKF(1))

IF(IP .EQ. 1) NKK(IP) = NKK(IR)

CONTINUE

NKKMAX = EKMAX/DE + 0.5

IF(NKKMAX .LT. NKKDIM) GO TO 79

XDU = NKKDIM - 1

DE = EKMAX/XDU

SETUP 75

SETUP 76

SETUP 77

SETUP 78

SETUP 79

SETUP 80

SETUP 81

SETUP 82

SETUP 83

SETUP 84

SETUP 85

SETUP 86

SETUP 87

SETUP 88

SETUP 89

SETUP 90

SETUP 91

SETUP 92

SETUP 93

SETUP 94

SETUP 95

SETUP 96

SETUP 97

SETUP 98

SETUP 99

SETUP 1000

WRITE(6,1) IZA

STOP

END

SUBROUTINE SETUP2
Generates Transmission Coefficients for Incident Channel

**Example Code Segment**

```
GO TO 75
79 NPROMAX=NMXMAX*NJDIM+2
C GENERATE TRANSMISSION COEFFICIENTS FOR INCIDENT CHANNEL
NELL=NEE(IDP)
NPTS=NTC(IDP)
INDEX=ITCLC+(IDP-1)*NEDIM*NJDIM
CALL ECRD(TC, INDEX, NPTS, IERR)
K = ISEARCH(EC, ETC(I, IDP), NDDIM, INDDIM, NDDIM, A5, A6)
NLP=NLIN(IDP, K+1)
NLX=NLX+1
DO 85 J=1, NLX
CALL INTERP(ETC(I, IDP), TC(I, J), N,2, ECM, YOUT)
IF (YOUT.LT.0.) YOUT = 0.
85 TC(J)=YOUT
RETURN
```

**Common Blocks**

```
COMMON/LCINDEX/IPBC, IGLC, IZEROLC, IPPLC, IPPLC, IECGLC, ISGLC, ITCLC,
1 IJSTCLC, INHOLC, ITLC, ITELCLC, IAJLC, IAJLC, INDIM, NINDIM, NINDIM, NGRDIM, NDDIM
2 NDDIM, NNDIM
COMMON PHO(40,200), T(39,200), P(80), SP(200,6), PP(80), SPP(200,7)
1, SPNGN(200), PL(50,6), G(200,6), RHOFTTR(40)
COMMON/TCOEF/ETC(25,6), T(25,30), BCD(7), XSPIN(7), NHLIM,
1 NPART, NEEH, NOC(6), NTC(6), IZAD(7), XMASS(7), NEEFDIM, NLIN(6,25)
2 NLP(6,200), JRAP(200,6)
COMMON/LEVEL1/EL(50), AT(50), XNL(60), ELMAX(60), NLEVDM
1, IR(200), SG(200), NGRAYS(200), RHO(200)
COMMON/BASIC1/NI, XNLP(10), NR, LR(6,10), ZAI(60), ZA2(60), XM2(60)
1, ZATC(10), ZSRG(60), CST0R(60), CSLEV(60), CSID(6), EVAD(8), EAV(8)
COMMON/BASIC2/TITLE(16), ELAB, NE(6), ZAP(7), ZAT, XMT, NKKM(10), CNPI(10)
1, CNPT(10), S(60), SAC(18), IDI(60), IDP, IOE2(60), IUOF(6,19)
COMMON/BASIC3/GAMC(60), NPKMAX, NMAX, NKK(60), NKKM, TCP(30), GMDS(40), A(60), AA(60)
1, NHRO(60), XMT, NPROMAX, NTGC(26), NDDIM, IDECH(10), NKKCN(10), ECON, BBS(5)
COMMON/BASIC4/H2, XMP, XJP, PIT, NLX, XL, IDSTAT(7), SIC, CSL, CSH, PILLLY(50), BASIC(2
1, 3)
COMMON/PR ĐiQ/LPEQ, SIGR, PRE(6), CSIGR(60), N1TT(6), A1PHA(6), PRE(6,8)
COMMON/SUMPLK1/KP, KDC, 2P, lD, KNGN, JPI, MP, MP, LTR(10), LEV(10), SUMPKL(2)
1, 3
COMMON/SUMPLK2/XJCN, IPNC, JPNC, ECONJ, MP, JJ, J2, TGL, TLEV, XJ2, J3,
1, SUMPKL(2)
DIMENSION SCBUF(8000), NECON(2), XJINI(2), PI(3), SCBUF(80)
1, SCBUF(800), SCBUF(80), SCBUF(8000), SCBUF(8000), SCBUF(8000)
COMMON/IPROB, SIGR, PRE, PRE(6), SIGR, PRE(6), SIGR, PRE(6), SIGR, PRE(6)
1, 3
COMMON/SCBUF/XJCN(2), IPNC(2), JPNC(2), ECONJ(2), MP(2), JJ, J2, TGL(2), TLEV(2), XJ2(2)
1, SUMPLK(2)
DIMENSION SCBUF(8000), NECON(2), XJINI(2), PI(3), SCBUF(800)
1, SCBUF(8000), SCBUF(8000), SCBUF(8000), SCBUF(8000)
```

**Data Arrays**

```
DATA PIP, PI1/1.0, / , XJINI/* 0.5, = 1.0, / , PI1/1.0, = 1.0, 1.0, 1.0, 1.0
```

**Miscellaneous**

```
SPLIN (B, C, D, E) = B*A5 + C*A6 = AA*(D*A5+E*A6+D*E)
CALL SECONQ(TIME)
```

**System Parameters**

```
= TIME FROM START OF THIS ENERGY * 0.9, 3, * SECONDS, TOTAL ELAPSED * 0.27
= TIME = 0.9, 3, * SECONDS, * 0.27
```

**Zero Large and Small Core Arrays**

```
```
CALL FCRR(SPBUF, IP1BLC, NPO0, IERR)
CALL ECWR(SPBUF, IPLLC, 3000, IERR)
CALL ECRO(SPP, IZEROLC, 1400, IERR)
CALL ERCR(SPNN, IZEROLC, NMAX, IERR)
NPO0=NPO0+8000
DO 51 NL=1, NNDIM
NPTS=NKDIM+NPO0
INDEX=ISPLC*(N-1)*NPTS
CALL ECWR(SCBUF, INDEX, NPTS, IERR)
INDEX=IGLC*(N-1)*NPTS
CALL ECWR(SCBUF, INDEX, NPTS, IERR)
51 CONTINUE
DO 45 IB=1, 10
IBTAG(IB)=0
45 IBTAG2(IB)=0
C MAIN LOOP TO SET UP DECAYING NUCLEI
C
SIGR=0.
CALL ECRO(SIGTOT, IZEROLC, 10, IERR)
DO 500 I=1, NI
CALL SECONDTIME
TIME=TIME-TKEEP
IP=TIME(3,2) I,TIME,TIME,
2 FORMAT(/* START OF I=12,* LOOP,*>
1* TIME FROM START OF THIS ENERGY *=F9.3,* SECONDS*, TOTAL ELAPSED T* SPECTR59
2TIME =F9.3,* SECONDS,*>)
JOEUN= IOFCN(I)
NKCN= NKCNC(I)
IF(NKCN,LT,1) GO TO 60
IF((ICAPT,EQ,0),AND,(I,EQ,1)) NKCN=1
IBCN=IBUF(I,1)
IF (IBCN,GT,NIBDIM) IBCN=IBCN-NIBDIM
NIP= NIP(I)
NJDIM2=2*NJMAX
NJDIM=2+NJMAX
C ZERO ARRAYS AND CHECK BUFFERING
C NPTS=NKDIM*NIP
INDEX=IZEROLC
CALL ECRO(SP, INDEX, NPTS, IERR)
CALL ECRO(G, INDEX, NPTS, IERR)
NPTS=NLEVDMNPO0
CALL ECRO(SP, INDEX, NPTS, IERR)
CALL ECRO(SCBUF, INDEX, 8000, IERR)
DO 64 IP=1, NIP
IP=IBUF(IP,1)
IF (IP,LT,1) GO TO 64
IF(IBTAG(IP),GT,0) GO TO 64
IBTAG(IP)=1
IF(IB,LE,NIBDIM) GO TO 62
IB=IB+NIBDIM
IF(IBTAG2(IP),GT,0) GO TO 62
WRITE(6,1) I,IP,IB
1 FORMAT( /* == THE REACTION I=12,* IP=12,* IS ATTEMPTING TO REUSE BUFFER NUMBER IB=12,* BEFORE THAT BUFFER HAS BEEN EMPTIED, */
2* --- ABORT JOB.*)
STOP
62 CONTINUE
INDEX=IP1BLC*(IB-1)*NJDIM+2*NKDIM
CALL ECWR(SCBUF, INDEX, 8000, IERR)
IF (NARR,LT,1) GO TO 64
INDEX=INDEX+8000
A-17
CALL ECWR(SCBUF, INDEX, NAD00, IERR)
64 CONTINUE
IBTAG2(IBCNI)=1
66 IF (NKCN.LT.1) GOTO 500

CALL TRANSMISSION COEFFICIENTS AND LEVEL DENSITIES ON
INTEGRATION ENERGY MESH AND LOAD INTO LCM
CALL CMLOAD(L)

SET UP GAMMA-RAY CASCADE CALCULATION. DETERMINE WEISSKOPF OR AXEL
PARAMETERS AND COMPUTE GAMMA RAY TRANSMISSION COEFFICIENTS
CALL GAMSET(I)

MAIN LOOP OVER INITIAL ENERGY OF DECAYING COMPOUND NUCLEUS

UCN= UP=3AC(I)+DE
DO 400 K=1,NKCN
UCN=UCN*DE
JMAXCN=JMAXAST(K,1)
CALL ECRD(TTOT, IZEROLC, NJMAX2, IERR)
I=K+1

SET UP TRANSMISSION COEFFICIENT TO WIDTH CONVERSION FACTORS
INDEX=IRHDLCL*(K-1)*NJDIM
CALL ECRD(RHOFTR, INDEX, NJMAX, IERR)
DO 101 JCN=1,JMAXCN
RHOFTR(JCN)= 1./(RHOFTR(JCN)*6.12834E51)

INITIALIZE POPULATION OF ALL STATES
INDEX=IPBLCL*(K-1)*NJDIM+2+(IRN=1)*NJDIM*2*NKDI
CALL ECRD(PP, INDEX, NJDI2, IERR)

WIDTH SUMMING LOOP
DO 300 IP=1,NIP

LOOP OVER REACTION TYPES FOR THE DECAYS
DO 300 IP=1,NIP

TRANSFER LEVEL DENSITIES, TRANSMISSION COEFFICIENTS, LEVEL
ENERGIES, AND LEVEL SPINS TO SCH.
IF(ID, EQ, 7) GO TO 102
NPTS= NTC(ID)
INDEX=ITCLC*(ID-1)*NLDIM*NEEDIM
CALL ECRD(TC, INDEX, NPTS, IERR)
IF(NKK(IR), LT. 1) GO TO 102
NPTS=NLC2(IP)
INDEX=ITLC+NKDI+NLDIM*(IP-1)
CALL ECRD(AL, INDEX, NPTS, IERR)

102 NK2= NKK(IR)
IF(NK2, LT, 1) GO TO 103
NPTS= NRHO(IP)
INDEX=TRHOLC+NKDI*NJDI*(IP-1)
CALL ECRD(RH, INDEX, NPTS, IERR)

103 NLEV2=NKL(IR)
INDEX=ITLLC*(IR-1)*NLEV3
CALL ECRD(EL, INDEX, NLEV3, IERR)
INDEX=IAJLC*(IR-1)*NLEV+1
CALL ECRO(AJ, INDEX, NLEV, IERR)

MAIN CONTINUUM-TO-CONTINUUM COMPUTATION SECTION

RESIDUAL NUCLEUS ENERGY LOOP
KLOW=K+1
IF(KLOW,GT,NK) GO TO 200
KD=0
DO 195 KP=KLOW,NK2
KD=KD+1
XL= NLE(IP,KD)+1
JMAX2=JMAX(IP)
XJMAX2=XJMAX2
XJCN=XJCN+1.25*(OECON*(JOE2+1)+0,01)
INCHKEY=I+K+IP+KP

ZERO INITIAL POPULATIONS IN RESIDUAL NUCLEI
JMAX2=2*JMAX2
IF (M.EQ.2) CALL ECRO(P, IZEROLC, JMAX2, IERR)

LOOP OVER DECAYING COMPOUND NUCLEUS SPIN, PARITY
DO 180 JCN=1,JMAXCN
XJCN=XJCN+1.0
ECONJ= ECON*(2.*XJCN+1,0)*FSIGCN
DO 189 IPICN=1,2
PICN= PI(IPICN)
P1= PI*P12
JP12 = JPI(J2,IP12)

SET UP INITIAL POPULATIONS FOR LD=0 CASE
IF(INCHKEY,GT,6) GO TO 117
CALL INCHSUM(S)
PP(IPICN)=DP
SIGR=SIGR+DP
117 IF (PP(IPICN),LT,1,E-300) GO TO 180
IF (ID.NE,7) GO TO 181

GAMMA RAY TRANSITION SECTION - CONTINUUM TO CONTINUUM
DO 130 HP=1,NMP
LG= GML(MP)
PIL=PILL(LG+1)
XJ2= ABS(XJCN+GML(MP))+1.0
XJ2=XJCN+GML(MP)+0.001
XJ2=AMIN1(XJ2,XJMAX2)
DO 126 JJ=1,1000
XJ2=XJ2+1.0
PI2= PICN*GMP(MP)*PIL
J2=J2+1.0
IF(XJ2,GT,XJ2H) GO TO 130
IP12 = 1.501-PI2/2.
JP12 = JPI(J2,IP12)

CHECK FOR 0 TO 0 TRANSITIONS
IF(XJ2+XJCN,LT,0,1) GO TO 188
GO TO (112,120) M

ADD CONTINUUM GAMMA WIDTH TO TOTAL WIDTH SUM
112 DT= TGR(KD,MP)*MH(J2,MP)*DE
TTOT(IPICN)=TTOT(IPICN)+DT
G(K,IP)=G(K,IP)+DT*MHOTR(JCN)
GO TO 128
COMPUTE CONTINUUM GAMMA POPULATION INCREMENTS FOR LOOPS OTHER THAN THE FIRST

120  DP = PP(JPICN)*TGR(KD, MP)*RHO(J2, KP)*DE/TTOT(JPICN)
126  CALL SUMER(1, DE)
128  CONTINUE
130  CONTINUE
GO TO 180

PARTICLE TRANSITION SECTION -- CONTINUUM TO CONTINUUM

140  XJ2 = XJINI(JOE2).
DO 170 J2=1, JMAX2
XJ2 = XJ2 + 1.0
S2 = ABS(XJ2 - XJ1) = 1.0
S2H = XJ2 + XJ1 + 0.001
DO 166 IS2 = 1, 1000
S2 = S2 + 1.0
IF(S2 .GT. S2H) GO TO 170
L2 = XJ2 + NLE2(IP, KD)
IF(L2 .GT. L2H) GO TO 168
DO 166 L2 = L2L, L2H
PI2 = PI1*PILL(L2)
PI2 = 1.501*PI2/2.
JPI2 = JPI(J2, IP12)
GO TO (142, 150) H

ADD CONTINUUM PARTICLE WIDTH TO TOTAL WIDTH SUM

142  DT = T(L2, KD)*RHO(J2, KP)*DE
TTOT(JPICN) = TTOT(JPICN) + DT
G(K, IP) = G(K, IP) + DT*RHOFR(JCN)
GO TO 166

COMPUTE CONTINUUM PARTICLE POPULATION INCREMENTS FOR LOOPS OTHER THAN THE FIRST

150  CONTINUE
IF(TTOT(JPICN) .LE. 0) GO TO 166
DP = PP(JPICN)*T(L2, KD)*RHO(J2, KP)*DE/TTOT(JPICN)
160  CALL SUMER(1, DE)
166  CONTINUE
168  CONTINUE
170  CONTINUE
180  CONTINUE

TRANSFER ACCUMULATED POPULATION TO LCM BUFFER

IF((M, EQ, 1), OR, (IBUF(IP, I), EQ, 0)) GO TO 196
IF(IP == NBDIM) IB = IB + NBDIM
INDEX = IBL + 1 + NBDIM + (IB + 1) + NNDIM + NBDIM
CALL ECRD(SCBUF2(1), INDEX, JMAX22, IERR)
DO 199 J = 1, JMAX22
190  SCBUF2(J) = SCBUF2(J) + P(J)
CALL ECRD(SCBUF2(1), INDEX, JMAX22, IERR)
196  CONTINUE
195  CONTINUE
200  U2MAX = UCN + 5(1R)

MAIN CONTINUUM-TO-LEVEL COMPUTATION SECTION

LOOP OVER DISCRETE STATES OF THE RESIDUAL NUCLEI
DO 280 N1, NLEV2

A-20
XJ2 = ABS(AJ(N))
PI = SIGN(1.0, AJ(N))
EC2 = U2MAX*EL(N)
IF(EC2 GT 0.0) GO TO 285
KD = EC2/0.5
IF(KD LT 1) KD = 1
END

C GAMMA RAY SECTION == CONTINUUM TO LEVELS
IF(IO, NE, I) GO TO 240
DO 230 MP = 1, NMP
LG = GML(MP)
PIL = PIL*LG
PICN = PIL*GMP(MP)*PI
ECN = 1.501*PICN/2.
XJCN = ABS(XJ2*GML(MP)+1.0)
XJCNH = XJ2*GML(MP)+0.001
GO 228 JCN = 1.0
JCN = XJCN
IF((JCN GT JMAXCN).OR.(XJCN GT XJCNH)) GO TO 230
ECN = ECN*(2.0*XJCN+1.0)*FSICN
JPICN = JPI(JCN, JPICN)
IF(XJCN+XJ2 LT 0.1) GO TO 228
GO TO (29A, 29B, LGROPT)
294 TGRL = XKON*GML(MP)*EC2**((2*LG+1)
295 GO TO 210
296 TGRL = 1.0*(XJCN**2/XJCN**2)+1.0
TGRL = TGRL*WGK
210 IF (((JCN, GT JMAXCN)).OR.(XJCN, GT XJCNH)) GO TO 230
END

C ADD GAMMA WIDTH TO TOTAL WIDTH SUM
DT = TGRL
TTOT(JPICN) = TTOT(JPICN)+DT
G(K, IP) = G(K, IP)+DT*RHOFR(JCN)
GO TO 228
END

C COMPUTE LEVEL POPULATION INCREMENT FROM CONTINUUM TO LEVEL TRANSITIONS IN OTHER THAN THE FIRST LOOP
220 IF(TTOT(JPICN), EQ, 0) GO TO 228
DP = PP(JPICN)*TGRL/TTOT(JPICN)
226 CALL SUMER(2, DP)
228 CONTINUE
230 CONTINUE
GO TO 280
END

C PARTICLE TRANSITION SECTION == CONTINUUM TO LEVEL
240 XJCN = XJINT(JDGEN)
KE = ISERCH(EC2, ETC(1, ID), NEE(ID), AA, AS, AB)
XNL = NLEIN(ID, KE+1)-1
DO 270 JCN = 1, JMAXCN
XCN = XJCN
ECONJ = ECN*(2.0*XJCN+1.0)*FSIGCN
S2 = ABS(XJ2+XJ1)=1.0
S2H = XJ1+XJ2+1.0
DO 266 IS = 1, 1000
S2 = S2+1.0
IF(S2 GT S2H) GO TO 270
L2L = ABS(XJCN+S2)+1.0
L2L = MIN(L2L, NLEIN(ID, KE+1))
IF(L2L LT L2H) GO TO 268
DO 266 L2L = L2L, L2H
270 CONTINUE
266 CONTINUE
END
ADD PARTICLE WIDTH TO TOTAL WIDTH SUM

242 DT = TLEV

TTOT(JPICN) = TTOT(JPICN) + DT

G(K, IP) = G(K, IP) + DT * WOFTR(JCN)

GO TO 266

COMPUTE POPULATION INCREMENTS FOR PARTICLE-LEVEL TRANSITIONS AFTER THE FIRST LOOP

250 IF(TTOT(JPICN) .EQ. 0.) GO TO 266

OP = PP(JPICN) * TLEV / TTOT(JPICN)

CALL SUMFR(2, 0E)

CONTINUE

CLOSE M AND IP LOOPS.

300 CONTINUE

CLOSE K LOOP, TRANSFER SP AND PL TO LCM.

400 CONTINUE

Compute discrete gamma-ray cross sections and add to SPECTRA.

CALL GRINES

RETURN

END SPECTRUM

SUBROUTINE LEVDSET(ACN, A, A2)
IZA = IZA(IR)
I2 = MOD(IZA,1000)
IZ = IZA/1000
IN = I2
XA = I2
IF((A(IR).GT.50).OR.(IR.EQ.1)) GO TO 50
AGC = XA*(0.0917*(SZ(I2)+SN(IN)) + DEFGC(IDEF))
DAGC = AGC-ACNGC
A2(IR) = ACN+DAGC
PAIR(IR) = PZ(I2)+PN(IN)
CALL GILCAM(A2(IR),IR)
CONTINUE
RETURN
END
SUBROUTINE GILCAM (A,LR)

COMMON/LEVDEN/DEF(60),XNLGC(60),ECGC(60),UCUTOFF,DEFCN,TGC(60),
1 EGGC(60),EMATGC(60),PAIR(60),XMR3(60),XNLLN(60),S1(100),SN(150),
2 PZ(100),PN(150)
COMMON /SPNPAR/ SPIN,PARITY,KGRO
DIMENSION OE(AI)
DATA NDE,DE/4,1,0,1,0,1,0,001/
E=E=ECGC(LR)
CONST = 5.0571*XMR3(LR)
E = 0,1*PAIR(LR)+2.25/A
DO 50 I=1,NDE
DO 40 J=1,500
U = E-PAIR(LR)
V = E-PAIR(LR)
T = 1/(SORT(A(U)-1.5/U)
E01 = E+T*XNLLN(LR)
E02 = E+T*(ALOG(CONST*SORT(A*U)*3)/T)-2.*SORT(A*U))
DEL2 =E01-F02
IF(I*J.EQ.I) SIGN0 = SIGN(I,DEL2)
SIGN2 = SIGN(I,DEL2)
IF(SIGN2,.NE,.SIGN) GO TO 45
DEL1 = DFL2
E = E + DE(I)
CONTINUE
45 E = E-DE(I)
50 CONTINUE
DELAL=ABS(DEL1-DEL2)
IF(DELAL.GT.1.0E-03) GO TO 100
E=0.1*PAIR(LR)+2.25/A
EMATCHE=
U=E+PAIR(LR)
T = 1/(SORT(A/U)-1.5/U)
PRINT 1,LR
1 FORMAT(*++++*,GILCAM SUBROUTINE UNABLE TO MATCH DISCRETE LEVELS Jul1977)
11TH LEVEL DENSITY FUNCTION FOR RESIDUAL NUCLEUS IN REACTION IR =**JUL1977
2 IS = ****/
GO TO 101
100 EMATCH = E + DE(NDE)*(DEL1/DEL1-DEL2))
U = EMATCH - PAIR(LR)
T = 1/(SORT(A/U)-1.5/U)
101 E0= EC = T*XNLLN(LR)
EMATGC(LR)=EMATCH
TGC(LR)=T*S FGC(LR)=E0
RETURN
END
SUBROUTINE LCHLOAD(I)
C
C COMPUTE TRANSMISSION COEFFICIENTS AND LEVEL DENSITIES ON
INTEGRATION ENERGY MESH AND LOAD INTO LCH

1. FORMAT(// TRANSMISSION COEFFICIENTS ON SUBSET OF INTEGRATION ENERGY MESH AND LOAD INTO LCH)
2. IDY GRID(0)
3. FORMAT(ERR=12.3X, PARTICLE = A10, 3X, ID=12.3X, IP=12.3X)
4. FORMAT(// ENERGY = 12.3X, 3X, NEV=5X, JMAX INDEX = 13)
5. FORMAT(1IP, (E12.5))
6. FORMAT(// LEVEL DENSITIES ON SUBSET OF INTEGRATION ENERGY GRID=)
7. COMMON/LCINDEX/IPBLC, IGLC, TIERLOC, ISPIC, IPPLC, IFGLC, ISGLC, ITLC, INDEX 2
8. COMMON RHOD(40,200), T(30,200), P(200,6), SPP(200,7), RHOFTR(40)
9. COMMON/TCCOFF/ETC(25,6), TC(25,3), RCD(7), XSPIN(7), NLDIM,
10. COMMON/PART, NEE(6), NTC(6), IZA(7), XMASS(7), NEEDIM, NLEIN(6,25),
11. COMMON/LEVEL/PFL(50), AJ(50), AT(50), XNL(60), ELMAX(60), NLEVDM,
12. COMMON/BASIC/TITLE(16), FLAR, DE, ZA(160), ZA2(160), XM2(160),
13. COMMON/LEVEL/DEF(60), XNLP, GLF(60), UCUTOFF, DEFCN, TGC(60),
14. COMMON/PREQ/NSIG(200,6), NLEV, NNPIT, NIT,
15. COMMON/PRINT/IPTLCV, IPRTC, IPRMLD, IPRTMLD, IPRTSP, IPRTPGC
16. COMMON/SPIN/PARITY, KGRO
17. COMMON/NIP/NIP(1), NP(1)
18. COMMON/IR/IPL(1), NP(1)
19. COMMON/IPR/IPR(1)
20. COMMON/IPR/IPR(1)
21. COMMON/IPR/IPR(1)
22. COMMON/IPR/IPR(1)
23. COMMON/IR/IPL(1), NP(1)
24. COMMON/IPR/IPR(1)
25. COMMON/IPR/IPR(1)
DO 44 L=1,NL
CALL INTERP(GETC(I,1),TC(1,L),NE,2,EK,YOUT)
T(L,K)=YOUT
IF(T(L,K),GE,1.,t)(L,K)=
JF(T(L,K),LE,0.,T(L,K)=R.
CONTINUE
C
IFI(I,EQ,1.AND.ID,LE,6)45,55
45
KLM=(UP=SAC(1)-S(IR))/DE+0.5
EK=0.
DO 51 K=1,KLM
EPSIG(K,ID)=0.
EK=EK+DE
KE=ISERCH(EK,GETC(1,ID),NE,AA,AS,A6)
NL=NEIC(ID,KE+1)
DO 52 L=1,NL
CALL INTERP(GETC(I,1),TC(1,L),NE,2,EK,YOUT)
T(L,K)=YOUT
IF(T(L,K),GE,1.,t)(L,K)=
IF(T(L,K),LE,0.,T(L,K)=R.
EPSIG(K,ID)=EPSIG(K,ID)+(2.*CL_l)+1.1*T(L/K)
CONTINUE
C
TRANSITION COEFFICIENT PRINT OPTION
IFI(IEPTC,LT,2)GO TO 48
WRITE(6,1)
WRITE(6,2) ID,BOD(ID),I,IP,IR,NK,NL
KPR=IPRTC+1
DEFR=KPR
EK=DE(1,DEFR)
DO 46 K=1,NK,KPR
EK=EK*DE*DEFTR
NL=NELC(IP,K)
WRITE(6,7) EK,NL
WRITE(6,4) (T(L,K),L=1,NL)
KPTS=NK*NLDIM
NTC2(IP)=KPTS
INDEX=ITLC+NLDIM*(IP-1)
CALL ECMR(T,INDEX,KPTS,1,IER)
COMPLET AND STORE LEVEL DENSITIES AND YRASTS
50
EKMAX= UP=SAC(1)-S(IR)
XIEFF=7.47656E-3*XMR3(IR)**8
EK=DE.
DO 50 K=1,NK
EK=EK*DE
EX=EKMAX*EX
U=EX=PAIR(IR)
US=AMAX1(1,1+U*CUTOFF)
SJMAX=SORT(2.*US*XIEFF)
JMAX2=SJMAX*OE
JMAX2=MIN(JMAX2,NJMAX)
JRAST(K,IP)=JMAX2
SIG22=0.1776*SORT(A2(1R)*US)*XMR3(IR)**2
IF(Ex.LG.EMATGC(IR))GO TO 70
AUR= SORT(A2(IR)*U)
RHOE = EXP(2.*AUR)/(10**112*XMR3(IR)*U*AUR)
GO TO 72
70
RHOE = EXP((EX-ERGC(IR))/TG'C(IR))/(2.*TG'C(IR))
XJJS=1.0
IF(IDE2(IR),EQ,1)XJJS=0.5
DO 76 J=1,JMAX2
CONTINUE
LEVEL DENSITY PRINT OPTION
IF(IPRTGC.LT.1) GO TO 84
WRITE(6,5)
WRITE(6,6) ID,BCD(ID),I,IP,IR,NK,NJMAX
KPRT=IPRTGC
DEFTR=KPRT
EK=Y(EKMAX-1)
D(I) 62 K:1,NK,KPRT
EK=EK+O*DEFTR
EX:EKMAX-CK
JMAX2=JMAX(I,IP)
WRITE(6,3) EK,JMAX2
WRITE(6,4) (RHO(J),J=GJAX2)
NPTS=NK*NJMAX
INDEX=IRHO+1+NK*DIM*10*IP+1
CALL ECWR(RHO,INDEX,NPTS,IERR)
100 CONTINUE
RETURN

SUBROUTINE GAMSET(I)

C
C SET UP GAMMA-RAY CASCADE CALCULATION; DETERMINE WEISSKOPF OR AXEL GAMMA PARAMETERS AND COMPUTE GAMMA RAY TRANSMISSION COEFFICIENTS
C
1 FORMAT(/// * GAMMA-RAY TRANSMISSION COEFFICIENTS*, 10X*I=12,15X.. ENERGY*, 10(6X,AltF1.0,4X) )
2 FORMAT(F8.3, 1P,10(lX,Ell .4))

COMMON/BASTC!/NI,XNP(I),NIR,LR(6,10),ZAI(60),ZAI(60),XM2(60), BPASIC1 2
1 ZACN(IP),CSGR(60),CSTO(60),CSLEV(60),CS16(60),EAVD(60),EAV(60), BPASIC1 3
EXM=EXM+200/TITLE(16),ELAR,ELAR,ZAP,XAT,XM2, NKKM(10),CNPI(10), BPASIC1 2
1 CNPI(10),500,SAO(10),ID1(60),IDP,IO(10),60,IRUF(6,10), RCASIC2 3
2 ECM,IP,NKMAX,NJMAX,NKKM(60),NKKM(60),NKKM(60),NKKM(60),NKKM(60), BPASIC2 4
3 NRO(6),XJT, NPOPMAX,NTC(6),NJDIM, IOECN(10),NKKCN(10),ECN,BASIC2 5
4 JPT(40,2),XMP,XJP,PIT,NLP,KL,IDSTAT(7),SIC,CSL,CSH,PILL(30)RASIC2 6
5 JCAPT,PLBF(50,10),INPPT,KEEP BASIC7 2
COMMON/LEVDEN/DEF(60),XNLC(60),ECGC(60),UCCOUFS,DEFEN,TGC(60), LEVDEN 2
1 ESGC(60),EMATGC(60),PAIR(60),XMR(60),XNLLN(60),SZ(100),SN(150), LEVDEN 3
2 PIZ(100),PZ(100),LEVDEN 4
COMMON/SNPAR/ SPIN,PARITY,KGRA COMMON/GAMMA/N/HP,LGROPT,WS(6),GML(6),GM(6),R21(6),LMGHOL(6), GMMA 3
1 TGR(200,6),WKCON,CAXEL,GAXEL,ERAXEL,EXS(10),WKOWN, PRNTOUT DIMENSION RDUM(2) GAMSET16
DATA GAXEL/.5,9.,RO/1.25/ GAMSET17
C
NIP=XNP(I)
10 DO 50 I=1,NIP
IR= LR(IP,1)
10= IDI(IR)
IF(IO.EQ.7) GO TO 52
50 CONTINUE
RETURN
52 CAXEL=W,AP13*XMR(1),ERAXEL=AR1/AXMR(1),WKOWN=1.8E-8 CALL WEISSKF(I,IP,IR)
WRITE(6,10) I,WKCON
A-27
FORMAT(* GAMMA MEAN STRENGTH NORMALIZATION CONSTANT / IN*,
1 12,*, CONSTANT =1PE12,4)
70 RATIO = .4454758/(R0*XH2(1R)*XH3(1R)**2)
DO 75 MP=1, NMP
L = GML(MP)
IF((GMP(MP),LT;0.) GO TO 75
IF (L.LT.2) GO TO 74
IF(RE1(MP),EQ,0.) RE1(MP)=1.0E-6
74 RDUM(L)=RE1(MP)
75 CONTINUE
DO 78 MP=1, NMP
L = GML(MP)
IF((GMP(MP);GT;0:):OR, (RE1(HP);G+.O; )] GO To 78
RE1(PP) = RATIO*RDUM(L)
78 CONTINUE
NK= NKK(IR)
EG=0.
DO 90 KD=1, NK
EG=EG+DE
DO 90 HP=1, NMP
L = GML(MP)
GO TO (81,82), LGROPT
80 TGR(KD,MP)=WCKON*WKNDRM*RE1(MP)*EG**(2*L+1)
GO TO 90
82 TGR(KD,MP)=1.634925E+3*GAXEL*RE1(MP)*GAXEL*EG**4/1
( (GAXEL**2*EG**2)**2+(EG*GAXEL)**2)
TGR(KD,MP)=TGR(KD,MP)*WCKON
90 CONTINUE
C
C TRANSMISSION COEFFICIENT PRINT OPTION
IF(IPRTC,L.T.2) GO TO 100
WRITE(6,1) IR,IP,IR, (LMGHOL(MP),GML(MP),MP=1,NMP)
KPRT=IPRTC=1
DEFRKPR
EG=0.
DO 94 KD=1, NK, KPRT
EG=EG+DE*DEFR
WRITE(6,2) EG, (TGR(KD,MP),MP=1,NMP)
94 CONTINUE
100 RETURN
END
SUBROUTINE WEISSKF(1,IP,IR)
C
C OBTAIN NORMALIZATION FACTOR FOR WEISSKOPF APPROXIMATION FROM
INPUTTED STRENGTH FUNCTION
COMMON/LINDEX/IPBL,IGLC,I7EROLC,ISPLC,IPPLC,IEGLC,ISGLC,ITLC,
1 ISTLC,IRHLC,ITLC,IELLC,IAJLC,IA TLC,NIDIM,NIPDIM,NI2DIM,NGRIDM,LINDEX 2
2 NIDIM,NI2DIM.
COMMON RHO(40,200),P(80),SP(200,6),PP(200,7)
1,SPGN(200),PL(50,6),G(200,6),RHOFR(40)
COMMON/LEVEL1/EL(50),AJ(50),AT(50),XNL(60),ELMAX(60),NLEV
1, EG(200),SG(200),NORAY(60)
COMMON/BASIC2/TITLE(16),ELAB,DE,ZAP,ZAT,XTM,
1, NKKM(10),CNPI(10), BASIC2 2
1 CNPI(10),SAC(10),I01(60),IOP,IOE2(69),IBUF(6,10),
2 ECM,UP,IKNXM,NKMAX,NK(60),NKDIM,TCP(30),QMP(40),A(60),A2(60),
3 NRHO(6),JXT, HPOMP,NCTC(6),NJDIM, IDECN(10),KKCN(10),ECON,BASIC2 4
4 JPT(40,2),XMP,XJX,PIT,NLP,PNL,PNL,KL,IODST(7),SIC,CSL,CSH,PIU,L(30)
5,ICAPT,P,LIBF(50,10),INPOF,TKEEP
COMMON/TCOFF/ETC(25,6),TC(25,5),BCD(7),XSPIN(7),NLDIM,
1,NPRT,NEE(6),NO(N6),NCTC(6),IZADD(7),XMAS(7),NEEDIM,NLEIN(6,25),
2,E6(6,200),JRST(200,6)
COMMON/GAMMA/NMP,LGROPT,SW(10),GHL(6),GHP(6),RE1(6),LMGHOL(6),
GAMMA 2
A-28
IF(SWS(I) .GE.50,30)
RETURN

GAMCON=1.6$9938E=5*CAEXL*CAEXL

SET WKCON=1, IF EXSWS(I) IS EQUAL TO 0.
IF((EXSWS(I) .GT.0),AND,(NKK(IR),GE,1)) GO TO 48
WKCON=1.0
RETURN

READ IN LEVEL DENSITIES AND DISCRETE LEVELS
NPTS=RHOC(IP)
INDEX=IRHOC(IP)*NKD*M*NJDIM
CALL ECRD(RHOC,INDEX,NPTS,IERR)
NLEV2=NL(A(I))
INDEX=IFLLC(IR-1)*NLEV2
CALL ECRD(A(I),INDEX,NLEV2,IERR)
INDEX=IAJLC(IR-1)*NLEV2
CALL ECRD(A(I-1),INDEX,NLEV2,IERR)

FINO INITIAL K FOR INTEGRATION
NK=NKK(IR)
EKMAX=UP-SAC(I)-3(I)
EX=EKMAX+DE
DO 50 K=1,NK
EX=EX-K
IF(EX.LE.EXSWS(I)) GO TO 55
CONTINUE
50 CONTINUE
55 KLOW=K
EXLOW=EX

INTEGRATE OVER COMPOUND NUCLEUS SPINS,PARITIES
SUM=0,
IPICOMPS=IP
XJCN=ABS(XJ+XJ)-1,0
XJCNH=XJ+XJ+0.01
DO 100 JJCN=1,1000
XJCN=XJCN+1,0
JCN=XJCN+1,01
IF((XJCN,GT,XJCNH),OR,(JCN,GT,NJMAX)) GO TO 110
100 CONTINUE

INTEGRATE OVER FINAL STATE SPINS,PARITIES
XJ2=ABS(XJCN-1)-1,0
XJ2H=XJCN-1,01
DO 90 JJ2=1,1000
XJ2=XJ2+1,0
J2=XJ2-1,01
IF((XJ2,GT,XJ2H),OR,(J2,GT,NJMAX)) GO TO 100
90 CONTINUE

INTEGRATE OVER CONTINUUM ENERGIES
EX=EXLOW+DE
DO 70 KP=KLOW,NK
IF(JRAST(KP,IP),.LT.J2) GO TO 75
EX=EX+DE
ED=EXSWS(I)+EX
GO TO (60,62),LGOPT
60 SFTR=WKNORM*ED*3
GO TO 70
```
62 SFTR = GAMCON*ED**4/((ERA*AXEL**2-ED**2)**2 + (ED*GAXEL)**2)
70 SUM = SUM + DE*RHO(J2,KP)*SFTR
75 CONTINUE

C C INTEGRATE OVER DISCRETE STATES
C  IF(NLEV2 < LT1) GO TO 90
C  DO 80 N = 1, NLEV2
C  IAJ2J = 2, IARS(AIJ(N)) = 0, P
C  IF(J2J,J2I,N,E) IAJ2J) GO TO 80
C  PIAJ = SIG0(AJ0, AJ(N))
C  IPIAJ = PIAJ + SIG0(AJ0, PIAJ)
C  IF(PIAJ,J2I,NE,IPICOMP) GO TO 80
C  ED = EXWS(I) = EL(N)
C  IF(ED <= 0) GO TO 70 90
C  GO TO (76,78), LGROPT
C  SFTR = KNORM*ED**3
C  SFTR = GAMCON*ED**4/((ERA*AXEL**2-ED**2)**2 + (ED*GAXEL)**2)
C  SFTR = GAMCON*ED**4/((ERA*AXEL**2-ED**2)**2 + (ED*GAXEL)**2)
C  SUM = SUM + SFTR
C  CONTINUE
C  CONTINUE
C  CONTINUE
C  WKCON = 3*SF/(I)/SUM
C  RETURN
C  END

PERFORM SUMS OVER 3 AND L OF INCIDENT CHANNEL FOR GIVEN COMPOUND
NUCLEAR SPIN AND PARITY

COMMON RHO(0, 200), T(30, 200), P(200), SP(200, 6), PP(80), SP(200, 7)
1, SPONGN(200), PL(200, 6), G(200, 6), RHOPTR(40)
1, RHO 2
1 COMMON/RH0(16), ELAB, DE, ZAP, ZAT, XMT, NKPM(10), CNPI(10), BASIC2 2
1 1 CNPI(10), S(60), SAC(10), ID(60), IDP, IOE(60), IRUF(6, 10)
1, BASIC2 3
1 2 ECM, UP, NKMAX, NJMAX, NKKM(6), NKKC(6), BASIC2 3
2, BASIC2 4
2 3 NRHO(6), XJCN, NPOPMAX, NTC2, NJDH, IOECN(10), NKKCC(10), ECNN, BASIC2 5
3 4 JPI(40, 2), XMP, SJP, NLP, XNL, KL, IDSTAT(7), SIC, CSL, CSH, PILLI(3M), BASIC2 6
4, SIAP, PLBIF(50, 10), INPOPT, NKEEP
4 1 COMMON/NAAMA/MNP, LGROPT, SWS(10), GM(6), GMP(6), REI(6), LGM(6),
4 1 TRL(200, 6), WKCN, CAXEL, GAXEL, ERAVEL, EXWS(10), MKNORM
4, GAMMA 3
4 COMMON/SUMALK2/XJCN, PIPC, JPICN, JPOC, BCE, JC, J2, L2, TGRL, TLEV, XJ2,
4 1 TOTAR(AR)
4 1 COMMON/PREFEQ/LPEQ, SIGR, PREGI(6), CSSI(6), NITR(6), ALPHA(6)
4 1 MX = (MM+1)/2 + 1
4 1 CS = CSL
4 1 DP = 0.
4 1 PICOMP = PICTPICN
4 1 LPICOMP = PICTPICNO + SIG(0,2, PICOM)
4 1 DO 60 ISP = 1, 1000
4 1 CS = CS + ISP
4 1 IF(CS = CSCH) MOD, PR0, 207, 70
200 LPL = LPL + XJCN + CS + 1.01
200 LPH = XJCN + CS + 1.01
200 LPR = MNP(LPH, NL)
200 IF(LPR = LPH) 201, 201, 60
201 CONTINUE
201 DO 55 LPL = LPL, LPH
201 LPP = PILL(LP)
201 IF(LPPI = LPICOMP) 55, 202, 55
202 CONTINUE
202 DO = ECONJ + TCP(LP) + DP
55 CONTINUE
```
CONTINUE
RETURN
SUBROUTINE SUMER(NN, DE)
ADD POPULATION INCREMENT INTO POPULATION ARRAY AND INTO SPECTRA
COMMON RHO(40, 200), T(30, 200), P(80), SP(200, 6), PP(80), SPP(200, 7)
COMMON/RHO(40, 200), PL(50, 6), G(200, 6), RHOFT(40)
COMMON/SUMRLK/KP, KD, IP, ID, KNGN, JPI2, H, DP, IK
COMMON/TOTALS/SIGTOT(10)
GO TO (51, 52), NN
P(JPI2) = P(JPI2) + DP
GO TO 58
PL(N, IP) = PL(N, IP) + DP
DS = DP/DE
SP(KD, IP) = SP(KD, IP) + DS
SPP(KD, ID) = SPP(KD, ID) + DS
IF (K = 2) GO TO 70, 70, 72
SIGTOT(IP) = SIGTOT(IP) + DP
GO TO (61, 62), KNGN
SPNNGN(KD) = SPNNGN(KD) + DS
RETURN
END
SUBROUTINE GRLINES
CALCULATE DISCRETE GAMMA-RAY CROSS SECTIONS AND SUM SPECTRA
TO GET INTEGRAL CROSS SECTIONS
FORMAT(// LEVEL DATA OUT OF ORDER, ZA=15,2X,ZA=15,4X,NL=13, GRLINES3
1 4X*IDATE=17, 4X* ABORT JOB,*) GRLINES4
COMMON/CLINDEX/IPBLU, ILGC, IZEROLC, ISPLC, IPLUC, IEGLC, ISGLC, ITLCLC, LCINDEX 2
1 ISTLCLC, IROHC, ITLC, IPLUC, IAJLC, IATLC, NIDM, NIPDIM, NIBDIM, NGRIDM, LCINDEX 3
2 NIDM, NIBDIM
COMMON/RHO(40, 200), T(30, 200), P(80), SP(200, 6), PP(80), SPP(200, 7)
COMMON/LEVEL/EL(50), AJ(50), AT(50), XNL(60), ELMAX(60), NLEVDM 2
1 ELC(20), SG(20), NGRAYS(60)
COMMON/BASIC/NI, XNIP(10), XMP, XJP, PIP, NLP, XNL, ZAP, ZAIP, XMT, NKKM(10), CNPI(10), BASIC 3
1 ZACN(10), CSSR(60), CSTOT(60), CSLEV(60), CSID(60), EAVI(60), EAV(60)
COMMON/BASIC/TITLE(16), ELAB, DE, ZAP, ZAT, XMT, NKKM(10), CNPI(10), BASIC 2
1 CNPI(10), S(60), SACC(10), IDI(60), IP, IDEN(60), IBUF(6, 10), BASIC 3
2 ECM, UP, NMAX, NMAX, NKKM(10), NCPC, TCP(30), QMDP, A(60), A2(60), BASIC 4
3 NMRG(60), XJT, NPOMAX, NTC(20), NJDIN, TDECN(10), NKKCN(10), ECON, BASIC 2
4 JPI(40, 2), XMP, XJP, PIP, NLP, XNL, PIP, IP, IDSTX(7), ICL, CSL, CSHP, PLLLL(30) BASIC 6
5, ICAPI(PLBUF(50, 10), INPOPI, KEEP 7
DIMENSION NTT(50), TGT(50, 40), NFF(50, 40), PR(50, 40), GRR(50, 40)
EQUivalence (IG, RHO), (NFF, RHO(1, 101)), (PR, T), (GRR, T(1, 101)) BASIC 7
MAIN CALCULATION LOOPS
CALL ECRD(PBLUUF(50, 10), INPOPI, KEEP BASIC 8
DIMENSION NTT(50), TGT(50, 40), NFF(50, 40), PR(50, 40), GRR(50, 40)
EQUivalence (IG, RHO), (NFF, RHO(1, 101)), (PR, T), (GRR, T(1, 101)) BASIC 7
CALL ECRD(PBLUUF(50, 10), INPOPI, KEEP BASIC 8
DIMENSION NTT(50), TGT(50, 40), NFF(50, 40), PR(50, 40), GRR(50, 40)
EQUivalence (IG, RHO), (NFF, RHO(1, 101)), (PR, T), (GRR, T(1, 101)) BASIC 7
ADD PARTICLE-INDUCED POPULATIONS TO STATES THAT GAMMA DECAY

IB=IRUF(IP,I)
IF(IB,LF,93) GO TO 90
DO 40 N=1,NLEV2
40 PLBUF(N,IB) = PLBUF(N,IB)+PL(N,IP)
ID = ID1(IP)
IF(ID,NE,7) GO TO 90

COMPUTE DISCRETE GAMMA CROSS SECTIONS
IZA2=IZA2(IR)
READ(KL) IZA,NL,LOAD
IF(IZA,EG,IZA2) GO TO 50
WRITE(6,1) IZA, IZA,NL,LOAD
STOP

NG=0
DO 60 N=1,NL
PL(N,IP) = PLBUF(N,IB)
READ(KL) EL(N),AJ(N),AT(N),TAU,NTT(N)
NT=NTT(N)
IF(NT,LT,1) GO TO 60
DO 58 KN=1,NT
NG=NG+1
IG(N,KN)=NG
58 READ(KL) NFF(N,KN),PR(N,KN),CPR(N,KN),AMR,LL1,LL2
CONTINUE

NGRAYS(IR)=NG
NGR=NG
DO 70 NN=2,NL
N=NL+NN2
NT=NTT(N)
IF(NT,LT,1) GO TO 70
DO 66 KN=1,NT
NG=IG(N,KN)
NFF=NF(N,KN)
EG(NG)=EL(N)=EL(NF)
DP=PL(N,IP)+PR(N,KN)
DP=DP+PL(NF,IP)+CPR(N,KN)
SG(NG)=DP
CP(IG(IR))=CP(IG(IR))+DP
KD= EG(NG)/DE + 0.5
IF(KD,LT,1) KD=1
DS = DP/DE
SP(KD,IP) = SP(KD,IP) + DS
CONTINUE

INDEX=INDEX+(I=1)*NLEV2*NIPDIM
CALL ECWR(SP,INDEX,NPTS,IERR)
SUM INDIVIDUAL SPECTRA

90    ED=0.
      NK=NNK(IR)
      DO 92 K=1,NKMAX
      ED=ED+DE
      EAV(IR)=EAV(IR)+ED*SP(K,IP)
      CSTOT(IR)=CSTOT(IR)+SP(K,IP)
      IF(CSTOT(IR).GT.0.) EAV(IR)=EAV(IR)/CSTOT(IR)
      CSTOT(IR)=CSTOT(IR)*DE

92    CONTINUE
C
C SUM LEVEL POPULATIONS FROM CONTINUUM AND LEVEL TRANSITIONS
      DO 94 N=1,NLEV2
      CSLEVEL(IR)=CSLEVEL(IR)+PL(N,IP)
      CONTINUE
C
C SUM COMPOSITE SPECTRA
      DO 100 ID=1,7
      CSID(ID)=0.
      EAVID(ID)=0.
      ED=0.
      IF(IDSTAT(ID).LT.1) GO TO 110
      DO 108 K=1,NKMAX
      ED=ED+DE
      EAVID(ID)=EAVID(ID)+ED*SP(K,ID)
      CSID(ID)=CSID(ID)+SP(K,ID)
      IF(CSID(ID).GT.0.) EAVID(ID)=EAVID(ID)/CSID(ID)
      CONTINUE
      CSID(ID)=CSID(ID)*DE
      CONTINUE
      CSID(ID)=CSID(ID)*DE
      RETURN
C
C SUBROUTINE DATAOUT
C
C MAIN OUTPUT ROUTINE
C
1 FORMAT((1,H1,10X,*RADIATION WIDTHS* /)
2 FORMAT((1,H1,10X,*SPECTRA FROM INDIVIDUAL DATAOU77
1 RESPONSE * /)
3 FORMAT(16X,10(A6,F5.0))
4 FORMAT(46,10,A6,F5.0,1X)
5 FORMAT(16X,10,A6,F5.0,1X)
6 FORMAT(16X,10,A6,F5.0,1X)
7 FORMAT((1,H1,10X,*DISCRETE LEVEL INFORMATION DATAOU10
10 NAME * /)
9 FORMAT(// 3H I=12,3X,3H1P=I2,3X,3HIR=I2,3X,4HZA1m=F4,0,3X,4HZA2=F5DATAOU16
1,3X,19HSEPARATION ENERGY =F7.3,4H MV,3X,31HHACCUMULATED SEPARATION DATADOU17
20H ENERGY =F7.3,4H MV)
10 FORMAT(3H NUMBER OF LEVEL IN RESIDUAL NUCLEUS =I3,3X,22HNUMBER OF DATAOU19
1F GAMMA RAYS =I3,3X,3F RESIDUAL NUCLEUS ID =I5)
11 FORMAT(// 1L FINAL TRANSITION CONDITIONAL GAMMA GAMMA PRODUCTION DATAOU22
2 * * NO ENERGY PARITY CROSS SECTION TRANSITIONS LEVEL DATAOU23
3EL ENERGY PROBABILITY PROBABILITY NUMBER ENERGY CROSS SECTIO DATAOU24
C EN~QGY ~N~ flINARy
C (R)S
g?T1oN
PRINT
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DATAOU76
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C INDIVIDUAL SPECTRA PRINT OPTION
60 IF(IPRTSP,.LT.2) GO TO 70
ICT=0
DO 69 I=1,NIP
NPT= XNIP(I)
INDEX=ISPLC(I)*NKDIM*NIPDID
CALL ERC(VER,INDEX,NPT,IERR)
DO 68 IP=1,NIP
IR = LR(IP,I)
ZADUM(IR)= ZACN(I)
ICT = ICT+1
DO 62 K=1,NKMAX
SCBUF3(K,ICT) = SP(K,IP)
IF((ICT,LT,10).AND.,(IR,LT,NIR)) GO TO 68
IR=IR
NICT=ICT
IPL=IRH=NICT+1
C PRINT CROSS SECTIONS AND SPECTRA
WRITE(6,2)
WRITE(6,3) (HZAQN,ZADUM(II),II=IRL,IRH)
WRITE(6,3) (HZA1, Z1(II),II=IRL,IRH)
WRITE(6,3) (HZA2, Z2(II),II=IRL,IRH)
WRITE(6,4) BLANK, (HMDASH,II=IRL,IRH)
WRITE(6,4) BLANK, (HSIG,II=IRL,IRH)
WRITE(6,4) BLANK, (HBRN,II=IRL,IRH)
WRITE(6,5) HGM, (CSSGR(II),II=IRL,IRH)
WRITE(6,5) HLEV, (CSLEV(II),II=IRL,IRH)
WRITE(6,5) HTOT, (CSTOT(II),II=IRL,IRH)
WRITE(6,4) BLANK, (HMDASH,II=IRL,IRH)
WRITE(6,5) HEAV, (EAV(II),II=IRL,IRH)
WRITE(6,5) BLANK, (HSIG,II=IRL,IRH)
WRITE(6,4) HK, (HSIG,II=IRL,IRH)
WRITE(6,4) BLANK(1), HMEV, (HMEV,II=IRL,IRH)
EK=0.
DO 66 K=1,NKMAX
EK=EK+DE
WRITE(6,6) K, EK, (SPP(K,II),II=1,IPL), (SPGN(K)
CONTINUE
IF(IPRTSP,LT,1):ANO; (IPRTSP,LT,3)) GO TO 80
C PRINT COMPOSITE SPECTRA
WRITE(6,7)
WRITE(6,4) BLANK, (BC02(ID),ID=1,8)
WRITE(6,4) BLANK, (HSPEC,ID=1,8)
WRITE(6,4) BLANK, (HMDASH,ID=1,8)
WRITE(6,4) BLANK, (HSIG,ID=1,8)
WRITE(6,4) BLANK, (HBRN,ID=1,8)
WRITE(6,5) HTOT, (CSDID(IN),ID=1,8)
WRITE(6,4) BLANK, (HMDASH,ID=1,8)
WRITE(6,4) HEAV, (EAVID,ID=1,8)
WRITE(6,4) BLANK, (HMDASH,ID=1,8)
WRITE(6,4) HK, (HSIG,ID=1,8)
WRITE(6,4) BLANK(1), HMEV, (HBMEV,ID=1,8)
EK=0.
DO 74 K=1,NKMAX
EK=EK+DE
WRITE(6,6) K, EK, (SPP(K,II),ID=1,7), (SPGN(K)
IF(IPRTLEV,.LT.1) GO TO 90
C PRINT DISCRETE LEVEL AND GAMMA-RAY DATA
DATA0201
DATA0202
DATA0203
DATA0204
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DATA0206
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DATA0249
DATA0250
DATA0251
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DATA0253
DATA0254
DATA0255
DATA0256
DATA0257
DATA0258
DATA0259
DATA0260
ISERCH 2
ISERCH 3
ISERCH 4

C
C FIND PARAMETERS NECESSARY FOR SPLINE INTERPOLATION

A-37
X = ENERGY AT WHICH FUNCTION IS TO BE EVALUATED
EE = ARRAY OF FUNCTION ENERGIES
NE = NUMBER OF ENERGIES STORED IN EE
A, A1, A2 = SPLINE INTERPOLATION PARAMETERS

K = 0
IF(X, LT, EF(1)), OR, (X, GT, EE(NE))) GO TO 50
K = 1
10 IF(X, LT, EE(K)), GO TO 20
IF(X, LT, EE(K+1)), GO TO 40
K = K + 1
IF(X, LT, NE) GO TO 10
K = K - 1
GO TO 40
20 IF(X, EQ, 1), GO TO 40
K = 1
GO TO 10
40 H = EE(K+1) = EE(K)
H1 = X = EE(K)
H2 = EE(K+1) = X
A = H2*H1/6.
A1 = H1/H
A2 = H2/H
ISERCH = K
RETURN

50 IF(X, GT, EE(NE)) K=999
WRITE(6,1) K, NE
RETURN
END
SUBROUTINE PRECM

COMMON/LCINDEX/IPBLIC, IGLC, IZEROLC, IZPLLC, IZPLLC, IZGLC, ITLCLC,
1 ISTLCI, IZMLC, ITLC, IZELLC, IAJLC, IATLC, INDIM, NIDIM, NIDIM, NIRDIM, NIDRDY, LCINDEX 2
2 LCINDEX, NIDIM, NIRDIM
COMMON/RHO(40,200),T(30,200),P(80),S(200,6), P(80), S(200,7)
1, S(NPNC(200)), P(50,6), G(200,6), RHOFTR(40)
RHO 2
COMMON/TCEOEF/ETC(25,6), TC(25,30), ROC(7), XSPIN(7), NLDIM,
TCEOEF 2
COMMON/IPART, NEE(6), ND(6), NTC(6), IA1ATD(7), XMASS(7), NEEDIM, NLEIM(6,25),
TCEOEF 3
COMMON/NLP(6,200), JRAST(200,6)
TCEOEF 4
COMMON/LLEVEL1/EL(5P), AJ, J5P, AT(5P), XNL(60), ELMAX(60), NLEV
LEVEL 1
COMMON/LLEVEL1/EL(5P), AJ, J5P, AT(5P), XNL(60), ELMAX(60), NLEV
LEVEL 2
COMMON/LLEVEL1/EL(5P), AJ, J5P, AT(5P), XNL(60), ELMAX(60), NLEV
LEVEL 3
COMMON/BASIC1/NIT, NXP1P(1P), NIT, LR(6,10), ZAI(60), ZA2(60), XM(60),
1 ZAC(1R), CSR(60), COTD(60), CSLEV(60), CSAD(60), EAYV(60), BASIC 1
COMMON/BASIC2/TITLE(6), ELAB, DZE, ZAP, ZAT, XMT, NKKM(10), CNPI(10)
BASIC 2
1 CNPI(1R), S(60), SAC(1R), IOI(20), IDP, IOE1(20), IBUF(6,10),
BASIC 3
2 ECUP, HNKMAX, NJMAX, NKKK(60), NKKD, TCO(30), NMDP(40), A(60), A2(60),
BASIC 4
3 NRHO(6), XJT, NPOMX, NTC2(6), NJDIM, IOECH(1R), NKKCN(10), ECON,
BASIC 5
4 JPIC(40P, 2), XMP, XP1P, PIT, XNL, KL, IDSTAT(7), SIC, C61, CS, PILLL(30)
BASIC 6
5 DCAP1, PPLUF(50,10), INPOT, IKEEP
BASIC 7
COMMON/PREP/LPVE, SIG, PPRED1, (6), CSIG(6), NITT(6), ALPHA(6)
PREP 2
COMMON/PRED1/EPSIG(200, 6), NLEV, NPIT, NIT
PREP 2
COMMON/FITTING/ACN, FSIGCN, SIGEO
FITTING 2
COMMON/SPLNEP2, 20, PREPD1(6,200), SPZID(6,200)
PRECM 15
DIMENSION SPZID(6,200)
PRECM 16
DIMENSION PREDP(80), PREPD(80)
PRECM 17
NIP=XNP1P(1)
THE COMPUTER PROGRAMME

The programme starts with a loop DO 2000 IP=1,NIP. Within this loop, several variables are declared and initialized, including NMAX, NC, IR, ID, IF, NK, MKMAX, PK, PK.MAX, and others. The loop iterates for each IP from 1 to NIP.

Inside the loop, there are conditional statements and calculations. For example, IF (IP.EQ.7) GO TO 2000 ensures that when IP is equal to 7, the program jumps to the label 2000. Similarly, IF (NK.LT.1) GO TO 2000 prevents the execution of certain operations when NK is less than 1.

Various calculations are performed, such as MKMAX=NMK, IR=LR(IP), ID=ID(ID), IF(ID,EO.7)GO TO 2000, etc. These calculations are part of the algorithm designed to process the data or solve a specific problem.

The programme also includes conditional branches, e.g., IF (ID.EQ.8) GO TO 2000, which direct the flow of control based on the value of ID. Other conditional statements include IF (MKMAX.GT.50) and IF (MKMAX.LT.10).

The loop continues until all NIP iterations are completed, after which the programme proceeds to the next section or ends.

The programme appears to be written in a dialect of BASIC or a similar high-level programming language, designed to automate or solve a particular problem, possibly related to scientific or technical calculations. The specific application is not clear from the provided snippet.
NORMALIZATION OF PREQ

DO 1000 IP=1,NIP
IR=LR(IP,1)*ID=ID1(IR)
NP=NNK(IR)
IF(ID, EQ, 7, OR, NK, LT, 1) GO TO 1000
KLM=(UP=SAC(1)-S(IR))/DE+P.5
DO 31 I=1,KLM
31 PREQ(I)=PREQ(ID,I)

MOD OF CONTINUUM

NKCN=1

IB=IBUF(IP,1)
IF(IB, EQ, 0) GO TO 999
DO 400 KM=1,NKCN
KD=0
KLW=K+1
IF(KLW=NK2) 250, 250, 400
250 DO 399 KP=KLW,NK2
KD=KD+1
JMAX22=2*JRAST(KP, IP)
INDEX=IPBLC(KP)+2*NJOIM+(IB-1)+2*NJDIM*NKDIM
CALL ERCD(PRFP(1), INDEX, JMAX22, IERR)
DO 300 J=1,JMAX22
PPREP(J)=PPRE(J)
IF(SPP(KP, ID, 0) .LE. 0) 299, 298
298 CONTINUE
PREQ(KP)=FRACT+PREQ(KP)/SPP(KP, ID)
PREP(KP)=PPRE(KP)*PREQ(KP)
CONTINUE
300 CONTINUE
CALL FCWR(PRFP(1), INDEX, JMAX22, IERR)
399 CONTINUE
I=1
400 CONTINUE
999 CONTINUE

NLFILE=XL(NIR)
INDEX=IELLC(IP,1)*NELVNDIM
CALL ERCD(IL, INDEX, NLEV, IERR)
UUCN=UP=SAC(1)
UUMAX=UINC+8(IR)
DO 80 II=1,NLEV
ECC=UUMAX-EL(II)
KDD=EC2/DE+0.5
IF(SPP(KP, ID, 0) .LE. 0) GO TO 110
PL(II, IP)=PL(II, IP)*(FRACT*PREQ(KP)/SPP(KP, ID))
110 CONTINUE
80 CONTINUE
IF(IBUF(IP,1) EQ, 0) GO TO 81
I=1
81 CONTINUE
DO 401 I=1,KLM
SP(I, IR)=SPZID(ID, I)*SPP(I, ID)+SPZID(ID, I)
401 CONTINUE
402 CONTINUE
CONTINUE
RETURN
END

SUBROUTINE INTERP(X,Y,NPTS,NTERMS,XIN,YOUT)
DIMENSION X(1),Y(1),DELTA(10),A(10)

C C
SEARCH FOR X(1)
C
1 DO 19 I=1,NPTS
IF(XIN-X(I))LE.13.17,19
11 I=I+NTERMS/2
IF(I.GT.0)GO TO 21
11=1
GO TO 21
17 YOUT=Y(I)
18 GO TO 61
19 CONTINUE
I=10+NTERMS+1
21 I2=I1+NTERMS-1
IF(NPTS.GE.I2)GO TO 31
23 I2=NPTS
I1=I2-NTERMS+1
IF(I1.GT.0)GO TO 31
26 I1=1
27 NTERMS=I2-I1+1

C EVALUATE DEVIATIONS DATA
31 CONTINUE
DENOM=X(I1+1)-X(I1)
IF(DENOM.EQ.0.)100,101
100 YOUT=Y(I)
GO TO 61
101 CONTINUE
DELTA=X(XIN-X(I1))/DENOM
DO 35 I=1,NTERMS
IX=I1+I-1
DELTA(I)=X(IX)-X(I1))/DENOM
35 CONTINUE

C ACCUM COEF A
C
A(1)=Y(I1)
40 DO 50 K=2,NTERMS
PROD=1.
SUM=0.
IMAX=K-1.
IXMAX=I1+IMAX
DO 49 I=1,IMAX
J=K-I
PROD=PROD*(DELTA(K)-DELTA(J))
49 SUM=SUM+A(J)/PROD
CONTINUE
A(K)=SUM+Y(IXMAX)/PROD
50 CONTINUE

C ACCUM SUM OF EXPANSION
C
SUM=A(I)
55 DO 56 J=1,NTERMS
PROD=1.
IMAX=J-1
56 DO 57 I=1,IMAX
CONTINUE
DO 56 I=1,1MAX

56 PROD=PROD*DELTA(DELTA(I))
56 CONTINUE
57 SUM=SUM+A(J)*PROD
57 CONTINUE
60 YOUT=SUM
61 CONTINUE
RETURN
END
### APPENDIX B

#### GROUND2: GROUND-STATE MASS, SPIN AND PARITY DATA FILE

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APPENDIX D

SAMPLE PROBLEM SUPPLEMENTARY INPUT:
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| 0.1416 | 1.0 | 99 | 99 | 0 | 23052 |
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| 6.4366 | 2.0 | 99 | 99 | 0 | 23052 |
| 7.7935 | 2.0 | 99 | 99 | 0 | 23052 |
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**Notes:**
- The table lists energies and penetrabilities for the neutron continuum.
- The entries are formatted as scientific notation.
- The values represent cross-sections or similar physical quantities.

**Additional Information:**
- The data seems to be part of a larger dataset, possibly related to nuclear physics or related fields.
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ENERGIES AND PENETRABILITIES FOR THE PROTON CONTINUUM.
The document contains a table formatted in Markdown. It appears to be a mathematical or scientific table, possibly related to chemical or physical properties, given the context and symbols used.

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### Additional Information

- The table appears to be filled with zeros, indicating a placeholder or the beginning of a sequence.
- Further analysis would require context-specific knowledge to interpret the values accurately.
### APPENDIX E

**SAMPLE PROBLEM OUTPUT**

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APRIL 7, 1977 == STANDARD PARAMETERS

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++++++ GROUND STATE OF 25058 IS INCOMPLETELY DESCRIBED, SPIN,PARITY = 99,00 99,00 ++++
++++++ ASSIGNMENTS CHANGED TO, SPIN,PARITY = 0,00 1,00 ++++

LCH SPACE REQUIRED (EXCLUDING DISC BUFFERS) IS 225300
NUMBER OF LCM BUFFERS IS 4
MAXIMUM NUMBER OF ENERGY BINS IS 200

NIA  = 5  NMP  = 3  LGROPT  = 2  LPEQ  = 1  NJMAX  = 40  ICAPT  = 0

ZAP  = 1  ZAT  = 27059  OE  = 1.000 MEV XMT  = 58.93319 AMU  S= 7.492 MEV ECUTOFF  = .10 MEV
ACN  = 0.000 /MEV FSIGCN  = 1.000  DEFCN  = 0  SPINT  = 3.5  PIT  = 1

INICIDENT ENERGIES (MEV) == 1.000E+01

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AXEL APPROXIMATION USED FOR GAMMA-RAY TRANSMISSION COEFFICIENTS

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COLLI-MILAZZO CLOSED FORM USED FOR ABSOLUTE CAL OF PRE-EQUILIBRIUM CROSS SECTION

PRE-EQUILIBRIUM NORMALIZATION CONSTANTS ARE / NEUTRON PROTON DEUTERON TRITON HE-3 ALPHA
(INPUT) 0 0 1.000E-03 1.000E-03 1.000E-03 3.000E-03
(USED) 5.000E-04 5.000E-04 1.000E-03 1.000E-03 1.000E-03 3.000E-03

TRANSMISSION COEFFICIENT DATA
3 N + CD-59 TRAN. COEFS. FOR N, P, HE-4 ---- W=H FOR N 9=28=76 1
START OF SPECTRA SUBROUTINE. TIME FROM START OF THIS ENERGY = 0.002 SECONDS, TOTAL ELAPSED TIME = 22,122 SECONDS.

+++ GILCAH SUBROUTINE UNABLE TO MATCH DISCRETE LEVELS WITH LEVEL DENSITY FUNCTION FOR RESIDUAL NUCLEUS IN REACTION IR = 20 ++++

START OF I= 1 LOOP. TIME FROM START OF THIS ENERGY = 0.002 SECONDS, TOTAL ELAPSED TIME = 22,202 SECONDS.
GAMMA RAY STRENGTH NORMALIZATION CONSTANT / I = 1, CONSTANT = 6.8300E+01

START OF I= 2 LOOP. TIME FROM START OF THIS ENERGY = 2.477 SECONDS, TOTAL ELAPSED TIME = 24,597 SECONDS.
GAMMA RAY STRENGTH NORMALIZATION CONSTANT / I = 2, CONSTANT = 1.9080E+00

START OF I= 3 LOOP. TIME FROM START OF THIS ENERGY = 3.274 SECONDS, TOTAL ELAPSED TIME = 25,395 SECONDS.
GAMMA RAY STRENGTH NORMALIZATION CONSTANT / I = 3, CONSTANT = 1.0030E+00

START OF I= 4 LOOP. TIME FROM START OF THIS ENERGY = 5.065 SECONDS, TOTAL ELAPSED TIME = 27,185 SECONDS.
GAMMA RAY STRENGTH NORMALIZATION CONSTANT / I = 4, CONSTANT = 1.7300E+01

START OF I= 5 LOOP. TIME FROM START OF THIS ENERGY = 6.366 SECONDS, TOTAL ELAPSED TIME = 28,486 SECONDS.
GAMMA RAY STRENGTH NORMALIZATION CONSTANT / I = 5, CONSTANT = 4.7600E-01

END OF I LOOP IN SUBROUTINE SPECTRA. TIME FROM START OF THIS ENERGY = 6.367 SECONDS, TOTAL ELAPSED TIME = 28,507 SECONDS.
**N + CO=59 ↔ H=1 AND H=8 PRODUCTION ↔ 10 TO 40 MEV RUNS**

**APRIL 7, 1977 ↔ STANDARD PARAMETERS**

**LAB NEUTRON ENERGY = 1.4000E±01 MEV**

**BINARY REACTION SUMMARIES (COMPOND NUCLEUS ONLY)**

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<td>NEUTRON</td>
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**----- PRE-EQUILIBRIUM SUMMARY -----**

**IP = 2 ID = 1 OUTGOING PARTICLE = NEUTRON**

Initial Exciton Number = 3
Preq Normalization = 50000E⁻03
Compound X-sec(Barns) = 93549E⁻00
Preq X-sec(Barns) = 34940E⁺00

**IP = 3 ID = 2 OUTGOING PARTICLE = PROTON**

Initial Exciton Number = 3
Preq Normalization = 50000E⁻03
Compound X-sec(Barns) = 46740E⁻01
Preq X-sec(Barns) = 62595E⁻01

**IP = 4 ID = 6 OUTGOING PARTICLE = HELIUM-4**

Initial Exciton Number = 3
Preq Normalization = 30000E⁻02
Compound X-sec(Barns) = 11352E⁻01
Preq X-sec(Barns) = 53801E⁻02
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<td>AVG. ENERGY (MEV)= 8.39E+00 8.39E+00 8.39E+00 8.39E+00 8.39E+00 8.39E+00 8.39E+00 8.39E+00 8.39E+00 8.39E+00</td>
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### TOTAL PROD. C/S:

- 2.13E+00

### AVG. ENERGY (MEV):

- 2.476E+00
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**SEPARATION ENERGY = 7.172 MEV**
**ACCUMULATED SEPARATION ENERGY = 0.000 MEV**

**NUMBER OF LEVELS IN RESIDUAL NUCLEUS = 3**

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**In 1  IP= 2  IR= 2 ZA1= 1 ZA2=27059**

**NUMBER OF LEVELS IN RESIDUAL NUCLEUS = 8**

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**SEPARATION ENERGY = 7.492 MEV**
**ACCUMULATED SEPARATION ENERGY = 0.000 MEV**

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**In 1  IP= 3  IR= 3 ZA1=1001 ZA2=26059**

**NUMBER OF LEVELS IN RESIDUAL NUCLEUS = 3**

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**SEPARATION ENERGY = 8.275 MEV**
**ACCUMULATED SEPARATION ENERGY = 0.000 MEV**

**NUMBER OF LEVELS IN RESIDUAL NUCLEUS = 3**

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**In 1  IP= 4  IR= 4 ZA1=2004 ZA2=25056**

**NUMBER OF LEVELS IN RESIDUAL NUCLEUS = 3**

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**SEPARATION ENERGY = 7.172 MEV**
**ACCUMULATED SEPARATION ENERGY = 0.000 MEV**

**NUMBER OF LEVELS IN RESIDUAL NUCLEUS = 3**

---

**In 2  IP= 1  IR= 5 ZA1= 0 ZA2=26059**

**NUMBER OF LEVELS IN RESIDUAL NUCLEUS = 3**

**NUMBER OF GAMMA RAYS = 3**

**RESIDUAL NUCLEUS ID = 26059**
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<th>Final Level Parity</th>
<th>Transition Probability</th>
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- Separation Energy = 6.587 MeV
- Accumulated Separation Energy = 8.275 MeV

**Number of Levels in Residual Nucleus = 9**

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- Separation Energy = 11.699 MeV
- Accumulated Separation Energy = 8.275 MeV

**Number of Levels in Residual Nucleus = 1**

### Level 3

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### In = 3 IP = 1 IR = 0 ZA1 = 0 ZA2 = 25056

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### Separation Energy and Accumulated Separation Energy

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**SEPARATION ENERGY = 10.460 MEV**  
**ACCUMULATED SEPARATION ENERGY = 7.492 MEV**

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**ACCUMULATED SEPARATION ENERGY = 7.492 MEV**
**In 4 IP = 4 IR = 16 ZA1=2004 ZA2=25855**

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Number of Levels in Residual Nucleus = 7

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**In 5 IP = 1 IR = 17 ZA1 = P ZA2=27056**

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Number of Gamma Rays = 6  
Residual Nucleus ID = 27056

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### Level and Energy Table

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#### Level 2
- **spin** = 4.5, **parity** = \( -\)\( \uparrow \), **cross section** = 99.0 barns

#### Level 3
- **spin** = 1.5, **parity** = \( -\)\( \uparrow \), **cross section** = 99.0 barns

#### Level 4
- **spin** = 3.5, **parity** = \( -\)\( \uparrow \), **cross section** = 99.0 barns

#### Level 5
- **spin** = 2.5, **parity** = \( -\)\( \uparrow \), **cross section** = 99.0 barns

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### Level and Energy Table

#### Level 1
- **spin** = 3.5, **parity** = \( -\)\( \uparrow \), **cross section** = 99.0 barns

#### Level 2
- **spin** = 4.5, **parity** = \( -\)\( \uparrow \), **cross section** = 99.0 barns

#### Level 3
- **spin** = 1.5, **parity** = \( -\)\( \uparrow \), **cross section** = 99.0 barns

#### Level 4
- **spin** = 3.5, **parity** = \( -\)\( \uparrow \), **cross section** = 99.0 barns

#### Level 5
- **spin** = 2.5, **parity** = \( -\)\( \uparrow \), **cross section** = 99.0 barns

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### Level and Energy Table

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